Digital Equipment Corporation (DEC):

A Case Study of Indecision, Innovation and Company Failure

David Thomas Goodwin

Digital Equipment Corporation (DEC)
David Thomas Goodwin

Digital Equipment Corporation (DEC):

A Case Study of Indecision, Innovation and Company Failure

David Thomas Goodwin

Digital Equipment Corporation (DEC):

A Case Study of Indecision, Innovation and Company Failure

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. ir. K.I.J. Maex
ten overstaan van een door het College voor Promoties ingestelde
commissie, in het openbaar te verdedigen in de Agnietenkapel
op donderdag 8 september 2016, te 12:00 uur

door

David Thomas Goodwin

geboren te Liverpool, Verenigd Koninkrijk

Promotiecommissie:

Promotor:	Prof. dr. P. van Baalen	Universiteit van Amsterdam
Co-promotor:	Prof. dr. W. Buitelaar	Universiteit van Amsterdam
Overige Leden:	Prof. dr. H.W.G.M. van Heck	Erasmus Universiteit Rotterdam
	Prof. dr. J. Strikwerda	Universiteit van Amsterdam
	Prof. dr. P.C. van Fenema	Nederlandse Defensie Academie
	Dr. ir. J.W. Stoelhorst	Universiteit van Amsterdam
	Prof. dr. L. Karsten	Rijksuniversiteit Groningen
	Prof. dr. E.J. Fischer	Universiteit van Amsterdam

Faculteit Economie en Bedrijfskunde

Acknowledgements

I would like to thank a number of people without whose assistance this thesis may never have been completed.

Firstly I should like to thank my promotor Prof. dr. Peter van Baalen and my co-promotor Prof. dr. Wout Buitelaar, without whose guidance I would not have completed my transition into a more academic thought process. Gordon Bell, who directed me to the company archives and offered advice, Paula Jabloner, chief archivist at the Computer History Museum for her assistance in my study of the Digital Equipment Corporation archives, and to Dan Tymann for his facilitation in allowing me unrestricted access to the Ken Olsen archives, particularly obtaining the Olsen family permission and for allowing me to work long hours at the archives. I would also like to acknowledge the assistance of HP management who confirmed they would not seek to prevent my use of the Notesfiles as part of my argument. Thanks are also given to Bob Glorioso for his insight into the world of high performance computing and DEC's RISC strategy. I am particularly grateful to Don Gaubatz for his contribution on DEC Workstation Engineering, his encouragement and assistance, and for giving me access to his archives as part of my research. He facilitated contact with many high-level former employees, without which a full understanding of events at DEC would not have been possible. I would also like to acknowledge the many ex-DEC people (some of whom wish to remain anonymous) who have given me encouragement, have related personal recollections of their time at Digital and provided many documents about technology and strategy. In particular, thanks go to Dave Cutler for meeting me in Seattle and speaking so forthrightly about DEC, Bob Supnik for his many emails on products, technologies and management, Dileep Bhandarkar for his commentary on RISC and Bill Strecker for his view of DEC after Gordon Bell's departure. Last but not least, I would like to thank my wife for her encouragement and patience during the years that I have been researching DEC and for allowing me to visit the archives on a number of occasions.

Most of all I dedicate this thesis to Ken Olsen, who was the father of the company and to its employees for thirty-five years, and who sadly passed away before I could complete.

Glossary

ACM	Association for Computing Machinery
AMD	Advanced Micro Devices
ARD	American Research and Development
ARM	Advanced RISC Machine
ARPA	Advanced Research Projects Agency
AXP	Alpha Processor Codename
BBN	Bolt Beranek and Newman
BIPS	Billions of Instructions per Second
BOD	Board of Directors
CAD	Computer Aided Design
CalTech	California Institute of Technology
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CMOS	Complementary Metal-Oxide Semiconductor
CPSR	Computer Professionals for Social Responsibility
DARPA	Defence Advanced Research Projects Agency
DEC	Digital Equipment Corporation
DECUS	Digital Equipment Computer Users' Society
DG	Data General
DVN	Digital Video Network
ECL	Emitter Coupled Logic
EDS	Electronic Data Systems
EDSAC	Electronic Delay Storage Automatic Calculator
EDVAC	Electronic Discrete Variable Automatic Computer
EMC	EMC Corporation
EMCC	Eckert-Mauchly Computer Corporation
EMEA	Europe, Middle East and Africa
ENIAC	Electronic Numerical Integrator and Computer
FAB	Semiconductor Fabrication Facility
FBI	Federal Bureau of Investigation
FTC	Federal Trade Commission
GE	General Electric Company
HP	Hewlett Packard
HR-32	Hudson RISC, 32 bit.
IBM	International Business Machines
IDC	International Data Corporation
IEEE	Institute of Electrical and Electronics Engineers
IPI	Intelligent Peripheral Interface

IT/MIS	Information Technology/Management Information Services
LCG	Large Computer Group (DEC department)
LSI	Large Scale Integration
MCI	Telecommunications company
MICA	Multi-personality Operating System
MIPS (architecture)	Microprocessor without Interlocked Pipeline Stages
MIPS (company)	MIPS technologies
MIT	Massachusetts Institute of Technology
MTBF	Mean Time Between Failures
NBER	National Bureau of Economic Research
NCR	National Cash Register
NFS	Network File System
NIST	National Institute of Standards and Technology
NUMA	Non Uniform Memory Access
NVAX	DEC VAX Microprocessor
OEM	Original Equipment Manufacturer
OSF	Open Software Foundation
PARC	Palo Alto Research Centre
PCI	Peripheral Component Interconnect
PDP	Programmable Data Processor
PDT	Programmable Data Terminal (DEC based LSI-11 microprocessor based system)
PM&D	Product Management and Development
PRIME	PRIME Computer Inc.
PRISM	PaRallel Instruction Set Machine
PRO	DEC's PROfessional range of PC's.
PRTM	Pittiglio Rabin Todd & McGrath
QE2	Queen Elizabeth 2nd cruise liner.
R&D	Research and Development
RISC	Reduced Instruction Set Computing
RSX	Resource Sharing eXecutive
SAFE	Streamline Architecture for Fast Execution
SAGE	Semi-Automatic Ground Environment
SAP	System Analysis and Products in Data Processing, (German Company)
SEC	Securities and Exchange Commission
SG&A	Selling and General Administrative Expense
SGI	Silicon Graphics Inc.
SHOT	Society for the History of Technology
SMP	Symmetric Multiprocessing

SPARC	Scalable Processor Architecture
SPRU	Science Policy Research Unit
SRA	Systems Research and Applications
STF	Strategic Task Force
SUN	Stanford University Network
TCP/IP	Transmission Control Protocol/Internet Protocol
TTL	Transistor-Transistor Logic
UNIX	UNiplexed Information and Computing System
VAX	Virtual Address Extension
VLDB	Very Large Data Base
VLSI	Very Large Scale Integration
VMS	Virtual Memory System
VNS	Vogon News Service
VTX	(DEC's) Videotext service
VUP	VAX Unit of Power
WRL	DEC Western Research Laboratory
WWW	World Wide Web

Contents

Figures

Tables

1 Introduction

DEC: the Good, the Bad and the Ugly years.[1]

1.1 *Introduction*

The death of the minicomputer companies is a subject that has received little academic review with most simply attributing it to the disruptive technology of the personal computer. This is a rather simplistic conclusion as most of the minicomputer companies had disappeared or merged well before the rise of the personal computer. The majority of minicomputer firms failed during the 1970s due to simple competition and the rise of the dominant firms. There were about 100 US minicomputer companies founded between 1968 and 1972. All but seven survived into the next decade.[2] Ross Hamilton considered the failure of British minicomputer firms in a chapter of his thesis and found that British firms could not compete in the global market with the American companies who had government and military backing.[3] This would explain the demise of the British firms but not the American firms. As the computing paradigm shifted in the late 1980s very few of the remaining minicomputer firms were able to successfully convert to the newer technologies.

Digital Equipment Corporation (DEC) was one of those which not only survived but grew rapidly in the 1980s. The question is therefore, what caused the remaining minicomputer companies to fail? To answer this DEC is considered as a case study. The initial intention was to investigate the history of DEC, but on consulting the academic literature I began to realize that current theory on the failure of the company might be incorrect in some of its assertions. This thesis therefore disputes the theories of the likes of Schein, Christensen and Saxenian who attribute the failure to the lack of the 'money gene', the disruptive technologies of the personal computer and the rise of Silicon Valley and its culture.

---

[1] Spoken by Hans W. Dirkmann, at a DEC European reunion in Berlin 2007.

[2] G. Bell, http://research.microsoft.com/en-us/um/people/gbell/CGB%20Files/Mini%20and%20Micro%20Industries%20Computer%208410%20bw%20c.pdf (accessed July 6, 2015) list of US minicomputer manufacturers 1968-1972 according to Bell http://ed-thelen.org/comp-hist/GBell-minicomputer-list.html (accessed July 6, 2015) their fate was documented in http://ed-thelen.org/comp-hist/G-Bell-91-US-mini-1968-to-1982.html (accessed July 6, 2015)

[3] R. Hamilton, *Continuous Path: The Evolution of Process Control Technologies in Post-War Britain*, PhD Warwick University, 1997, supervisor Martin Campbell-Kelly

On June 11th 1998, DEC merged with Compaq Computer Corporation, an event that finally marked the end of the era of the minicomputer companies. The minicomputer had created a completely new computing paradigm, leading to the modern world where computers abound. Prior to its arrival computing was the domain of the few mainframe manufacturers. Even though the minicomputer changed the computing world, very little has been written about the companies that brought this about and even less about why the most of them failed.

In this thesis I explore the failure of DEC from a Schumpeterian viewpoint considering various theories on innovation, in particular Christensen's theories on Disruptive Innovation, Utterback's theories on the Dynamics of Innovation and Schein's analysis of the company. I also look at the impact of the downsizing process on the company's performance whilst trying to recover.

1.2 *Research Question*

By 1988 DEC had grown from its humble beginnings in an old woollen mill to a multinational company which was second only to IBM. The world of computing was changing rapidly in the 1980s and 1990s and many firms struggled to compete in the marketplace. DEC had moved from a minicomputer manufacturer to compete at all levels from the desktop to the datacentre including networking and storage. It was therefore a shock to Wall Street when they announced a major loss in 1992 after many years of rising profits. This was a period when innovation was influencing the computer industry at a much faster rate than it had been in the 1960s and 1970s and corporations were under attack from new ventures in many of their traditional markets. The main question this thesis looks to answer is 'what caused a company the size and reach of DEC to fail?' Was Schein correct in his theory of the money gene or was it mismanagement, indecision in innovation, Schumpeter's creative destruction, Christensen's disruptive innovation or the cumulative effect of all of them coming together in a catastrophic clash?

1.3 *DEC*

DEC was founded in 1957 by Kenneth Olsen and Harlan Anderson after they left MIT, where they had worked on the Whirlwind project, primarily on the TX series of test computers. Anderson left in 1966 after an on-going disagreement with Olsen. Meanwhile, DEC grew to become a multi-billion dollar company. Then from its peak in 1988, it went into rapid decline, searching for a strategy and finally selling to Compaq ten years later. The cause of the decline is not straightforward; this thesis seeks to identify the core reasons for the failure.

The views of many DEC alumni were sought and they bring in many theories ranging from 'it was doomed to failure in 1980' to 'there was no way it should have been sold'. Some blame Olsen, and some blame Robert Palmer, whereas others suggest that the senior management were the cause, and a few implicate the technical development people.[4]

In order to consider Schein's theory it was necessary to analyse the financial performance of the company to determine how well the management dealt with the company's income versus expense. We also look at the technology that was available for exploitation and the financial performance of the product lines sold to competitors.

In the 1980s, General Georges Doriot became ill and eventually died.[5] This was a great loss to Olsen as Doriot had been his mentor and shield from the board. He advised Olsen on many things and was very influential in many of Olsen's decisions. After his death, Amidon stated that Olsen became increasingly influenced by Harvard Business School in his management style.[6] Olsen's relationship with the board deteriorated even though he had increased its numbers, and eventually he was replaced.

DEC always attracted the most talented people who wished to work in a dynamic technical environment. Many renowned people in the field of computing were drawn to DEC: people such as Bell and Dave Cutler began early in their careers, whereas others such as Grace Hopper and Maurice Wilkes joined in very senior roles when they retired from their previous posts.[7] Wilkes tells of his visits to MIT, where he saw the Whirlwind and met Forrester and Everett.[8] Forrester had worked on core memory, which led to the memory tester that Olsen constructed while at Lincoln Labs. At the ACM meeting in 1952, Wilkes presented a paper on automatic programming and the panel included Grace Hopper.[9]

---

[4] Robert Palmer took over from Olsen as CEO of DEC in 1992.
[5] George Doriot was the founder of ARD, the venture capitalists that financed DEC at the beginning.
[6] Telephone interview with Debra Amidon, March 7, 2008.
[7] M. Northrup, *American Computer Pioneers*, Collective Biographies (Springfield, NJ: Enslow Publishers, 1998), 36; K. B. Williams, *Grace Hopper: Admiral of the Cyber Sea*, Library of Naval Biography (Annapolis, MD: Naval Institute Press, 2004), 172.
[8] M. V. Wilkes, *Memoirs of a Computer Pioneer*, MIT Press Series on the History of Computing (Cambridge, MA: MIT Press, 1985).
[9] M. V. Wilkes, 'Pure and Applied Programming'. Proceedings of the ACM Toronto Meeting (1952), 121.

2 Failure, Innovation and Disruptive Technology

2.1 *Introduction*

In 1942 Schumpeter theorised that the process of creative destruction was the essential fact about capitalism and that imperfect competition was the driving force.[10] He initially proposed one wavelike economic motion caused by innovation but later refined that to three of different lengths superimposed on each other. These were 'Kitchin' cycles of 40 months, 'Juglar' cycles of about ten years and 'Kondratieff' cycles of around 40 years. DEC certainly followed the Kondratieff cycle as it was in existence for just over 40 years. Entrepreneurial innovation was, according to Schumpeter, the driving force behind economic development and entrepreneurs were the leaders of capitalist society. He suggests that entrepreneurs could earn profits because for a time they produced and sold their products without direct competition so could dictate price.[11] Christensen has taken Schumpeter's theories and expanded them to view modern technological companies.

In 2003 Schein published his book on the rise and fall of DEC.[12] In it he concludes that the main cause of the company failure was a lack of the 'money gene'. Schein argues that DEC management was governed by an engineering culture, which prized innovation above profit. This thesis considers the failure of DEC and asks whether the failure was due to financial mismanagement as Schein suggests or was it due to disruptive technology and a failure to innovate. It also considers the claim by Christensen that the PC was the disruptive technology that brought about the downfall of the company. Schein concluded that DEC failed due to financial mismanagement whereas Christensen attributes it to a failure to move to a PC centric world.

Each of these potential causes could, to the casual observer, be credible explanations of the failure. However with more in depth analysis none of these causes appear to fully cover the issues at DEC and so do not prove themselves beyond doubt to be the cause of the downfall. Schein, for example, analyses the area of the company he is most comfortable with, management. He was a

---

[10] J. A. Schumpeter, *Can Capitalism Survive*, (New York, Harper Collins, 2009) 43.
[11] J. Medearis, *Joseph A. Schumpeter*, (New York, Bloomsbury Academic, 2013) 45.
[12] E. H. Schein, *DEC is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 1st ed. (San Francisco, CA: Berrett-Koehler, 2003). Schein is best known as a professor at MIT Sloan School of Management and a leader in organisational development. He was also a management consultant and spent many years advising DEC on process and organisational culture.

management consultant with the company for many years under Olsen and as such had a responsibility for management development. It is therefore understandable that he would consider the management ethos to be the cause. However his association with the company ten years before it was sold and he had very little contact with the company after that. He also gave his co-authors no time to alter the thrust of his conclusions by publishing before they had a chance to feedback. Christensen, along with others, theorises that the PC was the catalyst for the failure. DEC was in trouble before the PC was a major competitor so the cause pre-dated the disruptive innovation of the PC to its business. Again Saxenian's theory that it was an East Coast versus West Coast ethos is questioned as DEC had a major investment in research facilities in Palo Alto, being one of the largest employers in the area with major real estate and a major internet network management centre. All of this leads me to conclude that there must be another explanation for the demise of the company which has eluded the academic community so far.

2.2 *Innovation and Failure*

The consequences of innovation have been the focus of economists for many decades but it was Joseph Schumpeter who was most influential in the early discourse on the subject. Possibly the most important contribution to economics are his theories on innovation and entrepreneurship. He partitioned innovation into four processes, placing the entrepreneur at the centre.[13] Schumpeter was, in part, arguing that capitalism would not survive due to the demise of true entrepreneurs. He introduced his concept of the entrepreneur in one of his early works.[14] Schumpeter proposed his theory of creative destruction in chapter VII of his book, *Capitalism, Socialism and Democracy*.[15] In this, he considers the impact of new technology on firms and suggests that creative destruction is an internal process:

> The opening up of new markets, foreign or domestic, and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation

---

[13] J. A. Schumpeter, *Capitalism, Socialism and Democracy* (2nd ed., Floyd, Virginia: Impact Books, 2014 [1942]).

[14] J. A. Schumpeter and Redvers Opie, *The Theory of Economic Development: an Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*, Harvard Economic Studies (Cambridge, MA: Harvard University Press, 1934). Translated from the 1911 original German, *Theorie der wirtschaftlichen Entwicklung*.

[15] Schumpeter proposed Creative Destruction in a mere six pages of his 1942 book, *Capitalism, Socialism and Democracy*.

> – if I may use that biological term – that incessantly revolutionizes the economic structure from within, incessantly destroying the old one. This process of Creative Destruction is the essential fact about capitalism.[16]

Schumpeter also suggests that as businesses grow, 'the maintenance and value of existing investment and conservation of capital becomes the chief aim of entrepreneurial activity.' Schumpeter proposes a wave of economic development, which is a joining of the cycles of Kondratiev, Kuznets, Juglar and Kitchin.[17] These can be compared with Sigmoid's S-curves, which also define product cycles in terms of waves and are considered later in this chapter. In his theory of *creative destruction*, where something new kills something old, Schumpeter suggests that workers with obsolete skills should be laid off if a company is to survive. Schumpeter fails to consider reskilling or the adverse effect of redundancies on the corporate culture that was the core of many computer companies such as IBM, HP and DEC in the 1980s. He suggests that *creative destruction* causes continuous progress. However, he proposes a simplistic model that ignores many of the external influences that currently affect businesses, especially in our consumer-oriented society. C*reative destruction* was evident in the rise of Very Large Scale Integration (VLSI) and the personal computer, which led to a growth in client server computing and a standardisation that in many ways destroyed the workstation industry rather than the minicomputer industry.[18] Schumpeter portrays this as an improvement, although it is often not the best product that wins but the one that is priced competitively and well marketed.

Although Schumpeter is remembered for coining the phrase *creative destruction,* he borrowed this from Marx and only devoted six pages to the subject.[19] He states that 'in the process of creative destruction, restrictive practices may do much to steady the ship and to alleviate temporary difficulties' and that 'the process so disorganizes an industry for the time being as to inflict functionless losses and to create avoidable unemployment.'[20] However, this is contrary to his proposal that people with the wrong skills should be laid off. Schumpeter portrays the entrepreneur as the driver of innovation but later suggests that large companies are the main drivers of innovation. Certainly, this has not been proven

---

[16] Ibid 83.
[17] Ibid 96.
[18] VLSI technology packs many thousands of transistor circuits onto a single silicon wafer. This was a step change from the previous IC (Integrated Circuit) which had a limited set of functions.
[19] J. A. Schumpeter, Chapter 7, *Capitalism, Socialism, and Democracy* (London: G. Allen & Unwin Ltd, 1943).
[20] Ibid. 87-90.

to be the case in the computer industry, where much of the innovation has come from individuals with the help of venture capital. Schumpeter initially postulated that innovation and creative destruction happened within large companies but later altered this to include innovation from small companies. In the 1980s and 1990s many small companies began life with the help of venture capital as venture capital companies tried to emulate the success of American Research and Development Corporation (ARD) in their investment in DEC.[21]

Prior to the 1950s, most business start-ups received their funding from individual wealthy backers such as the Rockefellers and Vanderbilts, or from banks. Georges Doriot and MIT president Karl Compton started the first modern venture capital company, American Research and Development, who were, as a result, heavily MIT oriented. Doriot was therefore called the 'founder of modern venture capital' or 'the father of venture capital' in most accounts.[22] Meanwhile, on the West Coast, Fred Terman, Stanford Dean of Engineering, funded many start-ups in collaboration with the defence industry.[23] Arthur Rock moved from New York to the West Coast in the late 1950s to provide venture capital to the area. Rock was followed by some former members of the ARD team who believed that the West Coast offered a good opportunity for venture capitalism; they backed a number of start-ups in the 1970s.[24] Saxenian has suggested that West Coast venture capitalists were technically competent and had operational experience, which enabled them to offer assistance when there were problems with the business.[25]

There was a marked increase in US venture capital investments in the 1960s, followed by a virtual halt in the mid-1970s, due to recession and taxation. However, as Gompers shows, in the 1980s, there was a surge in pension fund contributions to venture capital and an easing of restrictions due to the Small Business Investment Act of 1980.[26] This, he suggests, began a manifestation of

---

[21] ARD had invested $70,000 in DEC in 1957 and achieved a return of over $400 million by 1968. Charles Waite, *Done Deals: Venture Capitalists Tell Their Stories*, ed. Udayan Gupta, Harvard Business School Press, (2000). 225

[22] For example, S. E. Ante, *Creative Capital: Georges Doriot and the Birth of Venture Capital* (Boston, MA: Harvard Business Press, 2008), xiii. Also M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, 2nd ed., Westview Press, Oxford, (2009), 200. ISBN 9780786729913

[23] S. Blank, "The Secret History of Silicon Valley," 2010, http://steveblank.com/secret-history/. (accessed July 3, 2015)

[24] P. A. Gompers, "The Rise and Fall of Venture Capital," *Business and Economic History* 23, no. 2 (1994): 9.

[25] A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, MA: Harvard University Press, 1994), 65.

[26] Copies of the Act are available from https://www.govtrack.us/congress/bills/96/hr7554 (accessed December 3, 2014)

the ‘herd mentality’ similar to the Internet bubble of the 1990s. He shows a peak in the returns on investment in 1982, with a sharp decline for the rest of the decade. Many of the pioneers of venture capital, such as Kleiner, Perkins and Johnson, had been students of Doriot at Harvard. Thus, even though they worked on the West Coast, they gained their skills in Boston.

Silicon Valley benefitted from its social networks, as shown by Castilla, who indicates that another Silicon Valley would be unlikely to succeed without a dense social network.[27] Castilla goes on to demonstrate that venture capital companies in Silicon Valley tended to invest more in start-up companies. They had 50% of their portfolio invested in start-up businesses, whereas Route 128 venture capital companies invested more in buy-outs and follow-on companies. Gompers shows that, by 1992, 48% of America’s venture capital dollars was being invested in the West Coast with only 20% in the Northeast.[28] Overall, the number of venture capital firms in the two areas was not vastly different. In 1998, there were 111 venture capital companies in Silicon Valley and 91 in Route 128.[29]

After Schumpeter proposed his theories there was little academic focus on innovation for a number of years. Fagerberg concludes that the turning point in the study of innovation was in 1965 when the Science Policy Research Unit (SPRU) was established at the University of Sussex when the scholarly papers on innovation increased from less than two per year to over ten in 1995 and doubled over the next decade.[30] In fact, such was the expansion of the literature that Fagerberg, Mowery and Nelson decided to compile many of the multitude of theories into a single volume.[31] In it they suggest that ‘the number of social-science publications focussing on innovation has increased much faster than the total of such publications’.

Since 1965 scholars have attempted to define different categories of innovation, especially in the technological area. Innovation and failure are often combined, especially when it involves technology companies, and definitions of innovation abound in the literature. In the 1980s and 1990s, innovation became mainstream once more as high tech companies surfaced. Much of this later work was done at

---

[27] E. J. Castilla, "Networks of Venture Capital Firms in Silicon Valley," *International Journal of Technology Management* 25, no. 1/2 (2003). Social networks also had a marked influence on innovation.
[28] P. A. Gompers, "The Rise and Fall of Venture Capital," *Business and Economic History* 23, no. 2 (1994): 8.
[29] Ibid.
[30] J. Fagerberg, D. C. Mowery and R. R. Nelson, *The Oxford Handbook of Innovation*, Oxford University Press, (2005), 2.
[31] Ibid.

Harvard and the Sloan School with Henderson and Christensen leading. There is generational innovation as considered by Henderson and Kim Clark, who suggest that radical and incremental innovation theory is incomplete and propose generational innovation as a better conclusion to the technological paradigm.[32] They later refined this into architectural innovation and modular innovation at the suggestion of Tushman.[33] Much of Henderson's work is based on studies of the highly specialised photolithography industry, which has a limited number of competing companies.[34] Itami et al categorise innovation as four different levels, suggesting that Henderson and Clark's component and architectural innovation are just the first two levels and proposing that managing multiple products is the third level, with innovation across markets being the fourth level.[35] Chesbrough performed interesting work on innovation when he looked at the experience of Xerox and their PARC (Palo Alto Research Centre) research arm.[36] He considered PARC's closed innovation approach, where it tried to keep innovations developed in the labs as its own products, and found that the more successful model was the open model, where developers left PARC and, with the help of venture capital, developed the products independently. Chesbrough and Rosenbloom then went on to look at the role of the business model in capturing value from innovation, again using Xerox as an example.[37] As a further example, they use DEC's involvement in the development of Ethernet and the spin-off of 3-Com, which went on to dominate the PC connectivity market.

Bruno and Leidecker compared the causes of business failure in the 1960s versus the 1980s and found that they had not changed much over the period.[38] Company failure is not researched as extensively as company success in business literature,

---

[32] Generational innovation was introduced by R. M. Henderson and K. B. Clark, *'Generational Innovation: the Reconfiguration of Existing Systems and the Failure of Established Firms'*, A. P. Sloan School of Management, Massachusetts Institute of Technology, (1989), working paper. Radical and incremental innovation are discussed in J. E. Ettlie, W. P. Bridges, and R. D. O'Keefe, "Organisational strategy and structural Differences for Radical vs. Incremental Innovation," Management Science, 10 (1984): 682-695.

[33] R. M. Henderson and K. B Clark, "Architectural Innovation: The Reconfiguration Of Existing, Product Technologies and the Failure of Established firms," *Administrative Science Quarterly* 35, no. 1, Mar (1990): 9.

[34] For example R. M. Henderson, "Underinvestment and Incompetence as Responses to Radical Innovation: Evidence from the Photolithographic Alignment Equipment Industry," *RAND Journal of Economics* 24, no. 2, Summer (1993).

[35] H. Itami, K. Kusunoki, T. Numagami, A. Takeishi, *Dynamics of Knowledge, Corporate Systems and Innovation*, Springer Science & Business Media, 10 Mar 2010: 29. ISBN 978-3-642-04480-9

[36] H. W. Chesbrough, *Open Innovation: the New Imperative for Creating and Profiting from Technology* (Harvard Business School Press, 2003).

[37] H. Chesbrough and R. S. Rosenbloom, *The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-off Companies*, Industrial and Corporate Change, Vol. 11, no. 3 (2002), pp. 529-555.

[38] A. V. Bruno and J. K. Leidecker, "Causes of New Venture Failure: 1960s vs. 1980s," *Business Horizons,* November–December (1988).

probably due to its being less popular. According to Dun and Bradstreet, 50,000 businesses fail each year and incompetent management is cited as the major cause in 90% of these failures.[39] Bruno and Leidecker identified a number of causes of business failure, including Product Timing, Product Design, Unclear Business Direction, Ineffective Team and One-Track Thinking. Their paper was written before *Disruptive Innovation* was brought into mainstream thinking by Clayton Christensen and so does not consider the influence of innovation on firms.

Innovation can be either disruptive or sustaining. Sustaining innovation can be defined as an innovation in current technology whereas disruptive innovation changes the whole market.[40] Christensen's book defines the fundamental differences between these two innovations.[41] He states that incumbents win in sustaining innovations, because they are highly motivated to win these battles with innovations that: appeal to their most valuable customers; tend to be higher margin; fit with their existing 'value network'; and match the 'mental model' they have built about how their industry works. On the other hand, good management is likely to be tripped up by disruptive innovations, since none of the above applies.[42]

Christensen built on Schumpeter's theories to develop his theory of *disruptive innovation*. With this theory, he went on to contend that Schumpeter was incorrect in suggesting that innovation would come from large companies and proposed that it mostly came from smaller, leaner ones. Christensen is widely cited in relation to innovation and disruptive technology. Christensen et al in their 2001 article for *Foreign Affairs,* consider disruptive technologies and how they create major new growth in the industries they create quoting the rise and fall of Japan as an example of how disruptive technology affects countries, as well as companies.[43] They discuss creative destruction in the form of the infrastructure supporting disruptive technology, concluding that 'even though the major companies have been steadily cutting jobs, smaller companies – many of

[39] Dun and Bradstreet. (1981), *The Business Failure Record.* New York: The Dun and Bradstreet Corporation.
[40] Quote from Christensen's web site defining key concepts http://www.claytonchristensen.com/key-concepts/ (accessed December 3 2014)
[41] C. M. Christensen, *The Innovator's Dilemma: The Revolutionary National Bestseller That Changed the Way We Do Business*, 1st HarperBusiness ed. (New York: HarperBusiness, 2000). xviii
[42] Ibid.
[43] C. Christensen, R.T. Craig and S. Hart, "The Great Disruption," *Foreign Affairs* 80, no. 2, March/April (2001): 80-95. http://www.foreignaffairs.com/issues/2001/80/2 (accessed December 3, 2014).

them disruptive in character – have quickly picked up the slack.'[44] Bower and Christensen discuss the failure of companies when technologies or markets change, citing DEC and IBM.[45] However, they focus on the companies rather than the market and only look at point failures rather than the overall reasons for their failure.

Christensen was inspired to develop his ideas on disruptive innovation by observing DEC, amongst others.[46] He considers the minicomputer as a disruptive technology that IBM ignored to their cost in the 1960s and 1970s. He also proposes in *Foreign Affairs* that the personal computer was another disruptive technology that did not necessarily meet the requirements of mainstream minicomputer users in the 1980s, but changed rapidly to replace the minicomputer, to the detriment of many established companies.[47] Christensen also asserts that minicomputer companies missed the PC revolution because the margins were too small. This is contrary to the majority of views expressed at the time, which suggest that minicomputer companies did not see the potential of the PC. Both Utterback and Acee continued Christensen's work on disruptive technologies and expanded on his original theory. Acee considers the PC as a high-end disruptive technology and goes on to suggest that high-end disruptive technologies tend to be more expensive than the product they replace.[48] This was obviously not correct for the PC, which Christensen correctly viewed as a low-end technology.[49] Christensen had advised Utterback on his theories and Tushman and Anderson expanded on those theories.[50]

---

[44] Ibid.; Whilst this might have been true for the American economy in general, the Route 128 area was severely affected by the loss of minicomputer jobs in the late 1990s. Route 128 is the main highway in Massachusetts along which the majority of the minicomputer companies were based in the 1970s and 1980s.
[45] J. L. Bower and C. M. Christensen, "Disruptive Technologies: Riding the Wave," *Harvard Business Review,* January-February (1995): 43-53.
[46] L. M. Fisher, "Clayton M. Christensen, the Thought Leader Interview." *Strategy and Business*, October 1, 2001, 25. http://www.strategy-business.com/article/14501?gko=ca7ad , (accessed June 20, 2015).
[47] C. M. Christensen, T. Craig, and S. Hart. "*The Great Disruption*." Foreign Affairs 80, no. 2 (March–April 2001)
[48] Comments from Masters submission by Mitsuhiro Kameda, "Disruptive Innovation: Value Change and Complementary Change" (Sloan School of Management, MIT, May 7, 2004, Supervisor James M. Utterback), http://dspace.mit.edu/handle/1721.1/17867 (accessed July 6, 2015) . Also, J. M. Utterback and H. J. Acee, *Disruptive Technologies: An Expanded View*, International Journal of Innovation Management, Vol. 9, Issue 1, March 2005: 1-17
[49] Christensen considered disruptive technologies to be lower-cost replacements, where they displaced current technologies, unless they added value that was not present in the replaced technology.
[50] J. M. Utterback, *Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change* (Boston, MA: Harvard Business School Press, 1994). xi

In a number of his publications, Christensen examines the hard disk drive industry and the improvements in size and performance, coupled with the rapid reduction in cost, which have occurred there. He mentions the S-curve in disk drive development and the disruptive technologies that shrank disk dimensions, and how industry leaders stumbled at each disruptive technology change. In *The Innovator's Dilemma*, Christensen looks at thin film technology, analysing whether leadership was essential in this field, and suggests that being the first entrant into a technology field does not necessarily imply future success nor becoming the dominant player in that technological field.[51] He then goes on to propose how to recognise whether a technology is disruptive or sustaining, and how to define the strategic significance of the disruptive technology. (Again, Utterback and Acee expand on Christensen's definitions.)[52] Christensen investigates technology S-curves and asks how value networks and the concept of S-curves relate to each other, postulating that disruptive technology does not fall into the normal S-curve as it gains its commercial start in emerging value networks before invading established networks. Many authors in the field cite this phenomenon; the PC being the most quoted example of disruptive technology in modern times.[53]

Christensen again highlights DEC as a case in point, asking whether the company had the capability to succeed with personal computers. He concluded that they could only have done so by owning a separate organisation, as their 'values' made it impossible for them to have a winning strategy within their mainstream organisation. He went on to explore 'creating capabilities through acquisitions,' which is one path that DEC, under Olsen, was not willing to follow, at the cost of the company (as will be shown later). Christensen and Raynor suggest that opening an architecture is not necessarily a mistake for a company, quoting IBM as an example.[54]

Christensen criticised the conclusions of Tushman and Andersen, who argued that firms are most at risk from entrants when the innovation destroys the competence of the firm.[55] Christensen is not, however, without his critics.

---

[51] C. M. Christensen, *The Innovator's Dilemma: The Revolutionary National Bestseller That Changed the Way We Do Business*,
[52] J. M. Utterback and H. J. Acee, *Disruptive Technologies: An Expanded View,*
[53] Christensen discusses the PC as a disruptive technology, but his main argument concern disk technology. Many people cite the PC but mostly referring to Christensen, for example, Gregory Yovanof and George Hazapis, "*Disruptive Technologies, Services, or Business Models?*," Wireless Personal Communications 45, no. 4 (2008): 569-583.
[54] C. M. Christensen and M. E. Raynor, *The Innovator's Solution: Creating and Sustaining Successful Growth* (Boston, MA: Harvard Business School Press, 2003).
[55] C. M. Christensen and J. L. Bower, "Customer Power, Strategic Investment and the Failure of Leading Firms," *Strategic Management Journal* 17, no.3: 199. M. L. Tushman and P. Anderson,

Danneels questions the definition of disruptive technology and asks, 'when does a technology become disruptive?'[56] He suggests that Christensen's 'cherry picking' of examples presents an analytical problem. Doering and Parayre wrote that 'significant emerging technologies are easily seen after the fact. But rarely are the winners clear at the outset.'[57] Most recently, Lepore suggests that disruptive innovation has few critics partly because it is headlong rather than unhurried.[58] She writes that Christensen handpicked his case studies beginning with the disk-drive industry. Lepore argues that many of Christensen's examples did not actually conform to his theories and much of his theory is based on an arbitrary selection of a successful firm as one that achieved revenues of greater than 50 million US dollars as valued in 1987. Lepore goes on to point out that many of the incumbent firms are still in business whereas many of Christensen's examples of disruptors were short lived. She also postulates that disruptive innovation can only be reliably seen after the fact and that Christensen's handpicked case studies are a notoriously weak foundation on which to build a theory. Gans agreed with much of Lepore's analysis, although he does conclude that at the core of every theory that reaches too far, there is a nugget of truth.[59] He goes on the write that, 'Christensen saw his theory as predictive even though its own internal logic says prediction is impossible. That's why he missed the mark on the iPhone.'[60]

Gans also identified another failing of Christensen's theory on disruption, stating that:

> Instead, the focus on the doomed incumbent leads Christensen away from the obvious alternative. The incumbent should 'wait and see.' They will see all manner of *potentially* disruptive technologies being deployed and instead of removing them from their radar as irrelevant, they should continue to monitor them to see what happens. Because, when the one in ten or a hundred or whatever turns out to be successful,

---

"Technological Discontinuities and Organizational Environments," *Administrative Science Quarterly* 31, no. 3 (1986).

[56] E. Danneels, "Disruptive Technology Reconsidered: A Critique and Research Agenda," *Product Innovation Management* 21, (2004): 246-258.

[57] D. S. Doering and R. Parayre, "Identification and Assessment of Emerging Technologies," in *Wharton on Managing Emerging Technologies,* ed. G. S. Day, P. J. H. Schoemaker, and R. E. Gunther (New York: Wiley), (May 2000): 75-98.

[58] J. Lepore, "The Disruption Machine, what the gospel of innovation gets wrong," *The New Yorker*, Annals of Enterprise, June 23, 2014.

[59] J. Gans, "The easy target that is the Theory of Disruptive Innovation," *Disruption*, June 16, 2014. http://www.digitopoly.org/2014/06/16/the-easy-target-that-is-the-theory-of-disruptive-innovation/ (accessed November18, 2014).

[60] Christensen suggested that the iPhone was doomed to fail in a Q&A with Jenna McGregor, the business editor at Business Week, reported by Bruce Nussbaum on June 18, 2007.

> they can then move to acquire them and realise a more 'orderly transition' to the new technology. Indeed, as I read Lepore, I got the sense that even with Christensen's iconic examples, the end result was incumbent preservation through acquisition. And this is not just theorising. My own recent paper with Matt Marx and David Hsu demonstrates just that: disruptive technologies (identified after the fact) are associated with start-ups competing and then being acquired as much as they are associated with those start-ups growing as independent firms.[61]

Innovation constantly impacts technology-based companies, especially those involved in newer technologies. Recently King and Baatartogtokh joined in the scepticism of Christensen's theories. They looked at a sample of 77 disruptive innovations corresponding to Christensen's work and concluded that 'many of the theory's exemplary cases did not fit four of its key conditions and predictions'. They found that the 'theory's validity has seldom been tested in the academic literature' and that 'theories can provide warnings of what may happen but they are no substitute for thoughtful analysis'.[62] Spencer and Kirchoff investigated how new technology-based firms brought about creative destruction and how dominant firms often failed in the face of disruptive technology.[63] They suggest that 'incumbent firms tend to excel at evolutionary, or sustaining innovations, rather than disruptive innovation.'[64] Evolutionary innovations improve current practices and capabilities with incremental changes as opposed to disruptive innovation, which involves a completely new technology. Spencer and Kirchoff propose that new technology-based firms have an advantage as they are not limited by compatibility with existing products and are not heavily invested in older technologies, and so they require less funding to develop their product. They are also not constrained by needing to support existing products nor large organisational issues. In their journal article, Spencer and Kirchoff make reference to companies that have failed due to creative destruction. Amongst these are Data General, Prime Computer and DEC.

---

[61] J. Gans, "The easy target that is the Theory of Disruptive Innovation,"
[62] A. A. King and B. Baatartogtokh, "How Useful is the Theory of Disruptive Innovation?" MIT Sloan Management Review, Fall 2015.
[63] A. S. Spencer and B. A. Kirchoff, "Schumpeter and new technology based firms: Towards a framework for how NTBFs cause creative destruction," *International Entrepreneurship and Management Journal* 2, no. 2 (2006): 145-156.
[64] Ibid. 151.

The response of firms to technology change has been investigated by academics such as Lavie.[65] In his paper, he builds on Tushman and Anderson's work and identifies three mechanisms of capability reconfiguration[66]:

- Capability Substitution: investigated by Tushman and Anderson following Schumpeterian principles.[67] Lavie suggests that capability substitution provides firms with three options for modifying their portfolio: retain existing capabilities, discard existing capabilities, or acquire new capabilities by merging with or acquiring firms with unrelated capabilities.
- Capability Evolution: investigated by Zollo and Winter.[68] Lavie goes on to suggest that existing capabilities can be modified and adjusted in an evolutionary manner through experimentation.
- Capability Transformation: investigated by Helfat and Raubitschek.[69] Lavie explains that a transformed capability can be distinguished from a new capability by the fact that it serves the same function as the pre-change capability. He cites the response of IBM to the advent of electronic computer technology in the early 1950s.

Lavie considers the cost of reconfiguration and postulates that previous studies had focused on the cost of the remedy rather than including the reconfiguration costs and they had all underestimated the cost of late response and insufficient market responsiveness. Lavie considers the two stages of capability reconfiguration – operational absorptive and cognitive absorptive – and uses IBM's move from providing scientific machines to business machines as an example.[70] In order to do this, he cites Usselman's 1993 Newcomen prize essay, although this suggests that IBM's success came initially from Government sponsorship rather than operational efficiency.[71]

---

[65] D. Lavie, "Capability Reconfiguration: An Analysis of Incumbent Responses to Technological Change," *The Academy of Management Review* 31, no. 1, Jan (2006): 153-174.
[66] P. Anderson and M. L Tushman, work is described in :- "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change," *Administrative Science Quarterly* 35 (1990): 604-633 and M. L. Tushman and P. Anderson, "Technological Discontinuities and Organizational Environments."
[67] M. L. Tushman and P. Anderson, "Technological Discontinuities and Organizational Environments".
[68] M. Zollo and S. G. Winter, "Deliberate Learning and the Evolution of Dynamic Capabilities," *Organizational Science* 13 (2002): 339-351.
[69] C. E. Helfat and R. S. Raubitschek, "Product Sequencing Co-evaluation of Knowledge, Capabilities and Products," *Strategic Management Journal* 21 (2000): 961-979.
[70] D. Lavie, "Capability Reconfiguration: An Analysis of Incumbent Responses to Technological Change,"
[71] S. W. Usselman, "IBM and Its Imitators: Organizational Capabilities and the Emergence of the International Computer Industry," *Business and Economic History* 22, no. 2: 1-35.

The effect of disruptive innovation becomes more complex when a firm has a number of diverse product lines, some of which will be challenged by innovation and some that are sustaining. Many of these product lines will meet disruptive innovation at different times in their life cycle. When firms form alliances to innovate, the situation becomes even more complex. Isabel Estrada, Natalia Martín-Cruz and Pilar Pérez-Santana considered the implications of human resources in this situation and how they can generate a climate for product innovation in multi-partner alliance teams.[72] Lavie, however, considers the competitive advantage that can be gained from alliances and questions the traditional resource-based view in an alliance situation.[73] He proposes a reformulation of the resource-based view that takes into account the gains from shared resources but goes on to suggest that mergers and acquisitions might be even more effective than alliances.

What, therefore, makes innovation critical to companies? Utterback concludes that whole industries can disappear by failing to innovate.[74] He postulates that external innovators destroy established industries and few of the original companies survive. This is another example of Schumpeter's *creative destruction*. Utterback investigates, amongst other things, the challenges of implementing a dual strategy and the 'danger of creating destructive turf battles'[75] as a result. This, again, is particularly relevant to this thesis, as DEC had a policy of multiple competing products, letting the market decide which prevailed. Utterback also considers the relationship between dominant design and the number of competitors. He shows that as a dominant design comes to the fore, the number of competing firms rises and then falls away as the product matures, creating a bell-shaped wave of firms. Utterback illustrates this with the example of the typewriter industry, but it can also be applied to the minicomputer industry as well as the personal computer. Utterback describes innovation in terms of overlapping, repeating waves that are a continuum of change. Most commentators on innovation use this form of representation, which is just an extension of the S-curve.

Sigmoid curves, or, more commonly, S-curves, have been known about and exploited in all industries since approximately 1845; Verhulst proposed his

---

[72] I. Estrada, N. Martín-Cruz and P. Pérez-Santana, "Multi-partner alliance teams for product innovation: The role of human resource management fit," *Innovation: Management, Policy & Practice* 15, no. 2 (2013): 161-169.
[73] D. Lavie, "The interconnected firm: Evolution, strategy, and performance," *Advances in Mergers and Acquisitions* 5, January 1 (2004): 127-141.
[74] J. M. Utterback, *Mastering the Dynamics of Innovation: How Companies Can Seize Opportunities in the Face of Technological Change* (Boston, MA: Harvard Business School Press, 1994).
[75] Ibid.

logostocs equation in his 1838 paper, after reading Malthus's work, while studying population growth.[76] The theory of the S-curve suggests that all businesses follow an S-curve in their development, taking a certain amount of time to reach a 10% market share and a similar amount of time to reach 90%. At this point, the company will fade away, unless it can re-invent its product or industry and begin a new S-curve. This is particularly relevant to the high technology industry, where it is strategically important to align product releases with the decline of existing product sales. Modis states that 'the projected life cycle of consumer products and the rate at which substitute products will gain market share is of vital interest to any company.'[77]

Anderson and Tushman propose an 'evolutionary model of technological change.'[78] They write that there are very few models for comprehending technological change. They demonstrated that there are long periods of incremental change in an industry.[79] These periods are interrupted by technological discontinuities. In an extension to their earlier work they propose that a Dominant Design comes after a discontinuity. Dominant Design had been proposed initially by Utterback and Abernathy.[80] Anderson and Tushman's technology cycle is analogous to the wave theory of Schumpeter or the Sigmoid's S-curve. Schumpeter defined technological discontinuities as 'an innovation that commands a decisive cost or quality advantage and that strikes at the foundation of existing firms.'[81] Anderson and Tushman categorised technological discontinuities as either competence enhancing or competence destroying.[82] Utterback and Abernathy proposed that Dominant Design was paramount to an industry's evolution.[83] Anderson and Tushman hypothesised that Dominant Designs can also become dominant by means of the market power

---

[76] P. Verhulst, (1838). "Notice sur la loi que la population poursuit dans son accroissement". *Correspondance mathématique et physique* 10: 113–121. (Accessed July 6, 2015): T. R. Malthus, *An Essay on the Principle of Population*, 4th ed., 2 vols. (London: Printed for J. Johnson by T. Bensley, 1807).

[77] Modis was employed at DEC for more than a decade as the head of the management science consultants group and is now a strategic business analyst. Theodore Modis, Chapter 1, *Conquering Uncertainty: Understanding Corporate Cycles and Positioning Your Company to Survive the Changing Environment*, Businessweek Books (New York: McGraw-Hill, 1998).

[78] P. Anderson and M. L Tushman,, *"Technological Discontinuities and Dominant Designs."*

[79] P. Anderson and M. L Tushman,, *"Technological Discontinuities and Organizational Environments."*

[80] J. M. Utterback and W. J. Abernathy, "*A Dynamic Model of Product and Process Innovation*," *Omega* 3, no. 6 (1975): 639-656.

[81] J. A. Schumpeter, *Capitalism, Socialism and Democracy* (New York, Harper and Brothers, 1942), 84.

[82] P. Anderson and M. L Tushman,, *"Technological Discontinuities and Organizational Environments."*

[83] J. M. Utterback and W. J. Abernathy, *A Dynamic Model of Process and Product Innovation*.

of the producer and they cite IBM's PC as a good example of this, even though it was not the fastest PC.

Asthana considers the point at which companies should abandon the current S-curve and move to a new one, and postulates that many companies do not jump because they are looking at competitors' products rather than the industry as a whole.[84] He cites IBM's failure to invest in RISC technology as being due its major competitors not investing, whilst companies that were investing, such as Sun and Apollo, were not visible to IBM. Asthana also goes on to suggest that corporate politics play a part in deciding whether or not to adopt a new technology and that the 'not invented here' syndrome also plays a part in decision making. This is reasonable for product classes going forward, but shows that firms also need to be aware of disruptive technologies if they are to survive, a point that many have missed.

2.3 *Downsizing*

Once a firm has missed the S-curve or had a disruptive technology affect its business, it often finds that its sales and margins decrease. This leads to a need to control costs and the firm often resorts to downsizing and a reduction in research and development. Serious studies of downsizing began with Cascio in 1993 just after DEC embarked on the largest corporate downsizing to date. Cascio argues that many of the anticipated benefits of downsizing fail to materialise as a result of a failure to break out of the traditional approach to organisational design.[85] Headcount reduction, he suggests, should be only one part of a process of continuous improvement. He goes on to suggest that these benefits do not materialise because the downsizing has a negative influence on productivity, morale and motivation. This certainly appears to be the case in the downsizing activity that occurred in many of the minicomputer manufacturers. Cascio's work was updated in 2009 by Gandolfi.[86] Littler and Gandolfi identified three stages of downsizing: the 1970s to mid-1980s; the mid-1980s to the early 2000s; and the early 2000s to the present.[87] They state that an analysis of the literature, empirical evidence and assertions of downsizing scholars shows that in the middle stage, job cuts were more severe and strategic. Littler and Gandolfi also

[84] P. Asthana, "Jumping the Technology S-Curve," *IEEE Spectrum* 32, no. 6, June (1995): 49-54.
[85] W. F. Cascio, "What Do We Know? What Have We Learned?," *Academy of Management Executive* 7, no. 1 (1993).
[86] F. Gandolfi, "Unravelling Downsizing – What do we know about the Phenomenon?," *Review of International Comparative Management* 10, no. 3 (2009).
[87] C. R. Littler and F. Gandolfi, "What happened to downsizing? Organizational continuity, managerial fashion, and signalling." *Academy of Management Conference, Anaheim*, paper presentation, (2008).

state that the language of downsizing in the middle stage created a focus and signal to capital markets.

Gandolfi writes more of this middle period and states that, 'prior to the mid-1980s the term downsizing appeared very infrequently in both the popular business press and the academic literature.'[88] He notes that the prime targets of layoffs in this period were technical, professional and managerial, as organisations tried to become 'lean and mean.' Gandolfi reports that many became 'lean and lame' as described by Mroczkowski and Hanaoka.[89] He goes on to suggest that in the middle period, 'downsizing was adopted as a strategy to bring about the "Wall Street effect" where an announcement of layoffs would yield immediate increases in stock prices.'[90]

In the 1980s and 1990s, many firms turned to downsizing, some driven by stock market pressures demanding greater profitability, others by the desire to make their corporations leaner. This began when the world economy fell into recession, but many computer firms continued with the practice, as industry changed from mainframe computing to client-server.[91] Budros offers some systematic thoughts on why firms downsize and proposes a conceptual framework for exploring organisational innovation; he differentiates between downsizing and restructuring.[92] Budros, in a later paper, considered two types of downsizing: voluntary downsizing, where firms pre-empt the potential economic pressures; and involuntary downsizing, where firms face economic pressures and there is shareholder activism.[93] Much of the wisdom conveyed by the books and papers on downsizing is attributable to the study of the activities of firms in the 1980s and their quest for profitability. Many theories on downsizing were formulated in the 1990s as a result of research on companies that were effectively at the forefront of the major downsizing process. Most of the papers merely offer common sense approaches to downsizing and standard methodologies that were observations on what went wrong with the process in those firms under consideration.

---

[88] F. Gandolfi, "Phases of Cost Cutting: Downsizing is Dead; Long Live the Downsizing Phenomenon," *Review of International Comparative Management* 10, no. 5 (2009): 866.
[89] T. Mroczkowski and M. Hanaoka, "Effective Rightsizing Strategies in Japan and America: Is There a Convergence of Employment Practices?," *The Academy of Management Executive* 11, no. 2 (1997).
[90] C. R. Littler and F. Gandolfi, "What happened to downsizing?"
[91] K. Heil,"Downsizing and Rightsizing," Reference for Business, accessed September 23, 2011, http://www.referenceforbusiness.com/management/De-Ele/Downsizing-and-Rightsizing.html..
[92] A. Budros, "A Conceptual Framework for Analysing Why Organizations Downsize," *Organizational Science* 10, no. 1 (1999).
[93] A. Budros, "The Mean and Lean Firm and Downsizing: Causes of Involuntary and Voluntary Downsizing Strategies," *Sociological Forum* 17, no. 2 (2002).

McKinley and Scherer, in their discussions of restructuring, propose that top executive cognitive order is often different from that of middle management and technical personnel, who perceive it as a form of cognitive disorder.[94] They suggest that there is often a lack of connection between upper and middle management in their communication about the goals of restructuring. O'Neil et al go further and suggest that middle managers play a crucial role in corporate downsizing but are often ill-prepared to make a full commitment.[95] They argue that only when the voices of middle managers are heard, will downsizing efforts be successful. Unfortunately, within most firms undergoing the downsizing process, orders come from senior management and are not the result of feedback from those implementing the process.

Mone and McKinley discuss organisational decline and innovation, postulating that politicking between coalitions exacerbates the difficulties of coordinating innovation in a power-diffused structure.[96] Folger and Sharlicki consider how managers distance themselves from employees to avoid criticism and antagonism.[97] They look at the reasons for discomfort and suggest that distancing is not related to who made the downsizing decision. This concurs with O'Neil et al, in that senior managers who focus only on bottom line numbers often ignore the organisational consequences of downsizing.

It is apparent that there are hidden dangers in uncontrolled downsizing, one of which is the loss of corporate networks, as described in Shah's paper on the structural implications of downsizing.[98] This is often an area that senior managers are completely unaware of because they are distanced from day-to-day operations. Cascio covers ten mistakes to avoid when restructuring, in relation to communication and the selection of personnel.[99] He also suggests that rather than downsizing to cut costs, a responsible strategy focuses on people as assets to be developed. All of this suggests that management has a pivotal role to play in any

---

[94] McKinley, Associate Professor of Management at Illinois University, and Scherer, Associate Professor at the University of Constance. W. McKinley and A. G. Scherer, "Some Unanticipated Consequences of Organizational Restructuring," *The Academy of Management Review* 25, no. 4 (2000).
[95] H. M. O'Neil, D. J. Lenn, and V. F. Caimano, "Voices of Survivors: Words That Downsizing CEOs Should Hear," *The Academy of Management Executive* 9, no. 4 (1993).
[96] M. A. Mone, W. McKinley, and V. Barker, "Organizational Decline and Innovation: A Contingency Framework," *The Academy of Management Review* 23, no. 1 (1998).
[97] R. Folger and D. P. Sharlicki, "When Tough Times Make Tough Bosses: Managerial Distancing as a Function of Layoff Blame," *The Academy of Management Journal* 41, no. 1 (1998).
[98] P. P. Shah, "Network Destruction: The Structural Implications of Downsizing," *The Academy of Management Journal* 43, no. 1 (2000).
[99] W. F. Cascio, "Strategies for Responsible Restructuring," *The Academy of Management Executive* 16, no. 3 (2002).

downsizing scenario and their actions can affect the success of any planned change. Often, this is not recognised by the senior management and only those who understand this can implement the downsizing process in the most cost-effective manner.

Two methodologies commonly used in downsizing, which are believed to be the least harmful to morale and the company, are natural attrition and early retirement. However, they are not without their price. Howard looks at the motivation of those who are considering early retirement and whether there is in fact a detrimental consequence to the company.[100] Howard addresses only managers; he overlooks the effect of the loss of technical personnel and the implicit knowledge that is also lost. Davidson, Worrell and Fox consider early retirement programmes and their positive influence on the stock price. However, they also note the potential for adverse selection issues, such as the poorest performing employees remaining and the most productive leaving, with a negative effect on companies.[101] In contrast, Lee suggests that the stock price reaction to downsizing announcements in general, is normally negative.[102]

It is not just the employees made redundant who are affected by downsizing, however. The morale of those left behind tends to decline as the rounds of downsizing continue. There is mistrust of management and their motivations, which often conflicts directly with the longstanding company culture. Mishra and Spreitzer identify four types of response from employees to downsizing.[103] First, there is the fearful response where employees reduce their level of commitment, reduce their concentration and procrastinate about decision-making. The second type of response is the obliging response where the employee does not feel threatened, is faithful to the company and follows orders. The third type of response is labelled as the cynical response. This is the response of employees who feel threatened by downsizing and are active and destructive in their response. They challenge and criticise management and try to sabotage the downsizing process. Finally, there is the hopeful response where the survivors are not threatened by the downsizing and are active advocates, who aim to help the organisation's performance. Mishra and Spreitzer go on to explore these archetypes in much more detail with respect to the reasons behind

[100] A. Howard, "Who Reaches for the Golden Handshake," *The Academy of Management Executive* 2, no. 2 (1988).
[101] W. N. Davidson, D. L. Worrell and J. B. Fox, "Early Retirement Programs and Firm Performance," *The Academy of Management Journal* 39, no. 4 (1996).
[102] P. M. Lee, "A Comparative Analysis of Layoff Announcements and Stock Price Reactions in the United States and Japan," *Strategic Management Journal* 18, no. 11 (1997).
[103] A. K. Mishra and G. M. Spreitzer, "Explaining How Survivors Respond to Downsizing: The Roles of Trust, Empowerment, Justice and Work Redesign," *The Academy of Management Review* 23, no. 3 (1998).

these reactions and their potential consequences to the business.[104] They hypothesise that trustworthiness in management has a direct influence on the retention of those who remain after the downsizing is over.

Culture plays an important part in the evolution of companies. The major computer companies such as IBM, HP, Data General and DEC all had employee-oriented cultures in the 1970s and 1980s. In his article "Downsizing and Organisational Culture," Hickok argues that eventually, the most important consequence of downsizing is the effect on the culture rather than savings on costs.[105] This is due to the fact that there is a power shift to management, where family relationships turn into competitive ones and the employer-employee relationship moves away from stable to short term. This thesis will seek to demonstrate that this was particularly evident in the case of DEC, which had an extremely long-standing and employee-oriented culture up until the resignation of its founder, Olsen. Walsh found that the DEC culture was maintained even beyond the final demise of the company.[106]

2.4 *Rise of Silicon Valley*

Geography had an important role to play in innovation in the high tech world of computing, especially in America. There is a rich literature describing the importance of geographical localism in developing innovative products. One of the most cited authors in this area is AnnaLee Saxenian. Saxenian compares Silicon Valley and Route 128 in Massachusetts in "The Limits of Autarky" and *Regional Advantage*.[107] In her discussions, she attributes the rise of Silicon Valley to the laid-back atmosphere between employees of different companies and their ability to switch employers without issue. She goes on to ascribe the proliferation of the West Coast companies to a more relaxed venture capital regime, as opposed to traditional East Coast conservatism. However, Kenney and Burg argue that it was a difference in technical trajectories that allowed Silicon

[104] A. K. Mishra and G. M. Spreitzer, "To Stay or Go: Voluntary Survivor Turnover Following an Organizational Downsizing," *Journal of Organizational Behaviour* 23, no. 6 (2002).
[105] T. A. Hickok, "Downsizing and organizational culture." *Public Administration & Management: An Interactive Journal* 3, no. 3 (1998).
[106] I. J. Walsh, "The Role of Organizational Identification in Post-Death Organizing," Wallace E. Carroll School of Management, Boston College, March 23 (2009). PhD dissertation. Supervisor J. M. Bartunek.
[107] A.Saxenian, "The Limits of Autarky: Regional Networks and Industrial Adaption in Silicon Valley and Route 128," in *HUD Roundtable on Regionalism* (1994); AnnaLee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, MA: Harvard University Press, 1994).

Valley to surpass Route 128 in terms of growth.[108] Their argument is compelling and one that we consider more reasonable to explain the rise of Silicon Valley than that of Saxenian. Earlier, Dorfman had suggested that the growth of Route 128 in the 1970s was spontaneous and linked to the proximity of the high tech universities, which would tend to complement Kenny and Burg's theory with MIT, Berkeley and Stanford focusing on different technical areas.[109]

Another view on the rise of Silicon Valley is presented by Lécuyer, who covers the early days of the area and argues that it began with firms manufacturing radio valves.[110] He points out that in the 1930s, West Coast companies such as Sperry and Varian thrived by selling radio equipment to the defence industry and that these companies were funded by individual backers or banks. Varian later tried to enter the minicomputer market, but was unable to compete with companies such as DEC, and its data systems division was eventually taken over by Sperry.

West Coast institutions and venture capitalists invested in the semiconductor industry and this was where its growth, and the name 'Silicon Valley', originated. Although Saxenian is often quoted, there are a number of debatable statements in her work. She compares DEC and HP in some detail, suggesting that people moved from firm to firm with relative ease in Silicon Valley and that there was less mobility on the East Coast. Moreover, she compares the loyalty of employees and the no-layoff policies of both HP and DEC. However, the major difference between the computer firms on the East Coast and the West Coast was that the West Coast recognised the importance of UNIX and RISC technology before the Route 128 companies.

The cultural differences between Silicon Valley and Route 128 are covered in *Regional Advantage* and much of this affected DEC in the 1980s, as DEC had research departments in California, as well as Massachusetts. Saxenian comments that 'much of DEC's Palo Alto laboratory contributed more to other Silicon Valley firms such as SUN and MIPS than it did to DEC.'[111] Certainly, there was a great deal of encouragement for the founders of MIPS from within DEC. Alarcon proposed that the availability of skilled immigrant labour was

---

108 M. Kenney and U. von Burg, "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128," *Industrial and Corporate Change* 8, no. 1 (1999).
109 N.S. Dorfman and Massachusetts Institute of Technology, *Massachusetts' High Technology Boom in Perspective: An Investigation of Its Dimensions, Causes and of the Role of New Firms* (Center for Policy Alternatives, Massachusetts Institute of Technology, 1982).: M. Kenney and U. von Burg, '*Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128'*, (1999), *Industrial and Corporate Change* 8 (1): pp. 67-103.
110 C. Lécuyer, *Making Silicon Valley: Innovation and the Growth of High Tech, 1930-1970*, Inside Technology (Cambridge, MA: MIT Press, 2006).
111 A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, 137.

partially responsible for the rise of Silicon Valley, reporting that there was a 30% immigrant population in the high tech industry, mostly from India.[112] He only examines the growth of global professionals rather than the penetration of individual firms in his paper, making it difficult to relate his assertions to the cultural differences between Silicon Valley and Route 128 as described by Saxenian.

Saxenian implies that venture capitalists in Silicon Valley were all experienced in the business and technical field and that those in Boston were all conservative bankers. However, as Gompers writes, 'Companies funded by ARD were considered to be members of the family. ARD's staff under Doriot's direction began providing industry expertise and management experience to the companies they backed in order to increase their chances of ultimate success.'[113] Saxenian goes on to write that DEC, amongst others, failed because it could not keep up with the faster and more flexible West Coast competitors, a contention that this thesis disputes. Two areas Saxenian does not comment on, but which are quite significant to the cultural aspects of the West Coast, are the influence of hippie culture on the population and also the mild climate of the region. Certainly, the West Coast was a far more relaxed and climatically appealing place to live, as commented on by Dormehl and Deutschman.[114] The rise of Silicon Valley companies, we would contend, was due to a unique set of circumstances: hippie culture providing a relaxed view of work; the advent of home computing providing an eager consumer; a low cost of entry for new ventures; venture capitalists looking for a new DEC to invest in; and the availability of VLSI circuits from local semiconductor manufacturers.

2.5 *Theoretical Perspectives*

The purpose of this case study is to determine the causes of the demise of DEC from a technology view point. It is grounded on Schumpeter's assertion that innovation creates growth and also streamlines processes leading to efficiencies which in turn reduce manpower requirements. The output will contain an analysis of the consequences of innovation on the management of the company, the technologies that the company developed and timescales of the implementation of the technologies as well as its impact on the personnel. We use Schumpeter's disruption theory as a basis and the innovation theories of

---

[112] R. Alarcon, *Migration between States and Markets* (August 2004). Ed. H. Entzinger, M. Martinello, and C. Withol de Wenden, Ashgate Publishing, Burlington VT. 28-41.
[113] P. Gompers, "The Rise and Fall of Venture Capital."
[114] L. Dormehl, *The Apple Revolution* (Ebury Publishing, 2012); A. Deutschman, *The Second Coming of Steve Jobs*, 1st ed. (New York: Broadway Books, 2000).

Christensen who updated Schumpeter's theories. In particular we consider Schumpeter's and Christensen's analysis of the S-curve and its relationship with the growth of companies. Our analysis looks at the three pillars of the theories. In separate chapters we will consider how DEC handled innovation in its product set over the years and in particular the 1980s when the company failed to keep up with the innovation in the industry, how it handled the reduced manpower requirements for the innovative products and how it managed its finances as margins reduced and manpower costs increased. We also show that the management were in a state of confusion and indecision in the 1980s after the departure of its technical guru Gordon Bell.

Schumpeter's initial theories, at first considered disruption from internal developments but then changed to view disruption as an external influence. In fact both views are equally credible depending on the type of technology involved. Either would cause the firm to react to the innovation in a controlled manner or in a reactive manner. Innovation theory dropped out of focus after Schumpeter until the SPRU was formed, after which it had resurgence in the 1980s onwards with Christensen and Henderson leading.

Schumpeter proposed his theory of creative destruction in a time when technical development was in its infancy and relatively slow. It was only when technical development accelerated that it was resurrected. In this period research and development departments grew in size and importance in high tech companies. Recently companies have started to protect not only their products but also their future concepts with patents. Patent laws have stifled some innovation in recent years as software and hardware complexity increases and patents proliferate. Since the mid-1990s, when the Federal Circuit concluded that an algorithm implemented in a computer could be patentable, there has been a surge of software patents.[115]

In the 1980s, innovation in technology was predominantly hardware based. Entrepreneurs and innovators were often the same person, especially in smaller companies but as a company grew these roles tended to separate. Christensen suggests that innovation can be managed and offers courses on managing it, however predictive innovation is not a certainty and an innovative product is not necessarily a successful product. For example, bubble memory was innovative in the 1970s but never succeeded as a product. Generally, innovation can only be measured after product release and often it is not the innovative company that

---

[115] A Kamdar and D. Nazer. *"Deep Dive: Software Patents and the Rise of Patent Trolls",* Electronic Frontier Foundation, February 28, 2013

makes a success of the product but an imitator. Prime example of this was Compaq's rise on the initial release of the IBM PC. Another example being Apple and the i-Pad. It was not the first tablet, Microsoft had one much earlier, but it was marketed well and became the leader. One of the side effects of innovation is a rise in the number of companies entering the market, followed by a natural weeding out. Essentially it becomes a bell shaped curve as the products mature and something appears to replace them.

Innovation relies on visionaries recognising the potential of a new product or new process and their ability to convince others, such as venture capital companies in the case of a new venture or the board in the case of an existing company, of the viability and sales potential of the innovation. In start-up companies, innovators tend to be individuals such as Steve Jobs and Steve Wozniak for Apple, Mark Zuckerberg for Facebook and Sergey Brin and Larry Page for Google. In larger companies it is not normally clear who innovates as it tends to be a team process, in the case of the IBM PC Bill Lowe took the concept to the board, Don Estridge led the team that built the PC but there were many involved in the total process. De Jong considers individual innovation and the role of leadership in his thesis.[116] In it he considers the construct of innovative work behaviour and the role of the individual in going beyond the scope of their job role to innovate. Since 2000 hardware has effectively stabilised and most technology innovation is now software based.

Scholars have theorized at length about innovation, the issues it presents to companies and how they should respond to it. Most have looked at single high tech products and specialised companies. However most of the high tech computer industry does not have the isolated environment that many scholars consider and so its response to innovation is determined by the totality of its current product range and future predictions for the company. It is extremely difficult for a company to plan for any innovation except for incremental/sustaining which could be classed as evolution as opposed to innovation. Innovative products tend to be the result of an individual piece of inspiration rather than a planned development. Disruptive innovation tends to be external whereas sustaining innovation is normally internally created. Companies need to react once a product is considered to be a potential innovation that would impact its business. If it is an internal innovation it needs to plan for product replacement and potentially margin reduction and manpower retraining or reduction. If it is an external innovation companies must consider whether to

[116] J. P. J. de Jong, *Individual Innovation: The Connection Between Leadership and Employees Innovative Work Behaviour*, PhD thesis, University of Amsterdam, supervisor prof. dr. D. N. den Hartog, 2007

create a competing product or simply buy out the innovative company once it is established. Many of the disruptive innovations have come from 'blue sky' thinking and 'midnight projects' that are outside the normal processes and firms that have allowed their employees the freedom to develop their theories have found themselves ahead of their rivals.[117] It is this type of corporate environment that encourages innovation without having a detrimental impact on the business.

In a large company it often falls to the marketing organization to analyse the impact of a new technology on the company and advise senior management. Innovation itself comes from the company's research and development teams which need a strong technologist as their leader. Product innovation in technology based companies has moved computers into the mass market and the rate of innovation has increased substantially over the past two decades. The result is that companies have to move a great deal faster in product analysis and development. No longer can they afford to spend four years in product development.

Innovation or evolution? There is a fine line between these terms. Often it is just the degree of evolution that makes it innovative. DECs systems each went through a number of evolutionary stages before there was an innovative event. In order to ascertain whether there was a failure of innovation it is necessary to look at the process whereby the company defines its product strategy and identify who was involved in the decisions as well as the technology involved. In such a large company there are a number of people responsible for technology based decisions however, as Schein identified, often decisions were made but not followed up by management. Schein classifies this as the 'DEC nod' where people agree in meetings but then ignore what they agreed to. DeLisi also wrote about the 'DEC Nod' in management meetings, believing this would eventually translate into an unwillingness to value external inputs.[118] This apparent disregard for others opinions has the potential to lead to missed opportunities and incorrect product development. It is also necessary to define the timelines of events that led to the company downfall in order to link innovation events with company crises. This is essential if we are to refute the theory that the PC was a major contributor to the fall.

---

[117] Midnight projects were unfunded developments that happened outside working hours in many high tech companies during the 1980s and 1990s. Google continues with the process today but allows their employees time during their working week for such work.

[118] P. DeLisi, 1998. A modern day tragedy: The Digital Equipment story. *Journal of Management Inquiry* 7 (No 2 June): 123

As Leporte suggested, Christensen and Henderson among others analysed a narrow product based set of companies to determine the impact of disruptive technologies. This is fine for smaller companies that only have single products but does not scale to fit the larger company with a diverse product range where a disruptive technology would not, on its own, bring the company down unless it affected the whole of the product range. We would propose that, in order for a major corporation to fail there must be a number of convergent disruptions, not just technical, creating a virtual tsunami of issues that the management and investors could not deal with. Utterback hypothesizes that the dynamics of innovation involves a rapid product innovation phase where rapid progress is made before it settles down.[119] We propose that there is another potential model behind innovation which has not yet been discussed in academia. This is the 'dormant innovation' that just sits in the background for a number of years until some change in circumstances or technologies brings it to the fore. UNIX was one such product, developed on a DEC PDP system but later ported across to many other systems.[120] Although developed in the 1970s UNIX did not appear in the datacentre in volume until the recession of the mid 1980s when cost became more prevalent in the choice of system software.

2.6 *Management of Technological Innovation*

Technological innovation management requires a thorough understanding of the technology, industry and business. Schumpeter had little to say concerning technological management nor the sources of technical change in diversified companies. If we look at the consequences of disruptive technology from a business perspective it leads us to the conclusion that business management in a technology company is reliant on technological management. In larger firms this is often not the entrepreneur but an advisory officer. Schumpeter has the entrepreneur as 'the agent of innovation'.[121] As firms grow then innovation is transferred from the entrepreneur to in-house teams. Small firms tend to focus their technological strategies on specific niche products linked to their key strengths whereas larger innovating firms tend to have a broader product focus. They typically have research and development laboratories and are

---

[119] J. M. Utterback, 'Mastering the Dynamics of Innovation', 124

[120] UNIX was developed in the 1970s by Ken Thompson, Dennis Ritchie amongst others but was always a low volume product mainly used in academia until the recession of 1980s compelled larger firms to re-evaluate their software costs and invest in UNIX as the cheaper option supplied by firms such as HP and IBM with the AS400 and AIX. UNIX was further propelled into the mainstream by the adoption of SUN workstations bringing it to the desktop.

[121] J. A. Schumpeter, 1934. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Translated from the German by Redvers Opie. With an Introduction by John E. Elliott. New Brunswick, NJ: Transaction Publishers.

divisionalized in their product structure.[122] When it comes to the management of technologies there are a number of functions within the company that need to have input. Along with R&D, production and marketing must have a say in the strategy. Thus company structure plays a major role in the technological strategy of the company.[123] For a large diversified organisation technical innovation can be segmented into a number of areas as indicated in table 1.

Table 1: Classification of technologies

Creative Technology	In house innovation that will enhance product offerings or create new business.
Disruptive Technology	External Innovation that has the potential to harm the company unless adopted.
Dormant Technology	Technologies that have been around for a number of years without major development but are poised to become disruptive.
Obsolete Technology	Technology that was important to the company but has now passed its potential.
Outlier Technology	Technology that is not considered to impact the current vision of the company

It is therefore necessary for the management team to consider all of the above technologies constantly if the company is to prosper. The technology management skills are therefore essential to complement the business management of a company. The technologist has to be a visionary and also have a strong personality to influence the business.

The PC could be considered an outlier technology in the eyes of the major computer manufacturers in the 1980s just as the minicomputer was an outlier technology for the mainframe manufacturers in the 1960s. Obsolete technologies, although straightforward, do present some challenges to large businesses. There is the problem of ongoing support for product including spares

[122] K. Pravit. 1990. *Technology, Management and Systems of Innovation*, California Management Review Vol 32 no. 3 Spring. 63.
[123] Ibid. 65.

holdings for hardware and support for software. Smaller companies tend not to have this issue. Dormant technology poses a number of problems for companies as it is known about and sits there with a low level of interest until it suddenly appears as a disruptive technology. The technologist needs to anticipate this transition. One such dormant technology was UNIX. It sat as a niche offering from 1971 until the mid-1980s. Christensen's views simplify the process to disruptive innovation rather than the complexity of the other various types of innovation/technology. In the case of technology companies innovation and technology are mostly synonymous. The above classifications are proposed as a model for technology companies.

2.7 *Conclusion*

In this chapter we have looked at the literature associated with innovation and disruptive technology. We have identified the current theories of why DEC failed and the theories around how innovation can disrupt the normal growth of a company if it is not handled competently. Schumpeter defined creative destruction and Christensen applied this theory to DEC. Schein had worked at DEC up to 1992, attending most senior management meetings as a facilitator, and concluded that managements financial capabilities were at fault. Christensen was not without his critics however and we need to consider this when looking at his theory of DEC's demise. One of the issues that Schumpeter considers as a consequence of disruptive innovation is the reduced manpower requirements due to increased efficiency. Finally we propose the theory of 'dormant innovation' which sits in the background for some time before suddenly appearing as a mainstream threat to current technologies.

3 Methodologies Used

3.1 *Introduction*

This chapter outlines the various methodologies used in the preparation of this thesis and the reasons for their selection. The thesis examines a complex subject and so it was necessary to employ a number of research methodologies to cover the rise and fall of the company and the state of its technologies at its merger. We consider DEC as a case study, applying both qualitative and quantitative methodologies in the analysis. The advantage of treating it as a case study is that it gives detailed evidence from a range of sources, and interpretation of that data is therefore more reliable. We started with a review of the literature and then conducted interviews with many of the actors responsible for managing the company as well as those in technical roles responsible for product development. A survey of many of the personnel that were affected by the downturn of the company was conducted to gauge the feeling towards the downsizing that occurred.

In selecting the literature it was important to define who the audience of this thesis might be. The most obvious would be the growing number of business historians that focus on the computer industry. Computing history has not been studied extensively in the past because it is a relatively new discipline. Some such as Martin Cambell-Kelly, James Cortada, Paul Ceruzzi, Michael Mahoney and Simon Lavington have been leading the way and are well known as computer historians.[124] The International Bibliography of Business History only references five books that mention DEC and most of those are just brief mentions.[125] The other section of the academic community that this will be of interest to is those that focus on technology and innovation in business.

Tosh reminds us that historical awareness, human memory and collective memory can be faulty and be moulded by tradition or nostalgia.[126] This informs us that care must be taken in collecting people's recollections of earlier times. Corporate culture has a major bearing on people and groups, tending to distort their view of the company and the time they spent working there. Tosh goes on to look at nostalgia and history as 'loss', with corporate culture having a bearing

---

[124] Ceruzzi's History of Modern Computing is an example of a brief compendium of computers through the years. Whereas Mahoney's Histories of Computing is more of a theoretical view of the history of computing.
[125] F. Goodall, T.Gourvish and S. Tolliday, International Bibliography of |Business History, (Routledge, 2013).
[126] J. Tosh, *The Pursuit of History: Aims, Methods, and New Directions in the Study of Modern History*, 5th ed. (New York: Pearson Longman, 2010), 320.

on this sense of loss. This sense of loss can easily lead to biased memories of "the good times."

A company timeline was constructed in the early stages of the study to align the products and people and to determine what and who influenced the company's development, and hence who should be interviewed as a priority. This is depicted in Appendix A6. Having worked for the company, I was able to gain access to many people more readily than an outsider might have done. Participants would probably not have been so candid in their discussions of events with someone who was an outsider. This insider status facilitated a clearer view of what really happened, but it also had the potential to influence my impartiality in some of the analysis. As I had worked in the UK rather than at corporate headquarters, some degree of separation was achieved, but care was taken to keep an open mind and not to allow my history to influence the research. Open questioning techniques were employed as much as possible to ensure that those being interviewed were not guided in their responses.

3.2 *Comparison with other companies*

A number of competitive companies of the time were also compared to ascertain what they did differently to survive the troubled times of the 1990s – and what mistakes were made by those that did not survive. Brief studies were made of four comparable companies and their actions: IBM, HP, SUN and Data General, with more focus being assigned to HP and IBM. Data from the Securities and Exchange Commission for the companies were compared, as were the company reports for two of the companies. Their relative positions in the Fortune 500 were also examined over the years to gain an appreciation of the size of the companies.

3.3 *Quantitative analysis*

The majority of the data related to qualitative methods; the quantitative analysis was mostly performed on the financial and employee population data. Figures reported to the Securities and Exchange Commission (SEC filings) in the United States were obtained, together with the company's annual reports from 1967 to 1996 and these were analysed to determine the financial health of the company over the years.[127] The data were amalgamated into a number of spreadsheets which provided graphs and observations, as well as some interpreted facts. Data were also collected from the company reports to fill in the areas not covered by

[127] SEC filings available from http://www.sec.gov/ (accessed June 22, 2015); also at Edgar Online.

the SEC filings.[128] These allowed analysis of the profit and loss, number of employees, assets and income for product and service. This was a quantitative analysis of a large amount of financial data from a number of years and provided a detailed view of the company performance over the years.

The costs of product development and personnel were also analysed and this too added to the understanding of the issues that were to affect the company in the 1980s. In terms of downsizing, the number of employees, cost of staff reductions and facility reductions were analysed along with comparative figures from competitors at the time. Again the figures were obtained from SEC filings.

3.4 *Qualitative analysis*

In a case study of a major company such as DEC, quantitative business results and major events are readily available and form the foundation for a factual account of what happened to that company over time. However, these facts tell only part of the story and it is possible, using techniques from history and the social sciences to use other types of data to assemble narratives and interpretations which help to explain how decisions were reached and why events turned out the way that they did. Internal documents, discussions and items such as the company's Notesfile entries provide valuable information for researchers, but the nature of such evidence provides some challenges for the historian.[129] These items are rich in detailed commentary, containing much personal opinion. The main issues for the researcher are the existence of bias in the original material, and the difficulty in interpreting such data at a distance of some thirty years from the events and dilemmas described. There are inevitable contradictions in such a wide range of evidence, and the researcher must find ways to establish facts and interpret opinions through the mass of information that is available.

These issues have been widely theorised, as historians have had to deal with an increasing amount and range of evidence types throughout the past century. It has been pointed out that since the middle of the twentieth century historical knowledge has been a contested subject, with multiple paradigms being applied, and various theoretical traditions influencing the approaches that historians

---

[128] Company reports are available at the Ken Olsen Archives, Gordon College, Wenham, MA. Gordon College is a Christian college where Olsen was a trustee and board member. As well as the Archives, the college is also the home of the Ken Olsen Science Centre.

[129] Notesfiles were the heart of DEC's collaborative conferencing facility, which will be described later in this chapter.

take.[130] This is true whether or not historians are aware of their own approaches since all historians start with various assumptions and work according to their own choice of theories and frameworks.[131]

There are a number of issues that arise in such an undertaking and it is important at the outset to be aware of the strengths and weaknesses of each approach as it applies to the history of DEC. The interviews conducted as part of this study were used to gather details of individual experiences. The surveys and emails, on the other hand, use narrative methods, seeking to interpret the stories that people tell about their time at DEC. The analysis of company documents such as reports and memos are used in order to establish not only what happened at the time, but what it meant to the people involved, and what it means in the longer term, as reviewed with the benefit of hindsight. No one of these methods will produce the full facts, but taken together they provide multiple insights which can be used to give a rounded picture of events from several different perspectives. Effectively we build a business history of the company with a focus on the technological aspects of the business. Initially business history was focussed on the entrepreneurial aspects of a company. Chandler shifted the focus of business history to organisations and corporate management. This thesis gathers a very large amount of evidence and carefully sorts and compares individual items, looking for facts where possible, and corroboration between different individuals where the facts are contested or incomplete. This activity lies at the heart of modern social history: 'it is never really a matter of the facts *per se* but the weight, position, combination and significance they carry *vis-à-vis* each other in the construction of explanations that is at issue.'[132] This is the main focus of the thesis, seeking to outline what happened, as far as this is possible to do, and to interpret the significance of events as they happened, and also in the longer term as they affected the company itself and the wider industry.

The different types of evidence used are presented below, with brief outlines of their nature and the ways they are used. Public records and archives provided traditional historical materials and these are meticulously referenced. Personal testimonies and survey results are a much less reliable source of information because of the human phenomenon of social desirability bias.[133] Most people have an in-built desire to produce answers that they think are expected and

[130] M. Fulbrook, *Historical Theory: Ways of Imagining the Past* (London: Routledge, 2002), 12-33.
[131] Ibid, 4.
[132] K. Jenkins and A. Munslow, *Re-Thinking History* (London and New York: Routledge, 2003), 40.
[133] A. A. Stone, J.S. Turkkan, C. A. Bachrach, J. B. Jobe, H. S. Kurtzman and V. S. Cain (eds), *The Science of Self-Report: Implications for Research and Practice* (Mahwah, NJ: Lawrence Erlbaum, 2000. See also J-B.t E.M. Steenkamp, M. G. de Jong and H. Baumgartner, "Socially Desirable Response Tendencies in Survey Research" *Journal of Marketing Research* 47 (2), (2010), 199-214.

acceptable, and they generally seek to present a good image of themselves to others. This kind of bias is more likely to be present when questions about the individual's own feelings and actions are asked, and when particularly contentious or emotional issues are being researched. In this thesis the surveys conducted as a follow-up to the redundancy measures are a typical example of an approach which is susceptible to this kind of bias. They give a reasonably accurate picture of how employees rationalise the experience in front of the researchers, but there may be quite different feelings underneath the surface which individuals do not feel able to express, such as for example distress at the fate of their colleagues, or relief at finding themselves one of the survivors of the downsizing. In such cases the reasons for the survey, its origins and its various purposes, both overt and more subtle, will influence the way that respondents answer the questions and the way that a later researcher will interpret the results. In a case study such as this examination of DEC, all of these factors must be taken into account when analysing the results of the survey since the effect of social desirability bias can be to skew the results of any survey or questionnaire.

Any trace of organisational memory had been lost with the takeover of the company, especially the subsequent sale to H.P. as there was an effort to erase much of the history of DEC.[134] Thus episodic memory was considered.[135] Given the time gap of 20-30 years between the events described and the present time, there can also be considerable variation in the amount and type of recall that a participant has of any specific event or issue, and the passing of time brings to bear also the dubious benefit of hindsight, which colours earlier experiences and also affects which details are remembered and which are forgotten. It is impossible to eliminate these sources of bias, since they are part of the human mental make-up, and originate largely at a sub-conscious level. The only way to deal with them is to be aware that they exist and state clearly any relevant factors which might influence the results. The case study approach has the advantage of allowing other information to be collated alongside personal statements survey results, allowing for a certain amount of corroboration and triangulation to be obtained.

One methodological issue which presented some difficulty was the incomplete nature of some of the data sets. Archival material was available for the Olsen years, for example, but much less material was accessible from the time that Palmer took over. The immediate consequence of this is to make analysis of this

---

[134] M. Rowlinson, C. Booth, P. Clark, A. Delahaye and S. Procter, *Social Remembering and Organizational Memory*, Organization Studies, Jan. 2010, Vol 31, No 1, 69-87
[135] E. Tulving, *Elements of Episodic Memory*, Oxford University Press, 1983, ISBN 978-0-19-852125-9

latter period more difficult, and to render some of the conclusions more tentative than those that were obtainable for the earlier period. When a company officially ceases to exist, its assets, including any records, can pass on to any other organisation which takes over some or all of the original company's parts. Mergers and takeovers are often conducted under considerable secrecy, leading to reluctance on the part of later owners to release documentation relating to those earlier transactions. This problem affects many areas of social history, particularly when the people involved in the area of investigation are still alive, and may have an interest in keeping some information private. This was particularly evident in interviews with members of the DEC board.

3.4.1 *Archives*

An obvious important source of information about any company is the company archives. In the case of DEC, it was quite a challenge to locate any archival material. HP has retained only the technical journals online and has very little reference to DEC on its company network. Communication with Bell led to the Computer History Museum, which had received a portion of the DEC archives. In 2005, HP donated what remained of the DEC archives to the Computer History Museum.[136] This consisted of nearly 2,000 linear feet of DEC records including:

- 725 record cartons of DEC documents dating back to the founding of the company;
- 170 linear feet of photographs and their card catalogue file system.
- 3,000 videotapes, primarily of engineering lectures, internal design protocols, meetings, training and customer materials.
- 1,700 magnetic tapes, many containing software programs.

HP had donated the technical portion of the DEC archives and many other DEC employees had also donated archival material.

Further investigation led to the Ken Olsen archives maintained at Gordon College, where many of Olsen's memos were stored in date order, offering an extremely interesting insight into what he was thinking during his management of the company. Discussions with the DEC archivist and the HP archivist have not shed any light on the location of the remaining parts of the archive. Again,

[136] This was reported by HP http://h18024.www1.hp.com/us/newengland/dec_collection.html (accessed October 23, 2012).

contact via the DEC Alumni provided some access to personal archives including strategy documents from the mid-1990s and also workstation archives.

Neither of the archives had been catalogued, and so referencing particular items proved to be challenging. Copies of the Olsen memos were created, with the permission of the curator, so that further analysis could be carried out without repeated visits to the archives. The memos are stored in three filing cabinets in the Olsen archives and are in date order.

3.4.2 *Personal contact*

Digital Equipment Corporation was a company with a culture that lasted well beyond the life of the company. When the downsizing started, a number of alumni associations sprang up that spanned the world. These associations are still alive almost twenty years after the company's demise and a number are still growing. The alumni associations were instrumental in the data-gathering process of this thesis, not only to locate any data that were available, but also to make personal contact with many of the ex-employees to gather their comments and feelings. Initial contact with the alumni associations gave access to over 2,000 people across the world. This provided an excellent view of certain actions of the company and information on product development, strategy and management. In the later part of the data-gathering, use was made of the 'LinkedIn' network, which provided access to over 17,000 ex-DEC employees. Alongside the contact from the alumni associations, personal introductions and web access enabled telephone conversations with many high-level managers and engineers involved with the company throughout its life.

A network of senior people was built and from there other contacts were subsequently made. Personal contact also enabled access to a number of papers written by senior people in DEC, reflecting on its demise and the reasons. Many of these were written for personal reference rather than publication, but were shared. These included *The Evolution of DEC: A personal perspective* by Robert Glorioso, former VP of the Information Systems Group at DEC; *A Case Study of the Failure of Digital's Workstation Vision*, by Steve Elmore, a systems consultant; *A Modern Day Tragedy* and *DEC's 64-bit Alpha Computer Architecture – Could it have Succeeded?* by Hans Dirkmann, President of DEC Europe.[137] Glorioso's paper will be referenced in Chapter 6, as it details many of

[137] P. DeLisi, 1998. A modern day tragedy: The Digital Equipment story. *Journal of Management Inquiry* 7 (No 2 June):

the engineering discussions and arguments that occurred in the early 1980s, and explains how these affected DEC's RISC programme.

Personal statements are commonly tinged with some bias depending on where, when and what the particular people were involved with. Many of the people were happy to talk, but a significant number did not want their comments attributed directly to them; others asked for veto rights on reporting of comments. A number of DEC's senior managers were contacted for their views and recollections of what happened during their time with DEC. The results of these contacts were mixed: some were happy to contribute, some did not respond, some said they would like to help but did not actually reply when questions were asked and finally there were those whose memories had failed and were understandably unable to contribute. Among these sadly were Ken Olsen, Stan Olsen and Pier Carlo Fallotti.

Attempts were also made to interview board members from the Palmer years, all of whom were still alive, many in their eighties. Even though contact was made with all of the board members in one way or another, only two were willing to talk directly about their time as board members, most saying they were unwilling to discuss such intrusive issues. Minutes from board meetings were reportedly sent to secure storage, but it proved impossible to locate the facility that housed them in Massachusetts.[138] Iron Mountain was e-mailed, but the company would not reveal whether it had any DEC documents without authorisation from the owner.[139]

During the investigation of DEC Workstation Engineering, contact was made with Don Gaubatz, a vice president of Workstation Engineering at the time of the MIPS episode. As will be detailed in chapter 6, the use of MIPS as an external supplier became an important issue in the fortunes of the company. This proved to be an extremely fortunate communication, as Gaubatz not only had a large amount of archival material which he made available, but also had many senior contacts. Gaubatz provided introductions to many people, enabling a much deeper analysis of the issues and also provided comments, documents and recollections from a much broader audience than anticipated at the start.

---

[138] The details about the whereabouts of the minutes were revealed in an interview with Ann Jenkins at Gordon College in October, 2009.

[139] Iron Mountain is a worldwide secure storage company with a facility in Boston. It was used by DEC during its existence, so is the logical location if the minutes still exist.

3.4.3 *Interviews and Survey*

Interviews were conducted to gain as much knowledge of the company's performance as possible whilst people's memories were relatively fresh. Use was also made of transcripts of interviews undertaken by Ben Strout who had spoken to a number of senior individuals connected to the company in his research for a documentary about Ken Olsen.[140] Strout unfortunately suffered a fatal heart attack during the filming of his documentary. This was subsequently taken up by Donald Boggs who provided the transcripts from the interviews, along with permission from Strout's widow, Yelana, for their use. The original transcripts combined consist of over 250,000 words. There were also a number of oral interviews available from various institutions that were referenced during the research.[141]

A total of twenty-five face-to-face or telephone interviews with senior members of the company were conducted. These, as well as a number of email conversations, gave a detailed picture of the company during the latter part of the century. On the whole, the interviews were conducted in an informal manner, resulting in some candid comments that might not have emerged had the interviews been held in offices. This approach was taken during one-to-one interviews by telephone or face-to-face. A more structured approach was adopted when it came to conducting the survey. A web-based survey was conducted of the DEC Alumni to understand the consequences of the downsizing that occurred in the 1990s; this is analysed in Chapter 7.

3.4.4 *Documentation and the Web*

As mentioned in the literature review, Schein's book on DEC primarily considered the management ethos and relationships in relation to the company performance.[142] Contact was made with Schein to determine whether he had any of the supporting documentation for some areas of his book, but unfortunately, he had not kept any of the material or transcripts of conversations. Other books, such as those of Bell and Rifkin, were used as sources to understand the

---

[140] Ben Strout, Teledynamics. I was introduced to Strout during a visit to Gordon College and he spoke about his documentary and the interviews he had undertaken. Strout produced documentaries for Discovery, TLC and other networks and had a master's degree from Indiana University.
[141] The main sources of oral interviews were from the Smithsonian, http://americanhistory.si.edu/collections/comphist/ (accessed July 6, 2015); The Computer History Museum http://www.computerhistory.org/collections/oralhistories/ (accessed July 6, 2015); and the ACM http://dl.acm.org/ (accessed July 6, 2015);.
[142] E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*.

technology path taken, and also the management interactions that defined some of the product decisions and directions.[143] Use was also made of the data and reports that were available on the web. For the technology, reference was made to the Digital Technical Journals to understand the later products, and their design processes and features.[144]

As DEC was at the start of the internet age, the web proved to be a valuable source of comment and connectivity. There is a large amount of DEC documentation preserved on the web. The main location is maintained by Al Kossow, who now works at the Computer History Museum, and his documentation is referenced in many places in this thesis. His web site contains many DEC manuals, handbooks and assorted memos, as well as software archives.[145] Many academic papers and oral interviews are available via the internet and reference has been made to many in this thesis.

3.4.5 *Strategy Documents*

DEC strategy was analysed over the years to consider whether the company had in fact followed a strategy and if it had proved to be the correct one. Kathy Hornbach kindly donated her archival material from the period and this provided an understanding of the turmoil of the company during the 1990s.[146] These documents have subsequently been donated to the archives at the Computer History Museum.

The relationship of product development to the S-curve and wave theory of lifecycles was analysed, in order to ascertain where the company went wrong in its direction. As will be shown, this highlighted the period when DEC was struggling to find direction and missed one of the S-curves in its product development cycle.

3.4.6 *VAXnotes and Notesfiles*

DEC had a product that gave them a significant advantage over competitors in their VAXnotes collaboration application. This proved to be invaluable in

---

[143] C. G. Bell et al., *Computer Engineering: A DEC View of Hardware Systems Design* (Bedford, MA: Digital Press, 1978); Rifkin and Harrar, *The Ultimate Entrepreneur: The Story of Ken Olsen and Digital Equipment Corporation*.
[144] Digital Technical Journal available from http://www.hpl.hp.com/hpjournal/dtj/past.htm (accessed June 12, 2015).
[145] www.bitsavers.org/ (accessed July 6, 2015).
[146] Kathy Levy Hornbach was a member of the Corporate Strategy and Alliance Group at Digital Equipment Corporation during the 1990s.

researching the company and gaining an understanding of the feelings of the employees. It was structured as follows: the product, VAXnotes, was organised into individual Notesfiles, each covering a different subject with a subject title. Within the Notesfiles, there were individual Notes and replies to Notes. In DEC's internal implementation of VAXnotes, there were many hundreds of different Notesfiles pertaining to a wide variety of subjects, both business and personal; most of these no longer exist in any form.

The Notesfiles were accessible from any Digital location worldwide instantaneously on DEC's internal network and were an excellent communication tool for discussions. They also provided a channel for product issue resolution, giving field engineers direct and immediate access to developers. DEC personnel were able to post Notes and receive replies from anyone else in the company, from field people to senior development engineers, and this was a real corporate advantage which was of immense help in dealing with customer technical issues, for example. The Notesfiles were moderated so that any untoward discussions or comments were removed. The Notesfiles could be member-only (for areas such as new product development discussions) or they could be open to all.

A white paper on VAXnotes states that:[147]

> In August 1989, 10,355 Notesfiles were active inside DEC, 390 of which were dedicated to employee interests such as "Good restaurants in the South of France". But the majority of network traffic went into the 9,965 conferences set up to discuss matters relating to DEC technology, such as the inner workings of VAX/VMS, how to best configure TCP/IP services for VAX/VMS, or even how to connect PCs and Macintoshes to VAX servers. The best thing about VAX Notes was the way that the people who engineered products would respond to questions that arose in the field, meaning that someone working in Hong Kong who encountered a problem with a product could ask a question in the appropriate conference at the end of their working day with a real expectation that the question would be answered by engineering in the U.S. by the time they came into work the next day. And if engineering couldn't answer, some other DEC employee probably would.

Currently 2000 different Notesfiles are still reachable on the HP network, hosted in Bangalore.[148] One area of the company Notesfiles that gave a valuable insight

[147] Comment by Tony Redmond, who integrated VAXnotes into DEC's ALL-IN-ONE product, related to the paper on The Camelot of Collaboration in Knowledge Management Magazine November 21 2001 by Patti Ankalam.
[148] Posting on Linkedin by HP employee (2013).

into the feelings of the employees was the 'Digital' Notesfile.[149] This consisted of 5,917 individual Notes with associated replies (sometimes over 400 replies per note), on a multitude of topics related to the company, its people, its products and its business. The record of the 'Digital' Notesfile was preserved by an ex-employee and made available via the web.[150]

3.5 *Summary*

The multiple methodologies used in the research for this thesis have been described in detail above and indicate that this is a complex subject requiring a number of different methodologies in order to capture the data for analysis. The main data sources were interviews, survey responses, financial reports from the company and archival data from the company archives, Olsen's archives and individual archives. Extensive use was made of networking to make contacts and secure access to information about the company and its products. The web was also a valuable resource in locating technical documentation, as was commentary from business journals on the company's condition at the time.

[149] Digital Notesfile archive: http://www.buschdorf.eu/vaxnotes/ (last accessed July 6, 2015).
[150] The Digital Notesfile archive was removed on July 17, 2010 by the HP Corporate IT Security Incident Response Team (CITSIRT), stating that 'This data contains HP confidential information'. This is a major source of company information that should be preserved for future research.

4 Comparison with other companies

4.1 *Introduction*

DEC was not the only company to face difficulties in the 1990s. Most of the remaining minicomputer companies failed during this period. In the 1980s, the computing paradigm shifted once more, traditional computer companies faced competition from start-up companies using newer technologies such as Reduced Instruction Set Computers (RISC) and VLSI enabling them to develop systems much quicker and also much cheaper than traditional systems.[151] Complementary Metal Oxide on Silicon (CMOS) replaced Emitter Coupled Logic (ECL) technology and workstations took over from the dumb terminals connected to mainframe computers in the computer room.[152] These workstations gave users power at their desk. They tended to operate using UNIX which again meant their systems were much cheaper than those with proprietary operating systems that most mainframes were operating as the mainframe suppliers charged a premium for their operating systems. The computing environment changed from dumb terminal access to mainframe computers to the client server model where much of the computing power was devolved to the client's desk. All of the established computer companies were affected by this paradigm shift. This and the recession of the 1980s severely impacted all of the established computer companies. There were a number of mergers, consolidations and closures in the late 1980s. Amongst the major ones were :-

- Nixdorf acquired by Siemens in 1991
- Mitsubishi closed its computer department in 1990
- Apollo acquired by HP in 1992
- Alliant ceased trading in 1992
- Control Data spin offs 1988 – 1992
- Honeywell sold computer department to Bull in 1991
- Fujitsu bought ICL in 1990

There were four main rivals for DECs core business in the 1990s: IBM, HP, Data General and SUN. These companies all had similar problems to deal with over the same period. In this chapter, an analysis of each of these companies is made, to demonstrate how they managed through the downturn, how their business

[151] RISC technology simplified the number of instructions a computer used, complex instructions being the responsibility of the compiler.
[152] CMOS circuits use less power than ECL and so can be packed closer. They have higher propagation delays so operate slower than ECL. As power dissipation and packing density became important CMOS became the preferred technology for VLSI.

model and internal processes helped them survive (or not) and to give a base to compare DEC's actions. Data General, IBM and HP are studied in more detail as they covered a similar product spread and customer base, HP being of almost identical size and income for much of the time that DEC existed. IBM, HP and SUN invested in RISC technology in the 1980s, which went some way to reviving them when the global slowdown hit. It will be shown that SUN in particular threatened DEC's traditional market with its SPARC products, initiated by Patterson. It will be shown that IBM, having failed with its System/38 minicomputer in 1979, took market share from DEC in 1988 with the AS/400, which had been upgraded with the 64-bit RISC PowerPC in 1995. It will be shown how HP brought out its RISC 'SPECTRUM' in 1987 to regain market share.

The comparison was limited to four, although a number of other companies were considered for analysis. DEC had many competitors over the years, such as Prime, Wang, SGI, Interdata and Varian. These companies all existed at some time during DEC's prime, but did not seriously rival the broad spectrum of DEC's product range and most were gone by the 1990s.

4.2 *IBM*

4.2.1 *Brief analysis*

In 1911 Charles Flint consolidated four tabulating companies into a group called the Computing Tabulating Recording Company (CTR). In 1924 this was changed to International Business Machines Corporation (IBM) by its then president Thomas J Watson Sr. Initially it manufactured mechanical machines but in 1946 it released the first mass produced electronic calculating device the IBM 603. In 1948 it released the IBM 604 Electronic Calculating Punch which performed addition, subtraction, division and multiplication using vacuum tubes. IBM grew rapidly with the revenue generated by military projects such as SAGE and WHIRLWIND.[153] In 1957, when DEC was formed, IBM's income from the SAGE project was $122 million and military projects amounted to over 50% of IBM's computer revenue. IBM did not sell its computers but leased them to customers. When the 1401 computer family aged, IBM had competition from other vendors, losing many system sales to its main rival, Honeywell's H-200.[154]

[153] WHIRLWIND was the computer developed at MIT in the 1950s that formed the basis of the US strategic air defence system (SAGE).
[154] The IBM 1401 was announced in 1959 and was an all transistor system. It was withdrawn in 1971. The Honeywell H-200 was introduced in the early 1960s to compete directly with the 1400. It was

IBM gambled and responded with the System/360 family, which was announced in 1964. This proved to be a hugely popular system and helped IBM grow rapidly.[155] The System/360 was followed by the System/370 and later the ESA/390 all utilising the same architecture.

IBM had a very similar culture to Digital. It was a company with a no-layoff policy and so redundancies were not an easy option.[156] IBM had used value-driven leadership as early as the 1920s and had a loyal longstanding workforce as a result.[157] This culture led to a workforce that felt it did not need to unionise. IBM was in a much worse position than DEC when it embarked on the search for a new CEO. IBM had increased capacity and manpower in the 1980s to meet a perceived increasing demand for mainframes. It had based its targets on the existing technological paradigm, as suggested in Mills and Friesen, rather than the one it had helped create.[158] In the 1970s, the company missed the chance to lead in the field of microprocessors by underestimating their potential and focussing on the mainframe market, failing to see the technology changing around them. This is an example of disruptive technology in action.

By 1987, IBM had seen the need to move to CMOS technology, which was beginning to replace ECL because of lower power consumption, but senior management was reluctant, believing instead that they could slow the industry and manage the transition to this new technology.[159] It was unwilling to believe that it could not maintain its position with ECL technology. IBM had also taken

---

over twice as fast and ran 1401programs through emulation. IBM successfully countered with the System/360.

155 The early years of IBM are captured by Pugh in *Building IBM* and the 360 and 370 systems are described in E. W. Pugh, *Building IBM: Shaping an Industry and its Technology*, History of Computing (Cambridge, MA: MIT Press, 1995); Pugh, Johnson, and Palmer, *IBM's 360 and Early 370 Systems*.

156 L. V. Gerstner, *Who Says Elephants Can't Dance?: Inside IBM's Historic Turnaround*; D. Q.Mills and G. B. Friesen, *Broken Promises: An Unconventional View of What Went Wrong at IBM* (Boston, MA: Harvard Business School Press, 1996). 65-66.

157 Value driven leadership is defined by Agnes Naera in *Communications and Organisational culture,* 25 Jun, 2014 as 'Values driven leadership approach requires a high degree of stewardship and accountability from a leader. It is a form of leadership that is based on service to others, individuals, and to a greater purpose, organisational and societal, and is both ethical and practical. Values driven leadership must be applied in our everyday behaviours, we must be authentic and active or we will be quickly exposed.Values driven leadership is guided by a compelling and inspiring future-focused vision that members can connect with rationally and emotionally. This vision is underpinned by a core set of values, forms the basis of an organisations/community credibility.'

158 D. Q. Mills and G. B. Friesen, *Broken Promises: An Unconventional View of What Went Wrong at IBM*.

159 S. Lohr, "Present at the Transition of I.B.M.," *New York Times*, October 26, 1993.

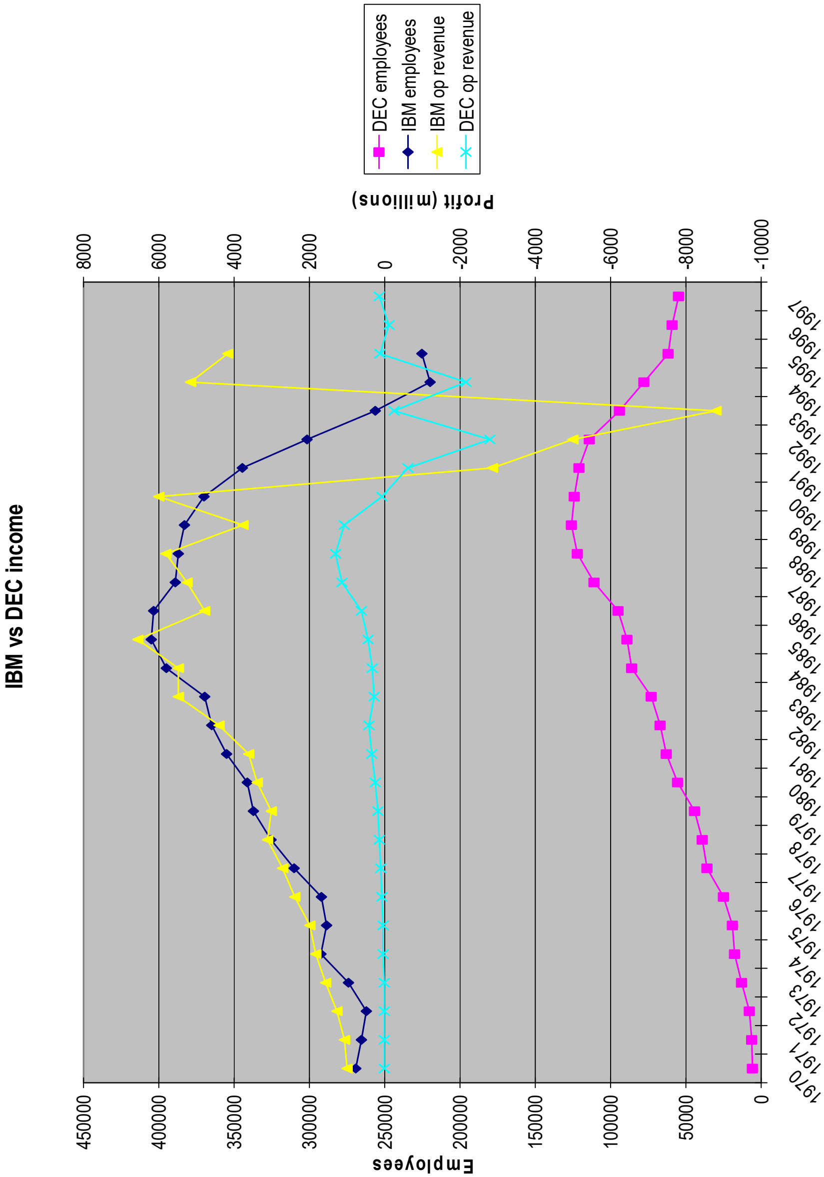
the lead in RISC technology research, but it took the company nearly twenty years to release a product using RISC.

As will be shown, one major error was in the PC arena where it had the lead. IBM had turned down Gates' offer of selling it control of MS-DOS, allowing Microsoft to flourish and Compaq to license MS-DOS and compete with IBM. The management also brought the PC business back into the mainstream company, thus stifling it with bureaucracy. IBM's development teams were decentralised and had proliferated. IBM management was by committee and it held many non-productive meetings, many of which were conflict driven. It was managed by a centralised and top-down driven structure. In the early 1990s, IBM executives responded to Wall Street and business magazine articles suggesting a break-up of the company by splitting the company into separate units.

IBM suffered from the increasingly aggressive activities of shareholders and their short-term view of performance and profit. According to Mills and Friesen, Wall Street had no real understanding of IBM, but that did not prevent the financial analysts from telling IBM how to run its business.[160] IBM also suffered from margin erosion with its move to smaller systems, where there was more competition, hence price pressures and consequently reduced margin. Akers began to break IBM up due to shareholder pressure. When Gerstner took over in 1993, the company had just reported losses of over $8 billion. Gerstner's book captures what he did to improve IBM's position, 'according to Gerstner'.[161] He ignored the calls for the company to be broken up and realigned it with more of a customer focus. IBM moved into DEC's domain of multivendor services and, in 2008, the performance of the IBM services division was 'the star of the show'. IBM even moved into the traditional DEC area by offering VMS support, which it still delivers today. IBM also followed DEC in terms of redundancy in 1992, giving 40,000 employees generous redundancy packages.[162] Gerstner re-focussed the company on services and the Internet, as described by Gary Hamel in the *Harvard Business Review*.[163] As can be seen from Figure 1, IBM's income tracked DEC's, but at a greater magnitude. IBM also began its downsizing as DEC was increasing the number of employees.

[160] D. Q. Mills and G. B. Friesen, *Broken Promises: An Unconventional View of What Went Wrong at IBM.*, *Broken Promises: An Unconventional View of What Went Wrong at IBM*.
[161] L. V. Gerstner, *Who Says Elephants Can't Dance?: Inside IBM's Historic Turnaround*.
[162] S. Willett, 'Giants Downsize: DEC regroups, IBM cuts jobs', *InfoWorld,* October 5, 1992, 8.
[163] G. Hamel, "Waking up IBM: How a Gang of Unlikely Rebels Transformed Big Blue," *Harvard Business Review*, July-August (2000).

Figure 1: IBM vs DEC – income and employees.



Plotted by David Goodwin from information in the company's annual reports submitted to the SEC.

In 1993, the IBM employee population was down to 256,000, a reduction of 150,000 from its peak in 1986.

Table 2: IBM company figures 1991 to 1999.

	1999	1998	1997	1996	1995	1994	1993	1992	1991
Revenue ($millions)	87,500	81,700	78,500	75,900	71,900	64,000	62,700	64,500	64,700
Cost			47,800	45,500	41,500	38,700	38,500	35,000	32,000
Profit			30,600	30,500	30,300	25,200	24,100	29,400	32,000
Op ex			21,500	21,900	22,700	20,200	32,700	37,600	31,700
Net loss	7,700	6,300	6,000	5,400	4,100	3,000	-8,100	-4,900	-2,800
Assets			81,500	81,100		81,000	81,100	86,700	
Liabilities			61,600	59,500		57,600	61,300	59,000	
Employees	307,000	291,000	269,000	240,000	225,000	219,000	256,000	300,000	344,000

(Figures compiled from SEC filings and Gerstner 2002)

Table 3: IBM income and employees 1982 to 1990.

IBM	1990	1989	1988	1987	1986	1985	1984	1983	1982
Employees	373,000	383,000	387,000	389,000	403,000	405,000	394,000	369,000	364,000
Income	68,000	62,000	59,000	55,000	52,000	50,000	46,000	40,000	34,000
Earnings	5,900	3,700	5,700	5,200	4,700	6,500	6,500	5,400	4,400

Source: Pugh 1995.

IBM also divested itself of PCs, hard disks and high end printers in the period 2000 to 2007 to focus on the higher margin businesses, rather than commodity.[164] The company also bought back stock to keep its stock price higher and avoid a hostile takeover bid.

[164] http://www.ibm.com/investor/article/printing-systems.html (accessed July 6, 2015).

4.2.2 *The IBM PC*

In 1980 Bill Lowe, IBM's Boca Raton laboratory director put forward the idea of a PC to the Corporate Management Committee, cautioning that a PC could not be successfully built within the current IBM culture.[165] IBM began development of its PC in July 1980 and released it in 1981 with eight application programs. Initially IBM considered using its own in-house RISC chip, the 801, but decided to go with an Intel chip to speed up development time as the team had knowledge of the Intel hardware. However, this eventually allowed other companies such as Compaq to reverse engineer the BIOS and create clone machines. IBM's initial PC was such a success that it could not keep up with orders.

Unfortunately, by 1983 internal politics were affecting IBM's PC development operations. It released a version of the IBM PC called the PC Junior, which was aimed at the home market, and it became a disaster for the company. It did not build in compatibility with the XT and skimped on quality components. IBM then started to curtail the PC division's autonomy and bring it back into the main company, something that Lowe had cautioned against and Chandler had commented on.[166] This led to a considerable loss of talent, some employees moving to Compaq, its major competitor in PCs. IBM also misjudged the market for PCs and set its margins too high, letting in the competitors. Whilst IBM hesitated over using the Intel 80386, Compaq released a system, based on the 80386, that was compatible with PC software. Because of the competition from companies such as SUN, IBM tried to build a workstation based on UNIX with PC emulation using a co-processor. This was another disaster for the company as the PC software ran more slowly than the PC-AT, but the system cost more. Later, IBM tried to introduce a portable PC but, at $4,000, it was twice the price of a standard desktop. Finally, in 1987, it released the PS/2 with OS/2 and this was successful.

In order to find an operating system for the PC, IBM had initially approached Digital Research, the makers of CP/M, which was the de-facto standard in 1980. IBM needed the operating system rewritten for 16-bits, as its PC was designed as a 16-bit system. It also presented Digital Research with IBM's normal non-disclosure agreement, which Digital Research refused to sign. With time running out, IBM went to Microsoft who had designed the BASIC for the Intel 8088.

---

[165] J. Chposky and T. Leonsis, *Blue Magic: The People, Power, and Politics Behind the IBM Personal Computer* (New York: Facts on File, 1988). 9.
[166] A. D. Chandler, T. Hikino, and A. Von Nordenflycht, *Inventing the Electronic Century: The Epic Story of the Consumer Electronics and Computer Industries*, 146.

Microsoft bought the rights to Seattle Computer Products Disk Operating System, and it converted its BASIC to run on it and modified the operating system to run on the IBM PC, renaming it MS/DOS. IBM's great mistake was not taking ownership of the operating system, allowing Gates to retain control and eventually market it to IBM clone manufacturers. By 1995, IBM had decided that it had lost the PC battle, having seriously considered buying Apple in 1994. OS/2 was losing market share to Microsoft's Windows and with the advent of the Internet, Gerstner moved his focus to network-centred computing, again just as DEC had decided.

4.2.3 *How did IBM recover?*

In January 1993, IBM's directors began the search for a new CEO to bring the company back from the brink of collapse after Akers' retirement. Akers' retirement was possibly brought on by pressure from the board and Wall Street. In fact, comments have been made that Akers was sacked in the same way as Olsen.[167] The company had lost a staggering $16 billion in the years 1991 to 1993.[168] According to Gerstner, Akers was obsessed with regaining the PC space with PowerPC and OS/2, and this was a strategy that would lead to even lower margins for the company.[169] Gerstner's appointment was controversial, as he had no experience in the high tech industry. When asked about long-term strategy, he responded 'the last thing IBM wants is a vision'. Gerstner refused to break up IBM, focussing on making the company more of a services business. He abandoned long-range planning as the industry was moving too rapidly for it to be effective. He eliminated functional fiefdoms, unlike DEC where they still controlled the company business[170]. He also changed IBM from a closed innovation company to an open innovation company.[171]

Gerstner also recognised that headcount reduction alone would not solve IBM's problems. He realised that further headcount reductions would be counterproductive and stopped them in September 1993. Gerstner concluded that, as described by Austin and Nolan in their study for class discussion at Harvard, IBM's management was inwardly focussed, bureaucratic and was no

---

[167] R. D. Austin and R. L. Nolan, "IBM Corporation Turnaround," Harvard Business School Case 600-098, November (2000).
[168] J. Menn and S. Silverstein, "IBM CEO to Step Down; He Led Big Blue's Turnaround", *LA Times*, January 30, 2002.
[169] L. V. Gerstner, *Who Says Elephants Can't Dance?: Inside Ibm's Historic Turnaround*.
[170] Bob Glorioso comment at Olsen memorial service: "So much infighting and backstabbing, I wish I had left five years earlier".
[171] H. Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting from Technology*, (Boston, MA: Harvard Business School Press, 2003).

longer customer-focussed.[172] One of his first actions was to attend a customer meeting of IBM's major US customers and, instead of staying for an hour, he remained for two days, having dinner and breakfast with the customers and talking openly about IBM. He also amended the company benefits scheme to retain top executives at the company and to discourage them from defecting. Gerstner actively communicated with employees regularly.

Gerstner realised that IBM needed to change radically and so he instigated a major re-engineering programme.[173] He assigned seven top managers to eight re-engineering projects with specific targets. Gerstner even reduced the size of the board by one third and began a series of employee communications to ensure that employees were not kept in the dark.[174] Gerstner recognised that his competition had workers who were young, enthusiastic, aggressive, flexible and willing to work around the clock.[175] He reorganised the compensation scheme to one of pay for performance, to encourage these traits at IBM and, in 1994, he embraced the Internet.

4.2.4 *IBM and the Internet*

In addition to Gerstner's realignment of the business and his customer focus, IBM was transformed by a few activists who recognised the Internet as the future. These were strategists who recognised a new disruptive technology. In his paper Hamel discusses how a mid-level programmer and a high-level strategist managed to propel IBM onto the Internet wave in the mid-1990s.[176] This was triggered by SUN taking IBM's raw data feed from the Olympic site and presenting the data as its own on the Internet. IBM had been shocked when it went to the first Internet World (an annual event for digital businesses) to find that DEC had by far the largest display booth. It immediately signed up for the largest booth at the next Internet World. This was the beginning of IBM's resurgence, based on a refocus on the mainframe, network-centric computing and a move into the services and Internet business. Not only was IBM focussed on RISC, services and the Internet but its management structure had been refocused and understood the strategy.

---

[172] R. D. Austin and R. L. Nolan, "IBM Corporation Turnaround."
[173] L. V. Gerstner, *Who Says Elephants Can't Dance?: Inside IBM's Historic Turnaround*, 63.
[174] Ibid. 75.
[175] Ibid. 105.
[176] Hamel, "Waking up IBM: How a Gang of Unlikely Rebels Transformed Big Blue."

4.2.5 *The AS/400 and RS/6000*

In the early 1980s, IBM found its customer base under threat from DEC's VAX family and top-to-bottom compatibility – something that IBM could not offer.[177] IBM was losing customers first in the scientific area, but later in its commercial space. IBM's response was the Silverlake project, which was described by the press and Bauer et al. as the 'VAX killer'.[178] The Silverlake development originated as a 'skunk works' project before progressing to a fully supported product development project.[179] So important was Silverlake to IBM that Akers, the CEO at the time, appointed an executive to run the launch of the system. Silverlake was renamed the AS400 and launched on June 21st 1988. The AS/400 proved to be an outstanding success for IBM, taking considerable market share, and by the end of 1990 had earned $14 billion dollars for IBM. The AS/400 proved to be a major competitor to DEC and was viewed by Olsen and Demmer as a direct threat.[180] In 1992, Olsen recognised that the company had made a serious mistake in not tackling the AS/400 threat sufficiently.[181] This machine was part of the IBM revival, followed by the RS/6000, based on the RISC PowerPC chip. The RS/6000 was first released in 1990, but the first system based on the 32-bit PowerPC was released in late 1993. The RS/6000 ran AIX, IBM's UNIX operating system and was the system that was to drive IBM's Internet business.

4.2.6 *Conclusion*

IBM was re-invigorated by the appointment of Gerstner as CEO. The company was failing, having not adjusted to the new wave of computing, which attracted less margin and the move away from the large mainframe systems. IBM was on the verge of being broken up when Gerstner arrived. He refocused the company, stopped the downsizing, restructured his management team and business strategy, and focused on the Internet. IBM was late to enter the RISC market, but succeeded with its RS/6000 system running UNIX. IBM also moved into the services and consultancy business with great success.

---

[177] Virtual Architecture eXtension (VAX) was DEC's 32-bit family of machines developed in 1975 and running DEC's VMS operating system.
[178] R. A. Bauer, E. Collar, and V. Tang, *The Silverlake Project: Transformation at IBM*, 158.
[179] Ibid. 24: 'skunk works' is used in the same manner as DEC's own 'skunk works' projects that were not officially funded.
[180] Memo February 19, 1992 from Olsen re: "The AS/400", located in Olsen Archives; Memo May 2, 1991 from Demmer re: "AS/400 announcement: Summary and Analysis", located in Olsen Archives.
[181] Memo August 4, 1992 from Olsen to Palmer re: "AS/400", located in Olsen Archives Gordon College.

4.3 *HP*

4.3.1 B*rief analysis*

HP was founded by two Stanford University graduates who had been encouraged to start in business by their professor, Frederick Terman. Frederick Emmons Terman was dean of the School of Engineering at Stanford University. The company began in a garage in Palo Alto as a manufacturer of audio oscillators in 1938, almost twenty years before DEC was founded. The company culture was defined in the 'HP Way' under the leadership of Packard and Hewlett which was lost in the 1990s.[182] This culture was similar to that of both DEC and IBM which valued the employee and offered a job for life.

According to the HP web site, David Packard and Bill Hewlett had diametrically opposed views on the computer business in the 1960s.[183] Packard decided that data processing was the future and Hewlett considered the market already too overcrowded. After building audio oscillators, HP moved into manufacturing test equipment, only moving into minicomputers in the early 1970s. HP had considered using DEC computers, and even considered buying the company before embarking on its own computer manufacturing. HP had spoken to Olsen regarding a potential purchase of DEC but decided the asking price was too high at $25 million.[184] HP even designed a 32-bit computer, the Omega, in the early 1970s but decided that the manufacturing cost was too much for the company and would take it into direct competition with IBM. Its first business computer was the HP3000 released in 1972.

As recorded in its annual report for the year, 1977 was a turning point for HP. Sales of its electronic data products exceeded those of its electronic test and measurement products.[185] Also in 1977, Bill Hewlett gave up the company presidency, and later his CEO role, to John Young, heralding a new era of managers who were not founder-owners. HP's first personal computer, the HP-85, was released in 1980, but was not a success. In 1984, HP released its extremely successful LaserJet printer that was to contribute to its growth and

[182] D. Packard, D. Kirby, and K. R. Lewis, *The HP Way: How Bill Hewlett and I Built Our Company*, 1st ed. (New York: HarperBusiness, 1995); M. S. Malone, *Bill & Dave: How Hewlett and Packard Built the World's Greatest Company* (New York, N.Y.: Portfolio, 2007); A. Yuen, ed. *Bill & Dave's Memos* (Palo Alto: 2DaysOfSummer Books,2006).
[183] http://www.hp9825.com/html/hp_2116.html (accessed July 6, 2015).
[184] D. Packard, D. Kirby, and K. R. Lewis, *The HP Way: How Bill Hewlett and I Built Our Company*, 102.
[185] K. A. Kuhn, Online Museum and Technical History of Hewlett-Packard, http://www.kennethkuhn.com/hpmuseum/ (accessed July 6, 2015).

maintain its income during the lean period a few years later. Both DEC and HP had internal conflicts in the 1980s and both had false starts in their implementation of RISC technology.[186] HP, unlike DEC, recognised the importance of RISC technology early and invested heavily. In 1983 HP commissioned McKinsey consultants to look at the company and define the structure for the future, one of the results of which was a chapter in Peters' and Waterman's book.[187]

HP had been losing ground to DEC and IBM in the early 1980s, when Joel Birnbaum proposed building a RISC system.[188] In 1985, after a number of internal projects had failed, HP embarked on the development of its latest product. HP had three competing projects: 'Vision', 'WideWord', and the RISC system that was to become 'Spectrum'. House and Price reported that HP had a number of task forces looking at the situation and decided that it needed a radical solution; the RISC system was chosen, a potentially company-saving decision.[189] Birnbaum had initially thought that it would take four years to bring to market, but in 1987 HP introduced its RISC system, the Spectrum, which helped save the company's computer operations from financial disaster during the collapse of the minicomputer market a year later.[190] HP also adopted UNIX as its main operating system offering. By 1990, HP had a lead in the RISC computer market, 66% of the desktop laser market, 70% of the inkjet market, and were the number one UNIX vendor in 1992.[191]

In the period 1984 to 1988, IBM and DEC had caused HP the most problems. House and Price show the relative growth of each company over the period and show HP lagging.[192] HP tried to catch up in the workstation market by buying Apollo in 1988, but was unable to integrate the products and never made a success of the purchase. HP's market during the troubled period from 1987 to 1994 was split (50% computer systems and 50% printing) and so it was not as vulnerable as the other companies in the sector were to the downturn. HP was vertically integrated initially but realised that it could not do everything and outsourced a number of items.

---

[186] A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route, 128*.
[187] C. H. House and R. L. Price, *The HP Phenomenon: Innovation and Business Transformation* (Stanford, Calif.: Stanford Business Books, 2009), 327.
[188] Joel Birnbaum led the development of PA-RISC, HPs first commercial RISC processor, having joined HP Labs in 1980.
[189] C. H. House and R. L. Price, *The HP Phenomenon: Innovation and Business Transformation*. 337-350
[190] M. S. Malone, *Going Public: MIPS Computer and the Entrepreneurial Dream*.
[191] A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route, 128*; C. H. House and R. L. Price, *The HP Phenomenon: Innovation and Business Transformation*.
[192] C. H. House and R. L. Price, *The HP Phenomenon: Innovation and Business Transformation*, 357.

HP suffered, as with all the other computer companies, and, in 1990, its earnings fell by 11%, even with the introduction of workstation technology. Also in 1990 Packard reports that HP had reached a crisis by becoming too committee-based, which was hampering decision making. The company stock was falling and Packard once again became involved in the direct running of the company. The company reduced the layers of management, recruited a new young CEO and disbanded many of the committees. In the early 1990s, HP dropped its proprietary networking stack and opted for ARPANET and OSI based networking. DEC and IBM resisted this move, as they both had successful proprietary products that they expected to be adopted by the industry. By 1993, HP's stock had risen markedly and the company was back on track. House and Price describe the restructuring and refocusing that enabled HP's dramatic recovery.[193]

HP had an open door policy all through the 1990s, whereas the once open door policy at DEC ended when Palmer took over, as attested to by Gaubatz.[194] However, HP paid a price for its recovery, laying off 5,000 people in two years and changing the company image irreversibly. Up until 1990, HP had a very similar culture to DEC. It was a family company with a no-layoff policy and so redundancies were not an easy option. In 1992 CPSR (Computer Professionals for Social Responsibility) reported that HP had used a VSI (voluntary severance initiative) to reduce its headcount.[195] It reported that sometimes this was good for the employee, sometimes it was bad, but it was a move away from its no-layoff policy and the start of multiple rounds of redundancy that are continuing today, as the company assimilates other companies. HP had an issue with understanding the paradigm shift with the PC and struggled, but succeeded with its PA-RISC systems by helping customers migrate applications simply and cost effectively, thanks to Magenheimer's optimizing compiler.[196]

In the early 1990s HP realised that it could not afford to continue to manufacture its own HP-PA chipset unless it could market it to other companies., Therefore, it went to Intel and proposed a partnership in its future development.[197] HP had problems with replacing a CEO in 1991, as described by Bianco, when it did not have sufficiently clear requirements for an effective selection process and forced

[193] Ibid. 362

[194] Private conversation with Goodwin May 16, 2011 Boston. Open door policy was management speak for easy access to higher management to discuss any issues an employee might have.

[195] http://cpsr.org/prevsite/program/workplace/cpu.007.html/ (accessed July 6, 2015): feature 3, voluntary severance at HP Labs.

[196] C. H. House and R. L. Price, *The HP Phenomenon: Innovation and Business Transformation*, 364.

[197] Ibid.

the new CEO into early retirement in 1999.[198] The board decided a change was needed, as the company was not growing. It announced the retirement of Lew Platt as CEO, although Platt suggests that he was not ready to retire and was effectively fired, like Olsen. He was replaced by Carly Fiorina who relates her activities in redefining HP and its strengths and weaknesses when she took over.[199] In her memoirs, she quotes the 'HP way' (covered by Packard, Kirby and Lewis), which went against what she wanted to do with the company.[200] Bianco shows just how far HP's culture had altered from that introduced by Bill Hewlett and Dave Packard. This is also shown clearly in House and Price's book *The HP Phenomenon,* where they state that HP pensioners were suddenly removed from eligibility to attend HP retiree events, as they were ex-Agilent employees.[201] Agilent was one of the many companies that HP took over in its rise. HP had a set of corporate values which are captured in House and which it also abandoned in the 1990s.[202]

The HP board also engaged with McKinsey and Company to define strategy, the outcome of which was an agreement that HP needed to be divided. This resulted in the spin-off of its non-computing activities into a separate concern called Agilent Technologies in late 1998. At the same time, it revealed a new strategy focussing on the Internet, some four years after DEC, IBM and SUN. Fiorina states that one of HP's failings when she took over was a lack of marketing.[203] There followed a number of acquisitions, such as StorageApps, Indigo and, the largest of them all, Compaq in 2002, resulting in HP finally acquiring DEC thirty years after it first tried to buy the company. More recently, HP acquired EDS to bolster the consultancy business.[204]

According to Fiorina, HP generated 11 patents a day in 2003 and 2004, and she presided over a painful period of business transformation during 2000 to 2004. The Compaq acquisition almost pulled the company apart, with opposition from Hewlett who believed it was the wrong course of action and a bitter battle ensued.[205] HP also resorted to external consultants to define its strategy. In 2004,

---

[198] A. Bianco, *The Big Lie: Spying, Scandal, and Ethical Collapse at Hewlett-Packard*, 1st ed. (New York: PublicAffairs, 2010).
[199] C. Fiorina, *Tough Choices: A Memoir* (New York: Portfolio, 2006).
[200] D. Packard, D. Kirby, and K. R. Lewis, *The HP Way: How Bill Hewlett and I Built Our Company*.
[201] C. H. House and R. L. Price, *The HP Phenomenon: Innovation and Business Transformation*, 448.
[202] Ibid. 519.
[203] C. Fiorina, *Tough Choices: A Memoir*.
[204] EDS, Electronic Data Systems was founded in 1962 by Ross Perot who had worked at IBM and proposed a division to design, install and operate customers systems, which was turned down by IBM. http://www.entrepreneur.com/article/197682 (accessed July 6, 2015)
[205] P. Burrows, *Backfire: Carly Fiorina's High Stakes Battle for the Soul of Hewlett Packard* (Hoboken, New Jersey: John Wiley & Sons Inc, 2003). 15.

HP again engaged McKinsey and Company to define strategy, including the possibility of splitting up the company, which had grown tremendously with the Compaq acquisition.

In 2005, there was acrimony in the boardroom with leaks to the press and comments about a dysfunctional board.[206] The net result of all of this was that Fiorina was dismissed by the board and replaced by Mark Hurd. Fiorina had presided over a tough time in HP's history, trying to complete the integration of Compaq, and handle a global downturn in the computer industry, whilst maintaining profitability. She appears to have been ousted because she disagreed with people on the board, especially Tom Perkins, and was concerned over leaks, rather than disagreement on future strategy. The investigation and repercussions of the activities of the board during this period indicate how far HP had fallen from the ethical times of Hewlett and Packard.[207]

In 2009, HP was sued by its own sales representatives over commission payments.[208] HP had continued to use the Omega commission calculation system that DEC had introduced when it changed to commission-based sales. This software had caused problems at DEC and it survived the Compaq and HP takeovers.

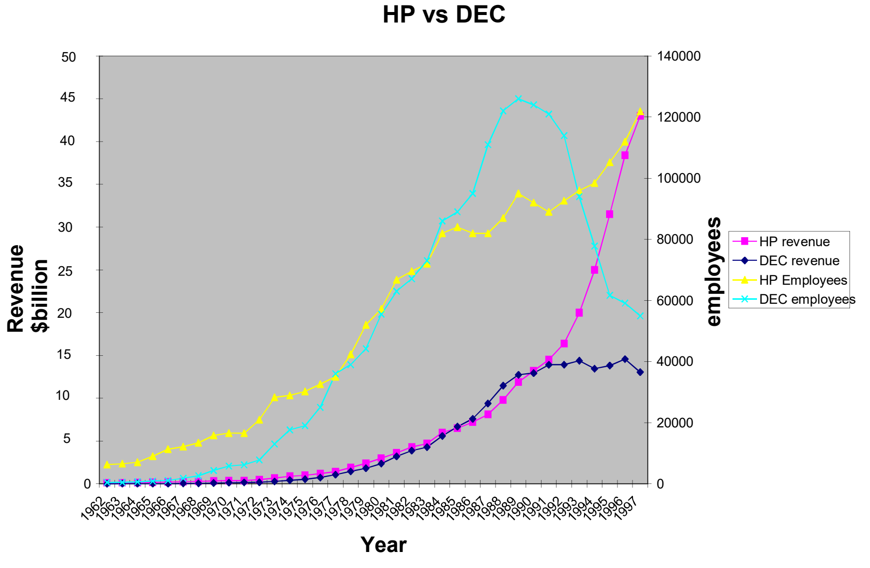
Table 4: HP company performance.

	1988	1989	1990	1991	1992	1993	1994	1995	1996
Equip ($)				11019	12354	15522			
Services ($)				3475	4056	4784			
Revenue ($)	9831	11899	13233	14494	16410	20317	25350	31519	38420
Cost equip ($)				5634	6625	8929	13012	17069	22013
Cost services ($)				2224	2533	3194	2478	2945	3486
R&D ($)				1463	1620	1761	2027	2302	2718
Sale & G+A ($)				3963	4228	4554	4925	5635	6477
Assets ($)	7858	10075	11395	11973	13700	16736	19567	24427	27699
Cash ($)	918	926	1106	1120	1035	1644	2478	2616	3327
Employees	86600	94900	92200	89000	92600	96200	98400	102300	112000
R&D				10.10%	9.90%	8.70%	8.00%	7.30%	7.07%

(taken from the company's SEC filings)

206 C. Fiorina, *Tough Choices: A Memoir*.
207 A. Bianco, *The Big Lie: Spying, Scandal, and Ethical Collapse at Hewlett-Packard*.
208 J. Sheck, "Ex-Employees File Lawsuit Against H-P Over Sales Pay," *Wall Street Journal*, August 8, 2009. http://online.wsj.com/article/SB124967566329915289.html (accessed June 4, 2015).

Figure 2: HP vs DEC – income and employees.



As can be seen from Figure 2, HP and DEC were of comparable size and income up to 1985 when DEC decided to compete with IBM, rather than focussing on its core competencies. HP reduced the percentage spent on R&D and kept SG&A under control. However, DEC was not the only company that missed an investment opportunity. HP was offered the Apple I design five times by Wonziak; each time he was turned down, with Hewlett later saying 'you win some, you lose some'.[209]

4.3.2 *Conclusion*

As with the other high tech firms, HP struggled in the early 1990s and had board and CEO problems. What brought it through was its early adoption of the two disruptive technologies of RISC and UNIX and its powerful printer business, combined with a realisation of the management, structural and marketing failures, and a willingness to adapt. HP also maintained tight fiscal controls after the scare in 1990 and diversified the business by acquisitions. Along with downsizing, carried out initially under the old corporate culture, it built for growth. HP adopted industry standard networking and curtailed its own chip

[209] R. Neate, "Interview with Steve Wonziak", *Daily Telegraph,* October 6, 2008.

manufacturing, realising that it was too expensive. It had a CEO who understood the need for growth as well as reining in costs.

4.4 *Data General*

4.4.1 *Brief Analysis*

Data General was founded in 1968 by Edson de Castro after DEC cancelled his project to develop a 16-bit machine codenamed PDP-X. In fact three of the four founders of Data General were from DEC. Data General was much like DEC, in that it kept its offices simple, and had no executive perks. However, it was unlike DEC in sales technique, which has been described as aggressive and commission-based.[210] Its first computer was the NOVA which was the first minicomputer based on integrated circuit technology. De Castro's company grew rapidly, releasing successive generations of 16-bit computers and moving on to semiconductor manufacturing and peripherals. Data General had an OEM strategy in the 1970s, but missed the microcomputer market and was caught out by the advent of workstations from companies such as SUN. Data General also brought out a PC, the DG-1, but, like DEC, it used a proprietary diskette format that was not compatible with other systems. The DG-1 also had a non-standard serial port: standard software that used the serial port would not run. Thus Data General failed in the PC market by not implementing industry standards. In 1978, Data General had entered the Fortune 500 list and was growing fast. This growth caused issues within the management structure of the company and de Castro, who had been trying to run the company single-handed, was forced to reorganise the management. He brought in an ex-IBM manager as senior VP to head the company's business operations.

Data General had recruited personnel for the upgraded Eclipse line, but production delays caused sales forecasts to be too optimistic and so it was overstaffed. Then, under the new management, it moved its sales model to direct sales rather than via OEMs. Data General tried to rival IBM and failed. In 1987, de Castro said in an interview with the *New York Times*, that the company had erred by 'focussing on very large corporate customers' that have been turning increasingly to IBM and DEC.[211] He also said the company had dispersed too much organisationally and geographically, adding that it simply had too much capacity. The company had also diversified by manufacturing its own

[210] http://www.fundinguniverse.com/company-histories/Data-General-Corporation-Company-History.html (accessed July 6, 2015).
[211] "Setbacks for Data General," *New York Times*, Business Days section, July 24, 1987.

components, semiconductors and peripherals. Data General also had conflict between its engineering teams as to who would design the upgraded Eclipse, delaying its introduction and letting the VAX from DEC take the market.

The upgraded Eclipse (MV/8000) was the result of a 'skunk works' project by Tom West that resulted in the cancellation of the 32-bit Fountainhead project, which was behind schedule.[212] The MV/8000 caused a recovery in Data General's revenues, but sales fell again in 1982, as Data General found that it was unable to compete with the new workstations. It added 3,000 employees (anticipating growth), but was again caught out by the recession of the mid-1980s. In 1985, the employee population had reached a high of 18,000.[213] Data General's reaction was to downsize, as profits slumped and a loss was reported in 1987.

It closed its semiconductor operation in 1986 and closed two manufacturing plants. In 1988 it laid off a further 1,000 staff and closed more plants. De Castro took full control once again and he refocused sales on OEMs. The board removed de Castro in 1990 and replaced him with Ronald Skates, who reduced R&D expense from de Castro's 12% to 8%, laid off more employees, reduced the workforce by 50% and sold off a subsidiary. Skates 'was considered a bean counter lacking the technical vision needed to steer the company through the rapidly changing currents of the computer industry', as reported by Edelman in the *Boston Globe* in 1990.[214] It also suggested that he had kept a low profile while directing a restructuring in which new products were cancelled.

After a small resurgence, Data General went into the red once again in 1992. In November 1994, Data General charged IBM with patent infringement, to which IBM responded with a counterclaim. According to the 1998 company report, the litigation was still going on. De Castro had begun the development of the AViiON UNIX server and that did, for a while after he left, provide some relief to the company, being moderately successful. The AViiON had sold approximately 30,000 systems and brought in $2 billion by 1995. Data General entered the UNIX market late because of an internal report that warned that it could not compete with its proprietary solution. Its software offering was the DG/UX operating system. Unfortunately, it based its hardware offering on the Motorola 88000 which, as mentioned previously, was not a success and was eventually withdrawn, leaving Data General to base its next product in 1995 on

[212] The story of the design of the MV/8000 is told by Kidder, *The Soul of a New Machine*.
[213] Data from http://www.fundinguniverse.com/company-histories/Data-General-Corporation-Company-History.html (accessed July 6, 2015).
[214] L. Edelman, "Can Ron Skates Save Data General?", *Boston Globe*, December 16, 1990.

the x86 series from Intel. This was already a crowded market and the product was not ready until 1996, according to its 1995 SEC report. Thus Data General missed the PC and the workstation S-curves, joined the UNIX RISC computer system market late and backed the wrong RISC processor.

In 1997, Data General focussed on the Internet market with its THiiN Line web appliance and servers.[215] In 1998, the company restructured again and discontinued the THiiN Line products.[216] Data General was eventually bought by EMC in 1999 for its NUMA technology.[217] Data General had two major products at the end: the AViiON enterprise server family, running Windows NT and DG/UX with NUMA technology, and the CLARiiON advanced storage product, which was one of the first with full Fibre Channel disk arrays and which is still sold today by EMC. In 2003, Fortune said of de Castro: 'he is viewed as an entrepreneur who didn't have the skill to adapt to a world overrun by desktop machines'.[218]

The company reports for 1990 to 1998 reveal the following ($ value is in thousands):

Table 5: Data General performance over the period 1990 to1998. Data from SEC filings.

Data General	1990	1991	1992	1993	1994	1995	1996	1997	1998
Revenue	1216401	1228834	1115947	1077869	1120505	1159316	1322250	1533169	1462109
R&D	140743	101986	111336	100172	90826	85886	99022	109984	118731
SG&A	444513	384317	357528	346740	341343	334337	309259	338443	338108
Restructuring	71700		48000	25000	35000	43000			82400
Net income	-132640	82992	-55964	-48761	-79778	-46703	28145	55900	-152395
Total assets	909437	944046	940454	866329	821864	832018	860443	1134868	1065064
Long term debt	56918	164911	162258	158352	156942	153457	149971	212750	212750
Employees	10600	8500	7100	6500	5800	5000	4900	5100	4700

[215] SEC filings: 1997 company report for Data General.
[216] SEC filings: 1998 company report for Data General.
[217] NUMA, non-uniform memory access, is where a computer can access its own local memory faster than shared memory, or another computers' local memory, in multiprocessor systems.
[218] J. Hyatt, "The Business That Time Forgot. Data General is gone. But does that make its founder a failure?' *Fortune Small Business*, April 1, 2003, http://www.money.cnn.com/magazines/fsb/fsb_archive/2003/04/01/341000/index.htm (accessed July 6, 2015). Data General and DEC were very similar: each missed the RISC, PC and workstation revolution, each removed its founder and resorted to mass downsizing and plant closures and each company was eventually sold. Both companies had resorted to a cost reduction policy rather than increasing their income. This eventually led to the company having insufficient funds to develop its full range of products and so it was forced to abandon some profitable or new product lines.

This shows that Data General downsized from 10,600 to 4,700, from 1990 to 1998, whilst maintaining its revenue. In 1998, the company went through another major reorganisation; this, rather than downsizing, absorbed much of the restructuring charge. According to the 1998 report, Data General had more than 200 US field offices and 130 international offices, with three worldwide customer support centres running a 24 x 7 operation.

4.4.2 *Conclusion*

Data General's recruitment strategy was based on an incorrect forecast for the Eclipse, which was its rival to the VAX and was aimed at IBM's share of the market. The system was late and missed the market. It moved its sales model to direct rather than OEM, had conflicts in the engineering departments and had too much manufacturing capacity. It removed its CEO in 1990 and replaced him with someone who was not suitable for the job. There was a wholesale asset sale and many employees were dismissed. There was a loss of morale and the company entered the UNIX market late. It missed the PC phenomenon, it was late into the RISC market and ended by trying to reduce costs rather than build for growth.

4.5 *SUN*

4.5.1 *Brief analysis*

SUN Microsystems began at Stanford University as a project by Andreas Bechtolsheim, which involved designing and building a workstation that was more powerful than the PC at the time at a similar cost. He used standard parts and software, choosing AT&T's UNIX as it was popular with scientists and engineers. SUN stood for Stanford University Network and Bechtolsheim began selling his machine in 1981. By 1982, he had joined with Vinod Khosla, SUN's first CEO, Scott McNealy, SUN's first Director of Manufacturing and Bill Joy, who was the software designer for SUN, to launch the company. The company's workstations SUN-1 and SUN-2 were an instant success, selling mainly to the University market.

SUN's break came with a $40 million contract with ComputerVision, a major CAD company at the time. ComputerVision had almost signed a contract with

Apollo but Khosla and McNealy (by sheer determination and cutthroat pricing) persuaded them to reverse the decision and go with SUN. According to Southwick, it virtually gave the machines away to gain the contract and blocked Apollo in the same move.[219] Apollo's management were not prepared for SUN's aggressive, unruly approach and complained that SUN did not play fair. Apollo's management were 'Boston gentlemen' and SUN's management were 'West Coast sandals and T-shirt'.[220] Saxenian compares the approach of SUN and Apollo, showing how the different management cultures affected the two companies and their growth, especially the Route 128 Bostonian conservatism that DEC shared.[221] Saxenian also comments on Apollo's late entry into the RISC market and its contribution to the company's failure.[222] She mentions Apollo's choice of CEO as a factor in its failure. It had elected for an established East Coast corporate executive to head the company in a fast moving and aggressive business environment.

However, SUN's growth was not without its issues. SUN had a problem with static affecting the monitor of the SUN-2, which nearly bankrupted the company, but it gave extended warranty on the systems until its engineers rectified the fault and this took them about a year. Khosla said that the problem nearly bankrupted SUN, and it had to ship two monitors with each system due to the high failure rate.[223] SUN's motto, was 'ship at all costs' and SUN is described by Saxenian as an opportunistic, 'win at all costs', 'take no prisoners' company.[224] After the ComputerVision deal, SUN began to have issues with its CEO Khosla and eventually the board removed him and put McNealy in charge in 1984. McNealy was described by Southwick, as having a short attention span, making his mind up very quickly.[225] In 1984, SUN released NFS and licensed it free to the industry, thus making it the industry standard for network file sharing. SUN products were initially based on the Motorola microprocessor and, in 1985, it released the SUN-3 based on the Motorola 68020, which was 15% cheaper than the equivalent Apollo system. The company began work on its own RISC system

[219] K. Southwick, *High Noon: The Inside Story of Scott Mcnealy and the Rise of Sun Microsystems* (New York: John Wiley, 1999).
[220] Ibid. 68.
[221] A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*.
[222] A. Saxenian, "The Limits of Autarky: Regional Networks and Industrial Adaption in Silicon Valley and Route 128."
[223] Vinod Khosla related the story on the Computer History Museum video: "SPARC at 25: Past Present and Future", published on You Tube, http://www.youtube.com/watch?v=w3ukXhEaYGI&feature=em-subs_digest (accessed July 6, 2015). This video has the founders and design engineers of SUN relating their experiences of the early days of the company.
[224] K. Southwick, *High Noon: The Inside Story of Scott Mcnealy and the Rise of Sun Microsystems*, 22; ibid. 69
[225] Ibid. 34.

in 1984, employing Patterson to help with the design. It was based on Berkeley's SPARC specification and the SPARC architecture was announced in 1987. Also in 1987, SUN teamed up with AT&T to develop UNIX System V Release 4. In the same year it became the world leader in workstations.

By 1988, the company had reached $1 billion revenue and continued that rise all through the 1990s. In 1989, it released the SPARCstation, its first RISC based system based on the SPARC architecture. Also in 1989 it made its first ever loss in the fourth quarter, due to underestimating the success of the SPARCstation and overestimating the demand for its existing Motorola based systems, as well as implementing a mainframe accounting system. This was an example of a disruptive technology having an impact on current products and margins. This only had a limited impact on the company, but it caused McNealy to focus more on the internal forecasting processes. By 1991, SUN was dominant in the RISC world, with 63% market share. In 1993, it shipped the one-millionth system and entered the Fortune 500 list. Also in 1993, it shipped the superSPARC, which fell below performance expectations and fell behind RISC offerings from HP, DEC and Motorola. SUN was saved by its next iteration, the UltraSPARC, which outperformed the opposition.

In the period 1989 to 1994, SUN experienced somewhat lean times, but, in 1994, the company began to take the Internet seriously with its external home page going online. It became the exclusive computer supplier for the 1994 football World Cup. SUN introduced the 64-bit UltraSPARC RISC processor in 1996. Also in 1996, SUN considered buying Apple, but McNealy did not like the price. Microsoft acknowledged SUN as competition in 1998, as SUN moved into the server market, and SUN was the leading supplier of UNIX based servers, having 26% of the US market.

McNealy stated that employing Windows NT would relegate SUN to 'an automotive dealer', selling Intel and Microsoft technology. Ultimately, Southwick suggests, Microsoft with Windows NT treated SUN as SUN had treated Apollo, undercutting its prices with low margins and high volume. SUN attempted to dislodge Microsoft from its position in the desktop market, with Java and the network computer, but failed. SUN's growth continued until 2001 when the Internet bubble burst and SUN began to report losses. In Southwick's book Baratz is quoted as saying that SUN had been a little naive in its JAVA licensing deal with Microsoft, 'assuming that Microsoft would behave like law-abiding citizens', stating that 'we were naive because we thought Microsoft would follow the contract'.[226] In 2002, SUN sued Microsoft, eventually settling in 2004 for a payment of $2 billion.

SUN was one of DEC's main competitors in the workstation market of the 1980s and 1990s. Unlike DEC, it had an aggressive management team led by McNealy and an aggressive sales force. SUN very quickly established itself as leader in the workstation market using commodity parts, and then moved into RISC technology to maintain a price/performance advantage. As can be seen from Table 6 and Figure 3, SUN did not suffer a downturn during 1988–1994, continuing its impressive growth while others were realigning their business. This was because it was already in the growth area of workstations and RISC, being the founders of the industry. SUN managed to maintain its margins by selling software and hardware, offsetting the shrinking hardware margins, as can be observed in Table 6. It also maintained R&D at around 10% and kept SG&A at around 26%.

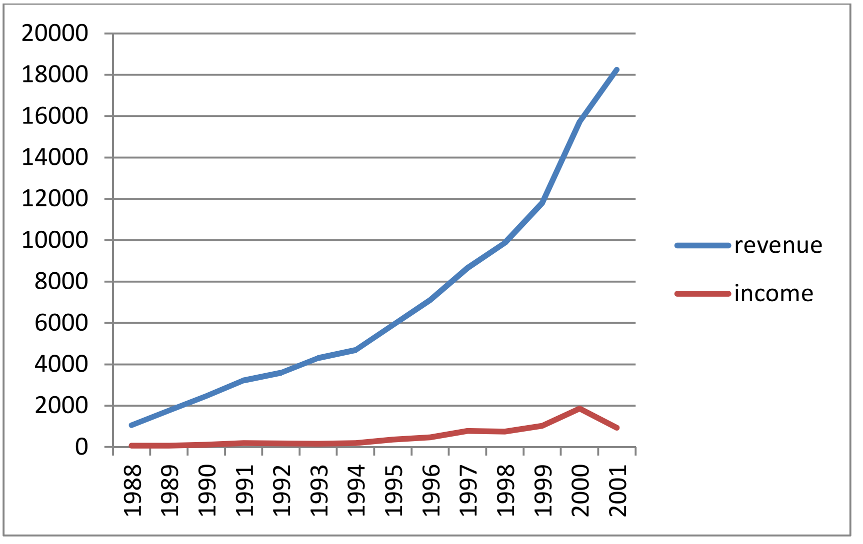
Table 6: SUN financial performance 1988 to 2001.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Revenue ($)	3589	4309	4690	5902	7095	8661	9862	11806	15721	18250
Income ($)	173	157	196	356	477	777	755	1030	1854	927
Assets ($)	2672	2768	2898	3545	3801	4697	5771	8499	14152	18181
Margin		41%	41%	42%	45%	51%	53%	52%	52%	45%
R&D	10%	10%	9.70%	9.50%	9.20%	9.60%	10%	10%	10%	11%
SG&A	27%	25%	25%	25%	25%	27%	28%	27%	25%	24%
Cash ($)	847	828	433	413	528	660	822	835	1101	1849
employees				14500	17400	21500	26600	29700	37000	41100

Data from SEC filings and Forbes 500 listings.

[226] Ibid. 146.

Figure 3: SUN revenue and income (1988 – 2001) in $thousand.



SUN peaked in 2001, however, and struggled to keep market share, losing out to Intel and Microsoft. SUN was eventually taken over by Oracle in 2010, 28 years after its founding. In an interview, McNealy suggested that SUN made an error in expecting customers to want 64-bit systems when 32-bit was good enough.[227] Many SUN customers migrated to competitors' platforms as a result. McNealy said that SUN was going to sell LINUX-based X86 computers that were just good enough, pricing them at less than the equivalent DELL PC.

SUN did not manufacture the SPARC chip, but licensed the design to a number of manufacturers, stimulating the low-cost volume production of SPARC systems. SUN's strategy at the end was its downfall; it focussed on its high-end hardware and ignored its software assets. UltraSPARC lagged behind in benchmarks and cost the company about 50% of its R&D budget.[228] In his paper to the Grenoble Graduate School of Business, Patrick Petit describes SUN's human resource management policies. He notes that 'the six years of continuous and repeating layoffs have had a disastrous impact on the motivation and morale of an exceptionally talented and loyal workforce' and that 'the management

[227] M. Ricciuti, "SUN CEO: We're "good enough"", *CNET News*, October 8, 2000.
[228] Case Study on Business Strategies: The Downfall of SUN Microsystems. http://www.mbaknol.com/management-case-studies/case-study-on-business-strategies-the-downfall-of-SUN-microsystems (accessed July 6, 2015).

policy has a destructive effect on the company's overall performance. Employees feel insecure because there is no way they can control their future.'[229]

Table 7: SUN's board and their ages in 1998 .

Board	**Age in 1998**
Scott McNealy	43
Michael Lehman	48
George Reyes	44
John Doerr	47
Judith Estrin	44
Robert Fisher	44
Robert Long	51
Kenneth Oshman	58
Michael Spence	55
average	**48**

In their paper, Hunt et al. described SUN in its latter years as being focussed on the quality of its products as opposed to the price, which is markedly different from SUN when it was founded.[230] McNealy was chairman of the board and the driving force behind SUN from the day it was founded to the day it was sold. The SUN board had nine members (Table 7), the average age of whom was 48, and the oldest being just 58.

An article written in 2004 performed a comparison with SUN and DEC considering whether SUN was imitating DEC.[231] It suggests that both companies had entrepreneurs as CEO rather than leaders, but at opposite ends of the personality spectrum. Insiders controlled the boards of both companies, where loyalty was the top requirement for membership. They both had exceptional growth with little competition and, at a time of market change, were not able to respond due to the wrong CEO. It goes on to say that:

> DEC's response to competition was to commit to open foundation, to de-commit to open foundation, commit to PCs but with proprietary operating

[229] Grenoble Graduate School of Business paper by Patrick Petit, "SUN Microsystems International Human Resources Management Case Study," August 2008.
[230] J. Hunt, P.Johnson, P. Johnston, S. Laidman and J. Link, "Clearing the Clouds Surrounding SUN," September 21, 2004. Available from Ohio University under SunReport.doc.
[231] http://www.thesunalsosets/Editorials.html , published October 1, 2004 (accessed June 3, 2011).

> system, then to de-commit, re-commit, offer services, offer no services. SUN on the other hand in response to Linux was to fight Linux, to commit to Linux, to commit to open systems, to de-commit to open systems, deny DELL as a competitor, have a 'cheaper than DELL' marketing policy.

In other words, both companies had a confused response to competition. It also suggests that, when DEC appointed Palmer, he ignored customers and focussed on the financial sector, going on to state that Palmer brought in Crawford Beveridge to manage HR and change DEC culture. McNealy also focused on the financial sector, neglecting customers, and in 2000 he hired Beveridge to lead the company's downsizing process which went very much like that at DEC, destroying company morale.

4.5.2 *Conclusion*

SUN rode the depression of the 1990s because it had caught the workstation wave and was leading the market. Later it tried to take on Microsoft and failed. SUN downsized using the same HR manager as DEC and the same processes that undermined morale. It retained its CEO too long and did not build a customer-focussed organisation. It also failed to embrace the Open Software Foundation even though its systems were UNIX based.

4.6 *Summary*

It has been shown that all of the companies mentioned suffered during the early 1990s due to the recession and the change in the computing paradigm, which took them all by surprise, apart from SUN. All of them lost out in the PC market in some way and all of them tried to realign management and at some time tried to reduce headcount by using redundancy, to varying degrees of success. DEC and SUN used the same HR manager to implement their downsizing processes with the same disastrous results. All the company cultures have been shown to be very similar, which made the downsizing process difficult for management and employees. Data General and SUN continued the downsizing process, whereas IBM and HP realised that this was not the only option available to them and built for growth. This could be considered as a major contributing factor in the formers' downfall, as IBM and HP survived, and SUN and Data General have all been absorbed into other companies.

Again, all apart from SUN changed their CEO because of pressure from shareholders and the board. IBM was fortunate in its selection, which came after an extensive search, as it selected a CEO with the skills to recognise how the company was failing and to put in place activities to return them to profitability. HP had a number of CEOs, all of whom were replaced when the board deemed they were no longer functioning. Data General cut back on new product development, cut costs and did not invest in growth, whereas IBM and HP moved into the growth areas, investing where they saw new markets, such as service and the Internet. SUN increased their R&D until it was at an unsustainable level, whereas HP reduced their R&D linearly over the years. All of the companies moved into the RISC and UNIX business, but at different times. HP, IBM and SUN all implemented RISC in the mid to late 1980s. DEC, Data General and SUN all tried to take on Microsoft in some way and all lost. IBM celebrated its 100th anniversary in 2011.

5 The Rise of DEC

5.1 *Introduction*

This chapter concerns the history of DEC from its beginnings in the Mill at Maynard, Massachusetts to its peak in 1988. It looks at the major products that made the company and also the management including the board. DEC began as a purely hardware company but gradually moved into the software business as it moved away from the scientific market into the business market. A number of the software products developed were used in-house to DEC's advantage such as VAXnotes and Vogon News and their importance to the company is highlighted. However it was DEC's hardware business that caused the company problems as will be shown in the next chapter. There were a number of people who were pivotal in DEC's growth and their contribution is covered in this chapter. DEC also had a number of opportunities to invest in other companies and also had offers for its business.

5.2 *The Founding and Subsequent Rise of DEC*

The beginnings of DEC date back to Lincoln Labs at MIT in Boston in the 1950s, where work on the strategic air defence system, SAGE, was continuing. It was there that Ken Olsen began his career and developed his ideas. It was at Lincoln Labs that Jay Forrester conceived the idea of magnetic core memory and he was granted a patent in 1955. Although the invention of magnetic core memory is often linked solely with Forrester, there were a number of other people who contributed. Three people, including Olsen, had worked on magnetic core memory in 1947 and all had been granted patents that led to a long legal battle, not resolved until 1964.[232] Forrester employed one of his students to investigate core memory; the subject of his master's thesis was 'A Co-Incident Current Magnetic Memory Unit'.[233] Along with the three who received patents, John Presper Eckert, Jan Rachman and Mike Haynes were also associated with its development.[234]

---

[232] Forrester, Wang and Olsen all received patents for particular implementations of core memory (Forrester and Olsen at Lincoln Labs, and Wang at Harvard): Olsen patent number 3,161,861 'Magnetic Core Memory (improvements)', Wang patent number 2,708,722 'Pulse Transfer Controlling Devices' and Forrester patent number 2,736,880 'Multi-coordinate Digital Information Storage Device'.

[233] W. N. Papian, "A Co-Incident Current Magnetic Memory Unit" (Massachusetts Institute of Technology, 1950).

[234] Eckert proposed an array of cores in 1945. Rachman developed his ideas alongside Forrester and had an extended patent battle with him over the invention. Haynes established magnetic core research

DEC's founders, Olsen and Anderson, had worked on the TX-2 project at Lincoln Labs and whilst there Olsen was assigned as liaison to IBM, the main contractor on the air defence project. Working with IBM, Olsen found that he immensely disliked the IBM organisational system, a factor which was to shape the structure he put in place at DEC.[235] According to Ante, Olsen was also disappointed that the business did not recognise what he had achieved with TX-2.[236] This was the primary reason that he decided to leave MIT to start his own company and, having been turned down by General Dynamics, he and Anderson went to American Research and Development (ARD) for funding for the new company.[237] Olsen created a business plan, building on what he and Anderson had gleaned from research at Lexington's public library and Professor Paul Samuelson's textbook on economics.[238] ARD pondered the merit of lending to this start-up company, but Doriot was convinced and so they invested $70,000 for a 70% stake in the company. Olsen and Anderson were somewhat naive in accepting the 70% stake in the company for such a small investment, retaining only 10% each.

As ARD did not want DEC to build computers, or be thought of as a computer company, Olsen and Anderson decided to name the company Digital Equipment Corporation rather than the Digital Computer Corporation.[239] When DEC became a public company in 1968, ARD's investment was worth $355 million. They had invested approximately $400,000 in the company. There was a special relationship between Doriot and Olsen that is not apparent in any other company of its type. Ante described this as: 'Doriot clicked with Olsen in a most profound way'.[240] This relationship was to last for thirty years and prove beneficial to both parties. DEC's rise helped ARD stock value to increase as well as its own.

In 1959 Olsen decided it was time for DEC to build its first computer, the PDP-1, which was designed by Ben Gurley. DEC had a ready market, including RCA, who had sold DEC some surplus 18-bit core memory. This was, according to

---

at IBM, as reported in computer science course 6.972 at MIT 'the Core of Engineering Revolutions' by P. Anderson, W. He, Y. Ma, B. Slutz and K. Lynch.

[235] E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 34.

[236] S. E. Ante, *Creative Capital: Georges Doriot and the Birth of Venture Capital*, 149.

[237] ARD was one of the first venture capital companies. It was founded by Georges Doriot, who was known as the first venture capitalist of America; his rules on venture capital investing are still applied today.

[238] P. A. Samuelson, *Economics*, 1st ed. (New York,: McGraw-Hill Book Co., 1948).

[239] S. E. Ante, *Creative Capital: Georges Doriot and the Birth of Venture Capital*, 151.

[240] Ibid. 178.

Figure 4 PDP-1

Photograph by David Goodwin at the Computer History Museum, Mountain View, California.

Anderson, the main reason that the PDP-1 was an 18-bit machine.[241] Bolt Beranek and Newman (BBN), bought the first PDP-1, serial number 1, in 1960 and developed a timesharing application that was to lead to multiuser access to computers, rather than batch as was the norm at the time.[242] This was one of the first timesharing systems developed.[243] DEC also gave a PDP-1 with a retail value of $120,000 to MIT, which at first seemed a strange thing to do. This machine however did not cost DEC anything, as it was tax deductible at fair market value, rather than the $40,000 it cost to manufacture.[244] Hence, it made a small profit on the transaction.

---

[241] G. Hendrie, "Oral History of Harlan Anderson," Computer History Museum, May 15, 2006, Reference X3590.2006. http://archive.computerhistory.org/resources/access/text/2013/05/102658022-05-01-acc.pdf (accessed July 6, 2015).

[242] Bolt, Beranak and Newman was founded by two MIT professors and a student, and had a long relationship with DEC. It was one of the founders of the ARPANET.

[243] J. McCarthy wrote about the development of timesharing on his history page at Stanford. J. McCarthy, 'Reminiscences of the History of Timesharing', http://www-formal.stanford.edu/jmc/history/timesharing/timesharing.html (accessed July 6, 2015).

[244] H. Anderson, *Learn, Earn & Return: My Life as a Computer Pioneer*, 114-115.

DEC's tenth employee was another important addition to the company: Ted Johnson was hired in 1958 as DEC's first salesman. DEC always maintained a close relationship with MIT during its period as an independent company, employing many of its engineering staff. In 1960, Olsen recruited Gordon Bell, who had worked under Gurley at MIT. One of the first systems that Bell was involved with was the PDP-6 but, when it was manufactured, there were a number of issues that caused tensions within the company. During this period Bell established DECUS.[245] Jay Forrester resigned from the board over memory patents, Bell left to go to Carnegie-Mellon and Anderson left because of a rift with Olsen, possibly because of problems with the PDP-6 and particularly the one returned from Gilmore's firm.[246] Anderson's departure was also the catalyst that forced DEC to go public, as he wanted to cash in his shares. By 1960, DEC had 117 employees and revenues of $1.3 million. Over the next five years, the number of employees grew to 876, DEC had 18 locations (5 outside the United States), and an income of $5 million.

5.2.1 *PDP-8 and PDP-11*

DEC released a number of systems over the years but the machine that really cemented DEC's name and reputation was the PDP-8, a 12-bit machine released in 1965. The PDP-8 has been considered the first PC.[247] This was because it was the first mass-produced computer that could operate in an office environment and which did not require specially trained IT staff. Variants of the PDP-8 were sold for more than two decades. Eventually these were put onto a single chip and embedded in numerous devices. According to Pearson, over 50,000 PDP-8s were sold in one form or another in its twenty-five year lifetime.[248] Even today, there are a number of simulators available for enthusiasts.[249]

[245] DECUS was one of the first user groups and was established to encourage sharing of programs between users of DEC equipment. It was started in 1961 and grew to be the largest computer user group in the world. Alan R. Earls, *Digital Equipment Corporation*, Images of America (Portsmouth, NH: Arcadia, 2004), 9; also Smithsonian Oral Interview with Gordon Bell, April 1995, Palo Alto. http://americanhistory.si.edu/comphist/bell.htm (accessed July 6, 2015).

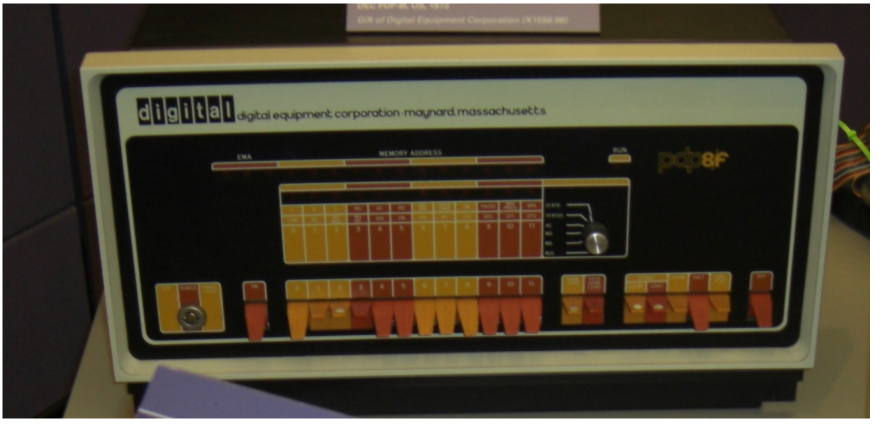
[246] G. Hendrie, "Oral History of John T. (Jack) Gilmore Jr.," at the Computer History Museum, February 13, 2007 Reference X3925.2007. http://archive.computerhistory.org/resources/access/text/2013/05/102658038-05-01-acc.pdf (accessed July 6, 2015).

[247] Lin Jones, currently the project leader of the National Computer Museum, holds this view.

[248] J. P. Pearson, *Digital at Work: Snapshots from the First Thirty-Five Years* (Burlington, MA: Digital Press, 1992), 55.

[249] PDP-8 simulators have been written for Windows, MAC and there is a Java applet available. A source for many computer system simulators is http://simh.trailing-edge.com/ (accessed July 6, 2015).

Figure 5 PDP-8/f



Photograph by David Goodwin at the Computer History Museum, Mountain View, California.

Designed by de Castro, the PDP-8 became a family of systems that started the minicomputer revolution. The PDP-8 also opened up the Original Equipment Manufacturer (OEM) market for DEC, where many third party firms used the PDP-8 as a front end to their added-value equipment. The term OEM was used by DEC from the early 1960s and this is probably the origin of the term in the computer industry. As with the first electronic computers, very few people were involved in the design of the first DEC computers – in particular, Anderson, Bell, Gurley, de Castro and Alan Kotok. Bell, as will be shown later, became pivotal in DEC's future success.

By 1970, the employee population had reached 5,800, revenues were $135 million and there were 68 locations worldwide, including training centres. In 1971, DEC opened its first full European manufacturing facility in Galway, Ireland. DEC already had limited manufacturing in Reading in the UK, but British political considerations, in particular a lack of incentives, impeded expansion there. Galway was soon followed by Puerto Rico and Kanata in Canada. Later, following British policy changes, a plant was opened in Ayr in Scotland.

The 1970s saw the introduction of the next major product for DEC, the PDP-11, which also sold for twenty-five years. The PDP-11 was a 16-bit machine and was to become the major contributor to the success of the company with its Unibus architecture enabling OEMs to add peripherals of their own design easily and sell them on. It was designed in response to Data General's NOVA system.

According to Ceruzzi, four DEC engineers visited Bell, who was on sabbatical; together they rejected the proposed design and opted for one based on work by McFarland.[250] The team then developed the Unibus concept for McFarland's design.[251] In its product lifetime of over 20 years, Pearson records that close to a million machines were produced in a family of around 30 variants.[252] This figure did not include a large number of clones built in the Iron Curtain countries, such as the SM-4, the SM-1420 and the SM-1600.[253]

Figure 6 PDP 11/70

Photograph by David Goodwin at the Computer History Museum, Mountain View, California.

---

[250] Harold McFarland was working on computer architecture designs at Carnegie-Mellon University along with Bell at the time and the PDP-11 was based on one of his designs.
[251] P. E.Ceruzzi, *A History of Modern Computing*, 198.
[252] Pearson, *Digital at Work: Snapshots from the First Thirty-Five Years*, 58.
[253] PDP-11s behind the Iron Curtain, http://www.village.org/pdp11/faq.pages/Soviet11s.html ; (accessed July 6, 2015).

Its design is attributed to Jim O'Loughlin, although DEC's first attempt at a 16-bit computer was codenamed the PDP-X and the design team for that was led by de Castro. De Castro left DEC, together with Henry Burkhardt III and Richard Sogge, to form Data General after the PDP-X project was cancelled. It was Data General's production of the Nova that spurred DEC on to the rapid development of the PDP-11 as a response to the disruptive innovation that was 16 bit computing that threatened its PDP-8 range.[254] The PDP-11 architecture influenced the design of many microprocessors as well as influencing the software architecture of systems such as CP/M and MSDOS.[255] The C programming language has a number of similarities to the PDP-11 instruction set and UNIX first ran on a PDP-11/20.[256]

5.2.2 *VAX and VAXclusters*

Bell returned to DEC in 1972 and on 25th October 1977, under Bell's technical direction, DEC released the VAX range, a series of 32-bit systems which was the next innovation that propelled the company into second place in the world computer market. The VAX range was a family of computers designed to scale and to take the company forward for many years. As can be seen from the company's growth, this projection worked very successfully for over fifteen years.[257] Data General tried to beat DEC to the 32-bit market with their Fountainhead Project but delays led to customers buying the VAX instead.[258] DEC had rapid growth, built on the back of the VAX range. The VAX was in production until the 1990s and as with the PDP-11 it had many clones.[259] By the 1990s the VAX was no longer leading in computing power and cheaper, faster UNIX machines were taking market share from DEC.

---

[254] G. Bell et al. describe the development and the technology involved in the PDP-11; Bell et al., *Computer Engineering: A DEC View of Hardware Systems Design*.
[255] P. E. Ceruzzi, *A History of Modern Computing*, 238
[256] http://minnie.tuhs.org/Seminars/AUUG96/pdppaper.html (accessed July 6, 2015). UNIX was initially developed on PDP-7 but was only named UNIX when it was a funded project on a PDP-11/20.
[257] DEC's growth is shown in chapter 5.
[258] Data General's problems are discussed in chapter 4.
[259] Systime in the UK built a clone of the VAX but most clones were behind the Iron Curtain. These were mainly the CM and SM series.

Figure 7 VAX 11/780

Photograph by David Goodwin at the Computer History Museum, Mountain View, California.

In 1983 DEC announced its VAXcluster technology that enabled multiple systems to communicate and share storage. This was done via a redundant hub named a star coupler allowing 16 nodes to be connected. In 1986 the company extended the architecture to enable communication over the Ethernet and expanded the number of nodes to 1024. These were called Local Area VAXclusters and gave customers a simple and relatively cheap ‘scale out’ expansion path. High speed Ethernet enabled DEC to offer disaster-tolerant systems with computers geographically dispersed. Clustering was a major selling point for DEC and was eventually ported to its implementation of UNIX. This was a product that was potentially a differentiator for the company during its problem period but it was undersold.[260]

Following Bell’s departure in 1983, there was no one with the same technical vision to define a family to continue from the VAX, as is shown in the chapter 6

[260] Personal email to Goodwin by Ed Kramer, subject: DEC’s demise, January 25, 2008; also email from Bob Glorioso, subject: DEC, January 23, 2008.

when the S-curve is discussed. DEC however did not only have the PDP-8, PDP-11 and VAX in volume production. It also had the PDP-15 and the PDP-10 (DECsystem-10) selling into niche markets. The PDP-10 in particular had a long established, loyal customer base, many of whom did not want to migrate to the VAX family when PDP-10 development was cancelled.

5.2.3 *Large Computer Group*

No history of DEC would be complete without mention of the Large Computer Group (LCG) and the PDP-10, DECsystem-10, DECsystem-20 products and customers. Although the PDP-8, PDP-11 and VAX were the volume products, the early ‘mainframe’ computers that DEC produced were pivotal in many of the technologies we have today and had very loyal customers, especially in academia. The PDP-10 was one of the first systems on the ARPANET: it was a PDP-10 that Bill Gates first hacked into as a student and he also developed the Basic interpreter for Altair on it.[261] The ‘Hacker’ community began on the PDP-1 at MIT and was connected with DEC computers through most of its life.[262] It developed the Jargon file on the SAIL PDP-10 at MIT and the Jargon file was hosted on PDP-10s until the cancellation of the Jupiter project in 1983.[263] To quote from Raymond:[264]

> Cheap timesharing was the medium the hacker culture grew in, and for most of its lifespan, the ARPANET was primarily a network of DEC machines. The most important of these was the PDP-10, first released in 1967. The 10 remained hackerdom's favourite machine for almost fifteen years; TOPS-10 (DEC's operating system for the machine) and MACRO-10 (its assembler) are still remembered with nostalgic fondness in a great deal of slang and folklore.

---

[261] S. Manes and P. Andrews, *Gates: How Microsoft's Mogul Reinvented an Industry and Made Himself the Richest Man in America*, 1st Touchstone ed. (New York: Simon and Schuster, 1994), 34.
[262] “3. The Early Hackers”. http://www.catb.org/~esr/writings/hacker-history/hacker-history-3.html (accessed July 5, 2015).
[263] The Jargon file was hosted for some time on the SAIL system at MIT. SAIL was the Stanford AI Language and the Jargon file was a collection of computer programmer slang. It was later published by MIT as ‘the Hacker’s Dictionary’. Eric S. Raymond, *The New Hacker's Dictionary*, 3rd ed. (Cambridge, MA: MIT Press, 1996).
[264] E. S. Raymond, *The Cathedral & the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary* (O'Reilly Media, 2001). 6.

Figure 8 KL-10

Photograph by David Goodwin at the Computer History Museum, Mountain View, California.

The DEC 36-bit family was in production for twenty years from 1964, when the PDP-6 was released, through 1967 when the first PDP-10 was sold, all the way through to 1983. The story of this is told in a DEC publication *Twenty Years of 36-bit Computing with Digital*.[265] Although DEC had a core of committed customers for their 'mainframe' computer systems, they did not represent a major source of income and the decision was made that the company could not afford the two development streams and so should focus on its VAX family. The VAX was considered by senior management to be the future of the company and the decision was to migrate the Large Systems Group's customers to the VAX product family. In 1983, it fell to Rose Ann Giordano to announce the cancellation of the Jupiter program at DECUS and with it signify the end of the DECsystem-10 product.[266]

Although DEC committed help with porting applications and product enhancements for a further five years and product support for a further ten years,

---

[265] Available from http://www.ultimate.com/phil/pdp10/20yrs (accessed July 6, 2015).
[266] The Jupiter was the follow on system for LCG customers, which was in the late stages of design when it was cancelled.

many PDP-10 customers decided to go to other vendors. The ending of the Jupiter project also spelled the end of ITS which was MIT's operating system for the PDP-10 series.[267] This continues the assertion of this thesis that DEC's decline began in 1983 with a number of factors coming together to influence the company's future, including its treatment of its loyal customers.

5.3 *Software*

In the 1980s, DEC moved from being primarily a hardware company into a systems company, with its services organisation competing with the major companies in the field. Initially DEC had relied on customers to write software for their computers, but later supplied operating systems such as RT-11, RSTS-11 and RSX-11 for the PDP-11 range, TOPS-10 and TOPS-20 for the LCG range and VMS for the VAX. Ceruzzi writes that 'Crucial steps in the evolution of Basic were taken in 1971 at DEC....RSTS-11 was developed and implemented in Basic....DEC engineers modified Basic such that it was implemented without taking up too much memory. These features were adopted by Microsoft a few years later for its version of Basic for PCs'.[268] By 1990 DEC had moved into applications as well as operating systems and had a large software development and support organisation. DEC had released ULTRIX-32 for the VAX in 1984 but had done little to gain a major share of the market, due to a lack of focus on UNIX in the 1980s.[269] It continued to ship new releases of VMS with additional functionality, but increasingly there was a focus on UNIX. As DECs problems were mainly hardware and managerial related the coverage of its software business is minimal. The software problems that hit the company are discussed in chapter 6 and are around DEC's late recognition of UNIX and its failure to unbundle VMS.[270]

5.3.1 *VAXnotes and Vogon News Service*

As the Notesfiles in DEC were of particular importance to the employees in performing their jobs, it is relevant to give a brief description of their history and use within DEC. The Digital Technical Journal has an excellent article on the development of VAXnotes, which can be summarised as follows. In 1980 a DEC engineer wrote a computer conferencing program K-NOTES that had its roots in the PLATO system. This became a necessary tool in the engineering department and a PDP-11 software developer carried out a 'midnight project' and developed

[267] MIT had decided to write their own operating system, ITS, rather than use DEC's TOPS-10.
[268] P. E. Ceruzzi, *A History of Modern Computing*, 204-205.
[269] ULTRIX was DEC's version of UNIX released on its PDP-11, Professional, VAX and Alpha systems.
[270] OpenVMS included many 'bundled' software products, run time languages, for example, that were included in the price even if the customer didn't require the software.

NOTES-11.[271] In 1984 NOTES-11 was moved to the VAX platform and VAXnotes became a funded project. It soon permeated the company worldwide. The main notes file about the company itself was the Digital Notesfile and there were country variants, such as the Digital-UK version for UK related topics. Two of the three developers of Lotus Notes were from DEC, one of which, Len Kawell, wrote VAXnotes. This was probably the first collaboration tool in the industry and many customers used it, although DEC never actually sold it as a product.[272] Gundry's paper on collaborative learning describes the features and capabilities of VAXnotes that enabled DEC as a knowledge based corporation.[273] Anklam wrote of VAXnotes that: 'It worked in the same way as modern conferencing databases, but was oddly more powerful and feature rich than many combining "communities of interest", "communities of purpose" and "communities of practice" geographically dispersed.'[274] She reports that an analysis in August 1989 showed there were a total of 10,355 conferences: 9,965 work related and 390 dedicated to employees' interests. VAXnotes eventually moved to a PC platform before evolving into SiteScape, running on AltaVista. There is still a version of VAXnotes running on the DECUS web site which has more than 50 technical conferences with over 18,000 technical topic streams.[275]

DEC also had one of the earliest online news services in its VOGON News Service that was published on DEC's Easynet.[276] It was established in 1983 by Alan Blannin and Marios Cleovoulou who described its beginning with these words:

> The VOGON News Service (VNS) started after a number of software engineers from Reading, England relocated to the Spit Brook Road facility in Nashua, NH, USA. Amongst them were Alan Blannin and myself. Alan asked a friend, Richard De Morgan, still in Reading, to send him the test match scores so that Alan could keep up to date on events in his favourite sport – cricket. Richard sent not only the requested results, but also included some small snippets of news.

---

[271] A 'midnight project' is one that often happened at DEC: it was an unfunded development worked on outside normal hours. VAXnotes was another example of a 'bundled' product with OpenVMS.
[272] One organisation that used VAXnotes for collaboration was CERN, as described by Tim Berners-Lee in his proposal for Information Management. Tim Berners-Lee, "Information Management: A Proposal," March 1989, CERN. http://www.w3.org/History/1989/proposal.html (accessed July 6, 2015).
[273] J. Gundry, "Understanding Collaborative Learning in Networked Organizations," in *Collaborative Learning Through Computer Conferencing - The Najaden Papers*, ed. A. R Kaye (Springer, 1992).
[274] P. Anklam, "The Camelot of Collaboration," *Inside Knowledge* 5, no. 2 (2001).
[275] DECUS notes conference http://eisner.decus.org/ (accessed July 6, 2015).
[276] The Easynet was DEC's internal intranet running the DECnet protocol.

> Alan forwarded this information on to other "expat Brits" in the U.S. and the VNS (although it wasn't known as such then) was born! Issue number one was "published" on the 3rd of August, 1981. Soon after, Richard, being at the time on node VOGON::, jokingly titled his MAIL to Alan "The VOGON News Service" and the name stuck.[277]

VNS was sent directly to over 6,500 email addresses and published on DEC's internal videotext system (VTX), so that it finally reached most of the company. It was published every weekday for over 15 years. There is no archive of VNS but a number of the issues can be found in the notes files. VNS carried company information, financial performance data, announcements, and published articles from news sources.

5.4 *When did things start to go wrong?*

DEC's early history was not as smooth a ride as some would contend; during its growth period there were many events that could have broken the company. There were also many potential suitors for DEC, including Xerox in 1966, AT&T in 1988, Mitsubishi in 1990 and Hewlett-Packard, all of which Olsen, Doriot and the board rejected.[278] DEC had considered buying Compaq in 1994 and Compaq merger talks went on in 1995, but the DEC management considered the loss of operating independence too great to accept at the time.[279] Had any of these offers been accepted the company would have been absorbed and many innovations potentially lost. Occasionally there were staff defections to create competitive start-ups, mainly due to differences of opinion on technology. One such defection was by Henry Burkhardt and Edson de Castro. Another was Len Bozak who left around 1979 for Stanford University where he developed the first Cisco products. Others left to contribute to other competitors such as SUN, MIPS and especially Microsoft.[280] As DEC grew in the 1980s, profits from the sales of the VAX systems obscured an underlying problem of declining margins as the UNIX workstation took over DECs traditional low end market.

Schein and others tell of DEC's management style, which was aptly described as conflict management.[281] However, this management style was also present in

---

[277] Published in the 3000th edition of VNS on January 19, 1994. This edition is available in Google Groups https://groups.google.com/forum/?fromgroups#!topic/soc.culture.british/BYWB3Xh_C7c (accessed July 6, 2015).
[278] S. E. Ante, *Creative Capital: Georges Doriot and the Birth of Venture Capital*, 179.
[279] L. Zuckerman, "For Digital's Chief, A Last Grab for Glory," *The New York Times.* May 25, 1997.
[280] E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 103–112; Schein writes mainly of management defections, but there were many technical defections that had a much greater impact on the industry and also DEC's eventual failure.
[281] Ibid.

DEC's engineering organisation.[282] There developed a rivalry between the Large Computer Group who designed the PDP-10 and PDP-15 and the 'minis', responsible for the PDP-8 and PDP-11.[283] This was to become extremely divisive for the company in the years to come, as indicated by Cutler.[284] The competing design groups were geographically dispersed with the Large Computer Group in Marlborough, Massachusetts and the 'minis' in Maynard, Massachusetts. The rivalry was often bitter and lasted for many years, even after the cancellation of the DECsystem-10 range. This was even quoted in a LinkedIn entry describing the products being developed at DECwest, including AltaVista, being 'caught up in the rivalry (read war or hatred) between Palo Alto and Central Engineering.'[285] Many of the DECwest engineers were originally from the Large Computer Group. This was not just a DEC problem, Data General had similar issues with its design teams (covered in chapter 4) along with many other computer companies such as Burroughs.[286]

Schein proposed that the management was the root cause of the company being in trouble by 1990, but he covered little of the final years of the company and the causes of its failure to rebuild itself. It is our suggestion that the failure was far more complex than Schein indicated, although he was correct in the assertion that the management was ultimately responsible. For example, Schein's book gives minimal consideration to the downsizing processes that were implemented during the 1990s, the effect that they had on the company, the personnel involved and their part in the company's eventual downfall. Schein tends to focus on the management meetings, the conflicts at those meetings and the lack of focus on money by the management.

Many of the ex-DEC employees have been very critical of Schein's writing, feeling it was biased towards money management and ignored the technical aspects, thus not portraying the complete story. Although it is a thorough reporting of the management meetings and the conflict culture of those meetings, it appears confused in its description of what else was going on in the company. Schein's views even led Bell to write an appendix to the book, which can be

---

[282] Pearson, *Digital at Work: Snapshots from the First Thirty-Five Years*. 88-89
[283] The PDP-10 and PDP-15 were considered mainframe class systems at DEC and were 36-bit and 18-bit machines respectively. The PDP-8 and PDP-11 were considered minicomputers and were 12-bit and 16-bit machines.
[284] Interview with Dave Cutler, Bellvue, Washington, October 5, 2010.
[285] This rivalry continues today as exemplified in other discussions within the LinkedIn files, where some of the comments continue to be vitriolic between the groups.
[286] Oral interview, Conducted by Bernard A. Galler and Robert F. Rosin for the Anals of the History of Computing, 'The Burroughs B5000 Conference', http://conservancy.umn.edu/bitstream/107105/1/oh098b5c.pdf (accessed July 6, 2015).

found on his website, offering his view on what went wrong.[287] Bell however also glosses over the downsizing process and its significance for the company's future. DeLisi commented that he and the other authors had collaborated in the book but that near the end Schein finished it alone, and he was not in total agreement with some of the conclusions.[288] He felt they were biased towards the area that Schein knew, rather than covering all the areas they had investigated, particularly technology.

Schein contends that DEC's management problems traversed the decades and it was only when the computer paradigm shifted that they caused problems for the company.[289] The assertion of this thesis is that other factors were pivotal in the company's fortunes; the major factors began during1982-3 and continued until 1988. In 1982, Bell had a heart attack, brought on by the stress of working at the level he did and his interaction with senior management. He took the decision to return to academia and DEC lost its direction from this point onwards. Bell was DEC's engineering VP, the visionary that defined the company's technical direction. He was the man behind the architecture and development of DEC's 32-bit VAX range and drove the engineering organisation. He had been in charge of engineering when DEC's work on the RISC systems first began and indicated that he understood the potential of the PC.

After Bell left there was no one with the same technical ability to co-ordinate all of the engineering groups. This gap was filled by the Strategic Task Force, led by Bill Strecker and often known internally as the Strecker Task Force. Olsen did not trust the STF and Strecker made many enemies because the STF not only had technology responsibility, but also budgetary responsibility for engineering. In the early 1980s, Shields also declared that DEC would go into direct competition with IBM and the company recruited staff for this initiative.[290]

The start of the final decline in DEC can be traced to the departure of a number of key employees at critical times in the 1980s that affected its operations. The main ones were Bell in 1983 and Cutler in 1988, but there were others in

---

[287] Gordon Bell's comments are in Appendix E of Schein's book: Gordon Bell, "Appendix E," in E. H Schein, *Dec Is Dead: Long Live DEC.* Also available on Bell's web page: G. Bell, "Appendix for Edgar H. Schein 'DEC is Dead, Long Live DEC'". http://research.microsoft.com/~gbell/CGB%20Files/DEC_Is_Dead_Bell_Appendix_Schein_Book.pdf (accessed July 6, 2015).
[288] Interview in Mountain View, February 15, 2008.
[289] Ibid. Ch. 9–11.
[290] Vogon News Service report October 10, 1989 citing Boston Globe article by Lawrence Edelman and Jane Fitz Simon, "The Trouble with Digital"; Email from Steve Wells in response to survey, Subject: Survey Comments; Email from Bob Brownson in response to request to DEC Alumni group Subject: DEC Thesis. Also comment from Richard Seltzer recorded at http://www.samizdat.com/dec.html (accessed July 6, 2015).

technical and managerial positions in the late 1980s that had an impact. Many senior managers left in the late 1980s due to disagreements with the company structure and responsibility changes that took some of the power away from those who had previously enjoyed it. This loss of personnel caused some commentators in the late 1980s to suggest that DEC was haemorrhaging talent. Later, Palmer hired many senior executives from companies such as IBM to try to bring in talent, but his choice of executive was not successful and many did not fit in with DEC's style and culture and left soon after joining, mostly with large compensation packages.[291]

Bell had defined the VAX strategy that kept the company moving in the right direction for a number of years, hiding the fact that it did not have a viable solution for what came after the VAX. Olsen believed that its superiority would suffice for years. Cutler when interviewed stated that had Bell still been there he would not have left the company and so Windows NT's threat to DEC's business might never have happened.[292]

Other new companies such as SUN grew to take DEC's traditional market of low cost computing and were much more able to develop rapidly without high overheads. In the networking field, DEC had a lead, especially with Ethernet technology, but again a start-up company called Cisco launched its first product in 1986 and quickly grew to challenge DEC.

Roberts considered high technology companies and their founders in the East Coast region and particularly those with MIT connections. Olsen was known as a successful entrepreneur for much of his career. [293] Roberts's analysis of Olsen and DEC includes an examination of Schein's involvement from 1966 to 1992, the DEC personnel who came from MIT and Sloan School and the courses provided by Sloan School for DEC managers. He highlights Olsen's stance that DEC would not undertake any government contract work, even though around 30% of its business came from government. One of the issues many high tech companies faced was quality versus consumer-perceived value in product development. Favaro considered this in 1996 and concluded that when there are conflicts between a company's economic interests and those of the customer

---

[291] Examples are Brebach and Lucente who joined in April 1993 and resigned in August and April 1994 respectively. Brebach joined from McKinsey and Lucente from IBM. Pesatori was brought in on a base salary of $550,000 (SEC filings for 1993) and severance of at least $1,300,000 (SEC filings for 1996) to build DEC's personal computer business. and left a failure, losing the company $200 million in FY93.
[292] Interview with Dave Cutler in Bellvue, Washington, October 5, 2010.
[293] E. B. Roberts, *Entrepreneurs in High Technology: Lessons from MIT and Beyond* (New York: Oxford University Press, 1991).

‘focussing narrowly on quality and customer satisfaction will not address or resolve these conflicts’.[294] One of the scenarios studied by Favaro is DEC, where declining customer satisfaction matched a decline in the company’s fortunes. There was a marked difference between computer companies in their view of quality, which concurs with Favaro’s view.[295] It is proposed that this became less important to customers after the PC was released and low cost workstations became available, when customers opted for price over quality. This allowed many more companies to enter the market and compete with the larger businesses.

Schein worked at DEC as a management consultant for thirty years alongside his role at the Sloan School of Management and so was well versed in the management culture of DEC.[296] He commented on the decline of DEC and these comments are considered alongside those of senior employees.[297] In December 2009, Harlan Anderson published his memoirs, in which he covered his turbulent relationship with Olsen and also offered some thoughts as to what went wrong at DEC.[298] He looks at Olsen’s relationship with the engineers, who were the power behind some of DEC’s early computers, and how this influenced the company. His comments are mainly on his early years at DEC and the views on the company downfall appear to be mainly repeating the views that appeared in the press at the time. He does not offer any new commentary on why the company failed nor on what could have been done to save it.

5.5 *Major events in DEC 1983 to 1998*

The following table is a timeline of the major events in the period of interest. It depicts the personnel changes that occurred, the financial performance and the main technologies of the company.

---

[294] J. Favaro, "When the Pursuit of Quality Destroys Value," *IEEE Software* 13, no. 3 (1996): 93-95.
[295] For example, DEC waited to release their thin film disks until their mean time between failures was acceptable; whereas SUN released the workstation with a known monitor issue.
[296] Schein drew on his experience at DEC alongside his work at the Sloan School of Management to develop his theories on organisational culture and executive development. He is a leading figure in behavioural science and group processes.
[297] E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*.
[298] H. E. Anderson, *Learn, Earn & Return: My Life as a Computer Pioneer*, 1st ed. (Redding, CT: Locust Press, 2009).

Table 8 Timeline 1983 – 1998

Year	Technical	Personnel	Net income	Employees
1983	DEC releases VAXclusters	Gordon Bell (CTO), Andy Knowles (VP) and Avram Miller (Pro 350/80) leave	$283 million	73000
1984	DEC ships its 25,000th VAX	Eric Hustvedt (tech) and Julius Marcus (strategy) leave	$328 million	86000
1985	DEC first computer company to register an internet domain	Barry Folsom (PC and Rainbow) leaves to join SUN. First ever layoffs.	$446 million	89000
1986	DEC announces Local Area VAXclusters	Ken Olsen named 'Americas most successful entrepreneur'	$617 million	95000
1987	DEC ships 100,000th VAX system	Dick Berube (PR), Jeff Kalb (low end dev) left, Georges Doriot died	$1140 million	11100
1988	Prism cancelled	Dave Cutler (architect) left	$1306 million	122000
1989	VAX9000 released	Kevin Melia (VP materials) left	$1073 million	126000
1990	VLSI VAX6500 released	Jack Shields (executive comm) left	$74 million	124000
1991	DEC first to offer internet tunnelling	James Osterhof (CFO) and Dorothy Terrell (VAX9000) left	-$617 million	121000
1992	DEC announces the Alpha	Ken Olsen ousted by board. Robert Palmer appointed	-$2796 million	114000
1993	New VLSI facility built at Hudson for Alpha	Edward Lucente (VP sales) left	-$251 million	94000
1994	DEC reported 2.1 billion dollar loss. DEC sells database product to Oracle	Fred Traversi (decentralised decision making), Tracy Gibbons (organisational consulting) and William Steul (CFO) left, Win Hindle (VP quality and ethics)	-$2156 million	77800
1995	DEC sells disk and tape business to Quantum	Dirk Meyer (Alpha architect) left. Bruce Claflin appointed VP PC business	$122 million	61700
1996	DEC releases 64-bit version of UNIX	Jack Smith (Executive committee) and Enrico Pesatori (PC business) left	-$112 million	59100
1997	DEC starts work on first hard disk mp3 player	Irene Lang (VP) left and Charles Christ (VP) retired	$141 million	54900
1998	DEC sells semiconductor operations to Intel. Compaq buys DEC for $9.6 billion		$380 million (3 quarters)	

6 DEC – Causes of the Fall

Schumpeter's creative destruction theory proposes that something new kills something old and workers with obsolete skills should be laid off if a company is to survive. This does not take into consideration the fact that large corporations still have to maintain current and previous products for a number of years so cannot easily lay off staff with older skills. Christensen postulated that innovation was either sustaining or disruptive and suggested that disruptive innovation came from smaller leaner firms which did not have the commitment of a current product set. This chapter consider how DEC responded to the advent of the newer technologies and describes how its management was indecisive in its actions. We identify the decisive meeting that was critical to the company's eventual failure and the decisions that emanated from that meeting caused by the loss of its senior technologist, Bell. In the 1980s DEC was a company with diverse product lines which was hit by multiple disruptive innovations whilst in transition and confusion.

How was a company with multiple diverse product lines so severely affected by innovation? Christensen hypothesized that it was the advent of the PC that caused DEC to fail. This is strongly disputed partly because the company was in trouble before the PC became mainstream and also because the PC did not replace DECs dominance in the datacentre. As we suggested in chapter 2, dormant technologies played a large part in DECs failure along with emerging technologies.

It is argued in this chapter that DEC missed the next technology wave (1985-1990), which contributed to its decline. It was hit by two disruptive technologies in quick succession after its finances were depleted by the VAX9000. In the second half of the 1980s DEC found itself under attack in all of its marketplaces. IBM was targeting DECs midrange with the AS400, SUN was taking the workstation market and UNIX was penetrating DECs datacentre market when firms looked to save money by investing in low cost UNIX systems for their datacentres after the depression. DEC had invested in expensive ECL systems while CMOS was emerging as the new disruptive technology for the computer industry and it did not invest in RISC technology early enough.[299] It did invest in CMOS technology but only for its VAX range which was now quite old and was

[299] In the late 1980s, CMOS was emerging as the new technology for the computer industry, while mainframes were still using Emitter Coupled Logic (ECL). DEC had both technologies under development but continued with ECL for the VAX 9000, as CMOS was not ready when the development project was initiated. CMOS was a much cheaper solution and was available concurrently with the release of the VAX 9000.

starting to run out of power. Later DEC had a number of opportunities to catch the technology wave but missed them all in the late 1980s due to indecision in technical management. It is argued that DEC was also affected by the world's financial waves.

The following reasons behind DEC missing the wave will be considered along with a discussion on the PC:

- DEC continued investment in the VAX 9000 when it was late and obsolete technology. This meant that development funds were diverted from products that could have moved the company forward and excess personnel were hired to sell into the high end market.
- The company missed the rise of the RISC workstation and so was late into the market. Indecision caused it to change direction a number of times in its own RISC program creating delays and confusion.
- DEC ignored UNIX as a mainstream software alternative to VMS.

It will be shown that, in the early years, under Olsen, DEC was very conservative, preferring to develop technologies itself. Olsen and Strecker's arrogance in their belief that VAX/VMS was the best system for DEC and its customers led to a research and development environment that was biased towards VAX/VMS to the exclusion of MIPS and UNIX. It was the ethos of 'not invented here' that was an error in many of DEC's technical fields. DEC's belief that it was technically superior and had the best products for customers affected the company's RISC research. The company was however persuaded to use another company's chip before reverting to its own in-house development leading to confusion for its customers.[300]

6.1 *The Financial Wave*

DEC's fortunes can be linked to disruptive technology and the 'S-curve' but they can also be linked to the world's financial 'wave'. From the time that DEC was founded to the time that DEC was sold to Compaq, the world passed through

[300] Strecker's STF was populated by long term VAX/VMS people to the exclusion of others as detailed in Bob Glorioso's 'evolution of DEC, a personal perspective' document that he shared. In it he also describes the MIPS decision which ultimately led to the development of the Alpha. Strecker also wrote a rebuttal of RISC architecture versus VAX/CISC suggesting VAX was the better solution. "Comments on 'the Case for the Reduced Instruction Set Computer'," *ACM SIGARCH Computer Architecture News* 8, no. 6 (1980): 25-33.

four recessions and the US six, including one double-dip in the early 1980s. The data in Table 9 is from the National Bureau of Economic Research (NBER). The NBER is considered the official arbiter of recessions, but, to quote from its web site:

> The NBER does not define a recession in terms of two consecutive quarters of decline in real GDP. Rather, a recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales.[301]

Table 9: Recessions of DEC period.[302]

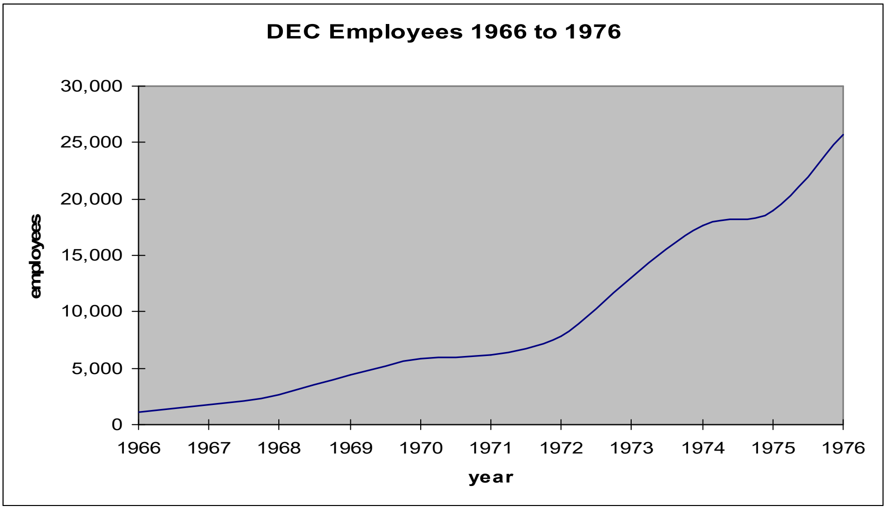
Date	Duration	Time since last recession	Peak unemployment
Aug. 1957-April 1958	8	39 months	7.5%
Apr. 1960-Feb. 1961	10	24 months	7.1%
Dec. 1969-Nov. 1970	11	106 months	6.1%
Nov. 1973-March 1975	16	36 months	9.0%
Jan. 1980-July 1980	6	58 months	7.8%
Jul. 1981-Nov. 1982	16	12 months	10.8%
Jul. 1990-March 1991	8	94 months	7.8%

Source: NBER

DEC suffered, like most other companies, in these recessions, but shielded its workers from redundancy by redeployment until the late 1980s, when economic circumstances and pressure from Wall Street forced it to resort to large-scale redundancies. In the 1970 and 1973 recessions, DEC reduced its hiring, stabilised its workforce and rode out the recession (Figure 9). The effect of the recessions on profit during this period is shown in Figure 10 and clearly demonstrates how the impact of the recessions affected growth.

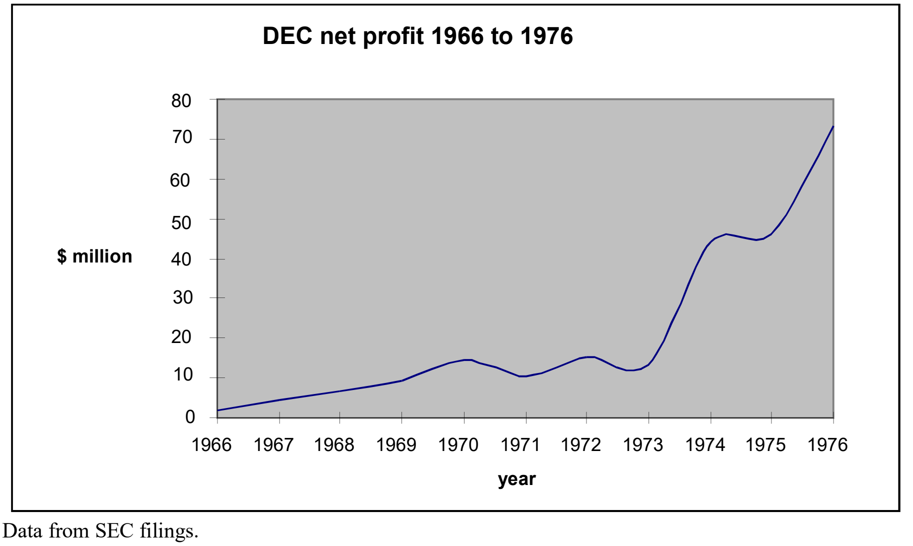
[301]National Bureau of Economic Research, http://www.nber.org/ (accessed July 6, 2015).
[302]National Bureau of Economic Research, http://www.nber.org/cycles/cyclesmain.html (accessed July 6, 2015).

Figure 9: DEC employees (1966–1976).



Data from SEC filings.

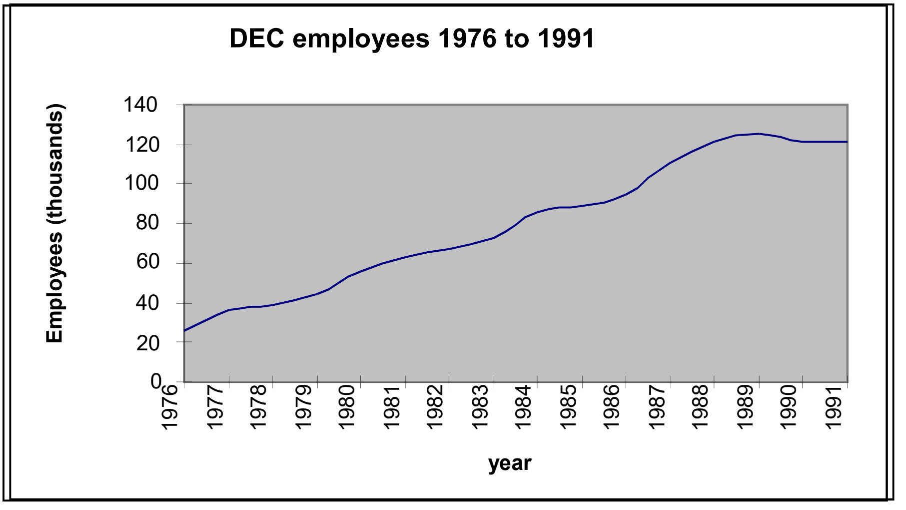
Figure 10: DEC net profit (1966-1976).



Data from SEC filings.

In the recession of the early 1980s, it appears that DEC did not apply the same restrictions on hiring as can be seen in Figure 11. This affected the company in 1983. Ken Olsen said in a speech to the Newcomen Society in 1982 that he had said publically '"DEC didn't need recessions to straighten us out", but that it wasn't true, recessions made DEC strong.'[303]

Figure 11: DEC employees (1976-1991).



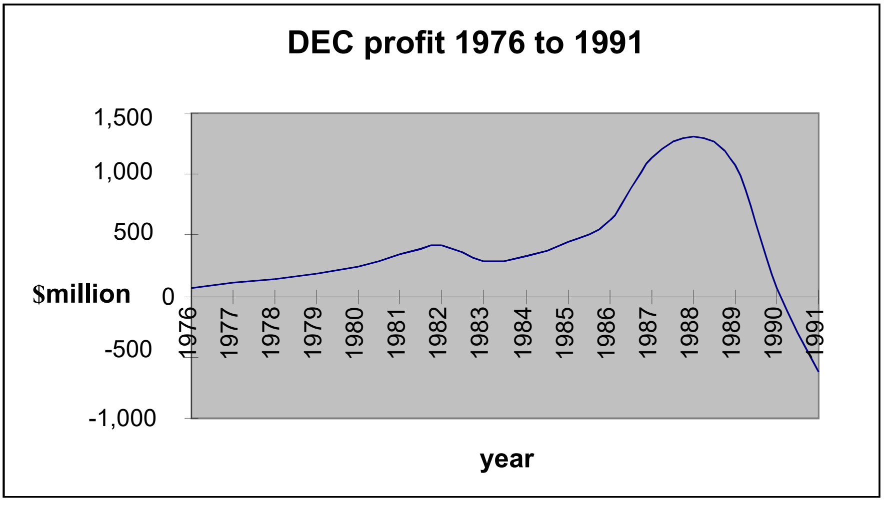
Data from SEC filings.

Again, this statement was true up until 1982 when no hiring freeze had been imposed and so expenditure grew and profits suffered for a number of years (Figures 12 and 13). In the mid-1980s, DEC was forced to reduce staff. The method it used is described in Allen and Morton, who conducted a study of employment security at DEC.[304] This was an example of how a firm could manage its workforce without enforced redundancies, thus maintaining its reputation for employment security. The major proportion of the reduction was in the manufacturing areas, primarily in the US. This was a forced reaction to the sudden decline in the stock market value of the company in 1983, when the value of the stock dropped by 29% in three weeks due to reporting problems within the company. DEC finally imposed a hiring freeze, retrained 4,000 new manufacturing personnel and only had to make 600 people redundant, as

[303] Olsen and Newcomen Society in North America., *Digital Equipment Corporation, the First Twenty-Five Years*, 16.
[304] T. J. Allen and M. S. Scott Morton, *Information Technology and the Corporation of the 1990s: Research Studies*, 499-516.

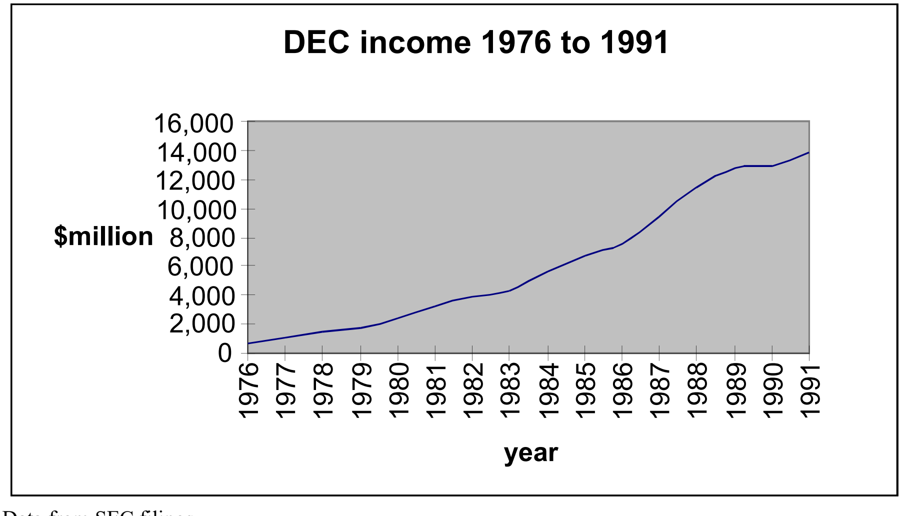
illustrated by Rifkin and Harrar.[305] All of this was undertaken over a three-year period from 1983.

Figure 12: DEC profit (1976-1991).



Data from SEC filings.

Figure 13: DEC income (1976-1991).



Data from SEC filings.

[305] G. Rifkin and G. Harrar, *The Ultimate Entrepreneur: The Story of Ken Olsen and Digital Equipment Corporation*, 275.

6.2 *The Technology Wave*

Christensen considered the S-curve and the challenge to identify and switch technologies when the point of inflection has been passed. He proposed that the engineering effort will increase as the product matures.[306] This is a factor that affects established companies more than start-ups and as the company's products diversify the engineering effort to maintain them all can become a millstone on the company. Modis states that: 'The projected life cycle of consumer products and the rate at which substitute products will gain market share is of vital interest to any company'. [307] He goes on to propose that 'Business, in the form of products, companies and entire industries, goes through five cycles which align with the S-curve'.

He suggests that the S-shaped curve also appears in other life cycles. For example, he states that:

- A product S-curve may typically have a life cycle of 6 quarters.
- A product family S-curve, consisting of a set of related products, will typically have a life cycle of around 5 years.
- Basic technologies or industry S-curves, consisting of a number of product families and associated companies, typically have a life cycle of approximately 15 years.

DEC followed these cycles successfully for many years. For product life cycles, it released a new major product almost every year from 1965, thus having overlapping S-curves. For family product lifecycles, it released the PDP-8 in 1965. The last model in the family was produced in 1979. There were 10 different models released in the 15 years. This heralded the start of affordable computing. Bell and de Castro are credited as being the main designers of the PDP-8. Five years later in 1970 DEC followed it with the PDP-11; the last product in the family was released in 1990. The PDP-11 family, excluding the 32-bit extensions, consisted of at least 23 models and was the leader in the minicomputer market for many years.

In 1975 DEC released the 11/70, this was meant to be a stop-gap machine, with 1000 planned. Eventually 10,000 were sold. Then, in 1977 the VAX 11/780, DEC's first 32-bit machine, was released. In 1984 the VAX 8600 appeared, in 1990 it released the VAX 9000 and finally in 1992 DEC released the 64-bit

[306] C. M. Christensen, 'The Innovator's Dilemma', 44

[307] T. Modis, *Summary: Conquering Uncertainty*, ed. Must Read Summaries, Kindle ed. (Amazon Digital Services Inc, 2012), 1.

Alpha family, fifteen years after the VAX 11/780. By the time DEC was taken over by Compaq, the VAX family consisted of around 135 models with the final VAX, in the Alpha range, being manufactured in 2005. These cycles fed DEC's considerable growth over the years. But by investing heavily in the VAX 9000 and not RISC technology until later, DEC missed the next wave, lost ground to its competitors and reduced the cash available for research. It allowed other companies to encroach on its traditional sales space whilst it tried to move up the power curve to challenge IBM's customers.

Modis first applied his S-curve theory to the VAX-11/750 in 1985 whilst working for DEC. He correctly predicted the peak for sales and the decline, a prediction which was not accepted by the DEC marketing community until it was proven.[308] Christensen looked at technology S-curves and asked how value networks and the concept of S-curves relate to each other?[309] He postulates that disruptive technology does not fall into the normal S-curve, as it gets its commercial start in emerging value networks before invading established networks. Clearly, DEC had disruptive technology with its minicomputer products, taking the mainframe makers by surprise and creating a new market for its product. However, in the 1970s Data General brought a system to market very quickly and forced DEC to respond to this threat with their successful PDP-11 range.

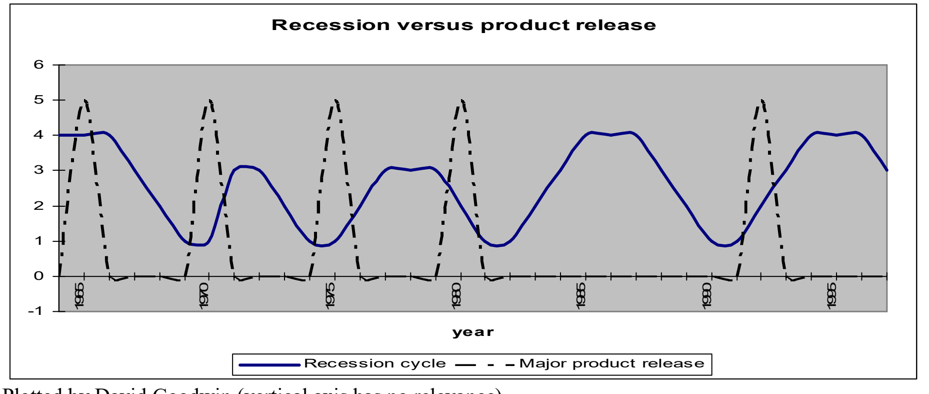
In this instance it was Data General who had the disruptive technology that forced a reaction from DEC. De Castro had worked on the design of the PDP-8 and was working on the next system, codenamed PDP-X, which was to be DEC's 16-bit offering. When he left to start Data General, his name was effectively wiped from DEC's official histories. The Data General story is related in Kidder's book.[310] Rifkin suggests that the team which left to form Data General were working on the design of the new company and the Nova design whilst at DEC; Olsen is quoted as saying that DEC had a copy of their log of what they were doing for their last two years at DEC, although he did not pursue a lawsuit.[311]

With regard to base technologies, DEC had overlapping S-curves, starting with the PDP-8 family in 1965 with transistor logic and the PDP-11 family in 1970 using integrated circuits. The VAX 11/780 was released in late 1977 using LSI

[308] T. Modis, *Predictions – 10 Years Later*, 2 ed. (Growth Dynamics, 2002).
[309] C. M. Christensen, *The Innovator's Dilemma: The Revolutionary National Bestseller That Changed the Way We Do Business*.
[310] T. Kidder, *The Soul of a New Machine*, 1st ed. (Boston: Little, Brown, 1981).
[311] G. Rifkin and G. Harrar, *The Ultimate Entrepreneur: The Story of Ken Olsen and Digital Equipment Corporation*, 94-96.

and the Alpha in 1992 incorporating VLSI. This was fine when there were base technology overlaps, but the Alpha was released over fourteen years after the VAX 11/780 and so at the limit of the S-curve, thereby creating problems for DEC in the area of uptake. This is graphically demonstrated in Figures 14 and 14, which shows the gap in major product release during the 1980s. The effect of this was hidden from the company by the profitable sales of the VAX and the sustained economic climate of the 1980s. When the recession arrived, it affected DEC badly, especially as the VAX 9000 was around two years late and released when the recession was at its worst, resulting in poor sales that did not meet the forecast.

Figure 14: Recession versus major product release.



Plotted by David Goodwin (vertical axis has no relevance).

Asthana considers S-curves in relation to disk drive technology and comments that the moving technology target is a phenomenon that needs careful S-curve analysis.[312] Again, this had a serious impact on DEC in the early 1990s, when a major development program should have put it in a leadership position in disk technology. However, it took the company so long to achieve an acceptable mean time between the failure rates of its first thin-film technology disk drive, the RA90, that the competition had released smaller, cheaper disks. This was one of the largest development projects in the company's history at the time and included a number of new technologies in the one product. DEC made a similar error in the VAX 9000 design, where it again introduced three new technologies at once which caused delays in product shipment.

DEC missed two disruptive technologies in the 1980s that could have kept it on the next S-curve. The company failed to take advantage of the advent of the

[312] P. Asthana, "Jumping the Technology S-Curve."

workstation and RISC technology by focussing on the IBM market and expecting that the VAX 9000 would be a rival for IBM. This allowed SUN, amongst others, to capture what was once DEC's traditional market. DEC realised very late how important the workstation market was and established a workstation engineering group in Palo Alto, California. This forced the company to use a third party chip from MIPS to challenge the competition and to cancel its own in-house project for a RISC chip codenamed PRISM (Parallel Reduced Instruction Set Machine). The MIPS processor gave DEC a successful workstation and market share, but success was short lived. DEC management decided that an in-house chip was the company's future and started the Alpha project. However, by the time Alpha was ready other companies had been shipping RISC based systems for a number of years. Systems from SUN (SPARC), IBM (PowerPC) and HP (PA_RISC) had gained considerable market share which DEC found difficult to counter.

The other disruptive technology was the personal computer which DEC, along with many other computer firms at the time, failed to recognise as a threat to its business.[313] DEC was in a position to compete with the IBM PC using its PDP-11 chipset had it recognised that the PC was aimed at a mass market.[314] DEC tried to create three products to compete in the marketplace, when one could have given it a lead. It set up three competing groups to build a PC, the Rainbow, running DOS and CP/M, a proprietary system based on the PDP-11 chipset, the Professional, and a word processing system based on the PDP-8 chip. The groups did not appear to know of each other's existence and did not use industry standard parts and so the systems were not compatible with each other or with the IBM PC standard.[315] The sales force were confused as to which was the PC competitor and missed sales of the Rainbow PC by putting the Professional forward as DEC's main offering.

Bower and Christensen depict DEC as missing almost completely the disruptive technology of the personal computer.[316] They blame 'arrogance … tired executive blood, poor planning' and, strangely, 'staying close to their customer'. Many however contend that DEC was not in a position to take on the PC market as their processes were aligned to medium volume, high margin products and not

[313] For example, HP rejected Steve Wozniak's offer of the first Apple PC http://www.foundersatwork.com/steve-wozniak.html (accessed July 6, 2015).
[314] Olsen called the PC effort KO but wanted a polished system and delayed the introduction with his requirements such as a streamlined VDU and the layout of the case as commented on by Avram Miller.
[315] Telephone interview by Goodwin with Avram Miller, DEC PC program manager, March 19, 2009.
[316] J. L. Bower and C. M. Christensen, "Disruptive Technologies: Riding the Wave."

the high volume, low margin market. Miller, when interviewed, did not believe that missing the PC wave had any influence on its demise.[317] Had the company recognised the workstation market then there might not have been a crisis of confidence a few years later. The UNIX workstation was DEC's main competitor during the 1980s not the PC. The PC only became a competitor to DEC when Microsoft released a version of Windows NT that enabled customers to take advantage of the client server capabilities.

In the mid-1990s, there were two other disruptive technologies with which DEC might have led lead the market, had the company been focussing on building for growth rather than fighting for survival. The first was fast networks linked to the requirements of the Internet, where DEC was in a lead position in gigabit technology. Palmer sold off the network business in 1997 to concentrate on 'core' products, considering the investment in R&D too great. The second was the Internet and all that that brought. DEC was the leader in Internet business, forming an Internet business unit under Rose Ann Giordano and creating some excellent products, such as AltaVista.

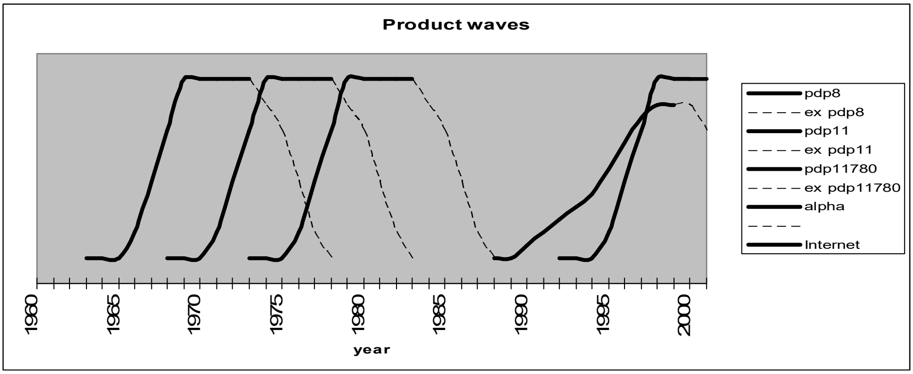
The final disruptive technology that had an impact on DEC was Microsoft's Windows NT which grew to take the datacentre software market from DEC. It was DECs mishandling of its RISC research that enabled Microsoft to develop Windows NT as will be shown.

DEC, according to staff interviewed, was aware of the 'wave'; DEC management was always talking about 'riding the wave'. However, as Figure 15 shows graphically, it missed the wave of the 1980s. The Alpha S-curve was late in starting and DEC was unable to get back on track until the Internet wave of the mid-1990s. Unfortunately, by this time the board had removed the CEO, installing someone who failed to understand the potential of the Internet and who was in the process of finding a merger partner or a buyer for the company.

It is clear that in 1997 DEC had once again got back onto the S-curve and was well placed to ride the next wave with AltaVista. AltaVista was the first successful Internet search engine. It was created in DEC's Western Research Laboratory by Louis Monier as a way to demonstrate the power of the Alpha processor and had already established the Alpha as a force with Internet business suppliers such as Amazon, because of its power. This was mainly on UNIX based systems, however, rather than VMS, and DEC still believed that VMS was its main offering.

[317] Avram Miller telephone interview, March 19, 2009.

Figure 15: New product 'waves'.



Plotted by David Goodwin (vertical axis is not relevant).

Products at the time tended to take five years in test and development and so nobody noticed that the market was changing and that DEC was not preparing for the next wave. However, development times were coming down from five years to one year or less, but DEC's structure and the VAX architecture did not allow for rapid development of systems.

6.3 *VAX 9000*

As a result of DEC's decision to target IBM customers the company began work on its next large machine, the VAX 9000. This was an ECL based system that was meant to propel them into the high-end business market. However an overambitious development using untested technologies led to delays and by the time it was shipped the CMOS VAX 6000 systems were available delivering a similar power at a fraction of the cost. The VAX 9000 shipped to customers in October 1989 but was retired soon afterwards.

The VAX 9000 was arguably a major contributor to DEC's problems by diverting research and development funds from other projects as well as engineering staff. The VAX 9000 project began in the summer of 1983 with the goal of developing a VAX mainframe to compete in the IBM market and move the company into the transaction processing market.[318] The VAX 9000 was DEC's most complex projects ever. It was to be a water-cooled ECL design. Prior to the VAX 9000 project, DEC had, as was their normal process, two parallel developments teams working on high end systems. One the DEC-10 team in Marlborough, and the other the VAX team in Maynard, both in the

[318] "VAX 9000 series", *Digital Technical Journal*, volume 2, no. 4, 1990, 11.

company's home state of Massachusetts. These developments were expensive and divisive in terms of engineering rivalry within the company, as well as management rivalry. Eventually the Marlborough effort was terminated. According to Glorioso the Marlborough team were considered outsiders by central engineering and suffered at the hands of the STF with many of their projects being cancelled. Most of the DEC-10 team, including Glorioso, were moved to assist the development of the VAX 8600 which was in trouble. Glorioso's team were almost disbanded when the VAX 8600 was launched.[319] Personal intervention from Olsen reprieved the team and they went on to successfully develop the VAX 8650, and then moved on to work on the VAX 9000.[320] Glorioso was the engineering manager of the VAX 9000 group.

In 1980, on the advice of Bell, DEC had taken a stake in Trilogy, which was attempting to use wafer scale integration to build an IBM-compatible system.[321] When Trilogy's technology failed, DEC invested a further $10 million to use Trilogy's interconnect and cooling technologies. These were to be used in DEC's next major system, the VAX 9000. According to Glorioso, DEC had problems with Trilogy's technology implementing multilayer chips and eventually created a newer and better multichip interconnect. The new planar logic packaging that was developed meant that the cooling technology designed for the VAX 9000 was superseded and thus obsolete.[322] The issues with Trilogy's technology were the main cause of delays in the development cycle of the VAX 9000. The project team reportedly found that technology changes affected their design process on a number of occasions leading to an extended development time.[323] However the VAX 9000 team also incorporated many RISC techniques and redesigned the VAX instructions into small, simple tasks to enable better pipelining in their design. These techniques were then utilised by the NVAX team and implemented in their product.[324]

According to Bell, the VAX 9000 cost between $3 and $6 billion to develop and only generated a maximum of $1 billion in sales.[325] Others put the cost between

---

[319] Personal communication to Goodwin from Bob Glorioso April 2, 2013: subject DEC.
[320] Personal communication to Goodwin from Bob Glorioso January 23, 2008: subject DEC.
[321] Gordon Bell, interviewed by David K. Allison, April 1995, Smithsonian Oral Interview, National Museum of American History, http://americanhistory.si.edu/comphist/bell.htm The VAX 9000: One ECL computer too many. (accessed July 6, 2015).
[322] VAX 9000 series, *Digital Technical Journal,* volume 2, no. 4, 1990, 11.
[323] Ibid.
[324] NVAX microprocessor, *Digital Technical Journal,* volume 4, no. 3, 1992, 9.
[325] G. Hendrie, "Oral History of Gordon Bell,", June 23, 2005. Computer History Museum, CHM Reference Number: X3202.2006.
http://archive.computerhistory.org/resources/text/Oral_History/Bell_Gordon_1/102702036.05.01.pdf (accessed July 6, 2015).

$2 and $4 billion. This represented 33% to 66% of DEC's R&D budget for the five years. This, together with the increased staff employed to compete in the IBM market space, had severe ramifications on DEC's cash flow and bottom line.

Glorioso had been tasked, together with Rose Ann Giordano, with attacking the commercial and transaction processing market that IBM held.[326] Glorioso suggested that he needed an enterprise UNIX on the system to allow a sale of 750 machines to the scientific community, including AT&T, which would have helped pay for much of the development.[327] Others, when interviewed, questioned whether these potential sales could have been realised. Glorioso went on to say he had commissioned the UNIX team at DEC to build a commercial UNIX for the system, but they spent the money elsewhere and only came up with a version that supported 256Mb memory. He suggested that the atmosphere at DEC was 'toxic' from 1987 to the early 1990s, with managers 'cutting each other's throats and ignoring customers'. He also said that his customers were constantly asking for UNIX, but Jack Smith's staff were unable to make a decision to invest. Glorioso suggested that Strecker's group did not deliver the suite of software to support the commercial market, even though, he said, Strecker had announced it.[328] Glorioso put this down to the STF wanting to undermine the ex-DEC-10 personnel.[329] Because of the delays, sales of the VAX 9000 were also hampered by the world recession, which meant that companies were not investing in hardware.

The Strategic Task Force concluded, on many occasions, that the VAX 9000 system should not be continued as there was, in their opinion, no way of selling enough systems to recover the investment.[330] Olsen constantly overruled the STF's proposal to scrap the system.[331] Glorioso suggested that he had to present the VAX 9000 to the Executive Committee almost monthly and at every other BOD meeting including the last BOD meeting at Doriot's home just before he died. There were not only internal doubts about the viability of the VAX 9000. Industry analysts on Wall Street also concluded that the market for large mainframes was dead.[332] According to *Business Week*, Wall Street analysts had initially predicted that sales of the VAX 9000 would hit $2 billion per year at a

[326] Glorioso at the time was DEC VP for the Information Systems Business.
[327] Personal communication to Goodwin from Bob Glorioso January 23, 2008: subject DEC.
[328] Also in Glorioso's communication of January 23, 2008.
[329] Personal communication to Goodwin from Bob Glorioso April 2, 2013: subject DEC.
[330] This was an opinion held by many in DEC, and expressed during interviews and feedback via e-mail.
[331] Also in Glorioso's communication of April 2, 2013.
[332] A. Khurana, "Marketing Strategy of Digital Equipment Corporation", *Management Paradise*, December 10, 2010.

margin of 65% that would have soon recouped development costs.[333] However, it was almost three years late according to some (Glorioso suggested that it was only one year late) and, in October 1989, came at a time when there was a recession beginning and consequently sales fell quarter by quarter, resulting in a projected revenue of only $450 million in 1991.

DEC's normal design period at the time was five years and so the release date for the VAX 9000 was expected to be 1988. However, the first customer shipment was in late 1989 but on-going technical issues resulted in volume shipments being delayed until early 1991. Technical and production issues also affected field readiness training. The first support training course for EMEA, held in Galway in March 1990, was conducted without the availability of a system for the engineers; all that was available was the battery backup cabinet.[334] The average sales price also dropped from $1.5 million to $1.2 million when DEC reduced the price to try to encourage more sales. Eventually DEC quietly took most of the machines back from the customers.[335]

The failure of the VAX 9000 is seen differently by various people interviewed. Glorioso believes it could have been successful if he had had the software support when launched; others believe it had no chance of being profitable. This led to bitter discussions between Glorioso and Demmer. However, the VAX 9000 was said to have the fastest vector processor at the time and continued to hold the lead for four more years.[336]

In fiscal year 1988, DEC had its best ever year, with record sales. However, this was the year of the stock market crash and recession in the US and Europe. Technology was changing and CMOS was about to overtake ECL. Olsen was heard to say 'Do you mean we have spent billions on the VAX 9000 and the NVAX is just as fast?'[337] Olsen was unable to see the next wave of technology that was moving rapidly into DEC's territory. The NVAX utilised much of the

[333] "The Big Engine that Hasn't," *Business Week*, June 23, 1991. http://www.businessweek.com/stories/1991-06-23/the-big-engine-that-hasnt (accessed July 6, 2015).
[334] The first training course in EMEA was in held at DEC's manufacturing plant in Galway, Ireland in March 1990. Attended by Goodwin.
[335] As suggested by Dave Cutler in a personal interview in Bellevue, Washington, USA, October 5, 2010.
[336] Personal communication from Bob Glorioso, January 23, 2008. Subject: DEC.
[337] D. Bernstein et al., "NVAX and NVAX+: Single-Chip Cmos Vax Microprocessors" (paper presented at the International Conference on Computer Design: VLSI in Computers and Processors, 11-14 October, 1992).They write that the NVAX was a single-chip microprocessor that implemented the VAX architecture. Pipelining techniques that have traditionally been associated with RISC CPUs are used to greatly improve the performance of these chips over previous VAX microprocessors. The NVAX is described in the *Digital Technical Journal* volume 4, no. 3, 1992. http://www.dtjcd.vmsresource.org.uk/pdfs/dtj_v04-03_1992.pdf (accessed July 6, 2015).

design work that went into the VAX 9000 but was implemented in CMOS technology. The NVAX taped out in November 1990 and shipped to customers in October 1991, severely curtailing any potential sales of the VAX 9000.[338] Had DEC cancelled the VAX 9000 a few years earlier when it was clear that it would not recoup the investment, redeployed the resources on the NVAX development, the NVAX could have been brought to market earlier and would have sold in place of the VAX 9000.

It is argued in this thesis that the VAX 9000 cost DEC dearly in finance and reputation. However, it could be argued that had DEC delivered on time then the VAX 9000 could have opened up the mainframe market for DEC, certainly in markets where vector processing was important. The delays were because of over ambition in terms of technologies and it is suggested that using more proven technology might well have delivered the system on time. This is an example of overambitious technology plans leading to missed opportunities and subsequent market failure. DEC was not the only company caught out by the rise of CMOS. MIPS, among others, were still working with ECL in the early 1990s.[339]

Many companies have failed when targeting the IBM marketplace with IBM retaliating with its own product set.[340] DEC however failed, not due to any retaliation from IBM who was experiencing its own problems at the time. The VAX 9000 hit DEC's bottom line, using scarce resources when there was a recession. It cost in terms of development funds and also salaries for the volume of salespeople hired in anticipation.

6.4 *DEC's RISC programme*

This section positions DECs RISC developments within the context of the wider industry and describes the confusion within the company as the engineers worked on RISC systems and management keep altering strategy and cancelling projects. It is therefore argued that another of the major causes of DEC's failure to remain on the S-curve was the debacle over its RISC strategy. The executive had a meeting at this time when it decided its RISC future. At this meeting they took a decision to go with a MIPS processor and sowed the seed of confusion within its customer base. During the 1983 period, DEC fell into disarray over its

[338] "NVAX microprocessor", *Digital Technical Journal,* volume 4, no. 3, 1992, 10. Taped out is the conclusion of the design cycle of an integrated circuit prior to manufacture.
[339] MIPS tried to implement the R4000 in ECL in 1991; Data General tried to implement an ECL 88000 in its AViiON in 1989; Convex were still using GaAs in its C3 and C4 systems into the early 1990s to try to stay ahead of CMOS.
[340] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, 2nd ed., 114. Antitrust proceedings were instigated in the US in 1969 against IBM.

RISC strategy and direction. Bell had predicted the rise of semiconductor technology and indicated that he 'would never have let the VAX 9000 proceed'.[341] In an interview in *Computer World* in 1987, Bell was asked about the VAX and what he saw as the next generation; he responded with a very prophetic comment.[342] He said that if he was still at DEC he would have selected VAX 2 architecture by 1986 for delivery in 1988 and this would probably be a RISC machine. Bell went on to author a paper with Strecker on lessons from the PDP-11, VAX and Alpha, in which they suggest that DEC lost control of its strategy in the 1980s with too many internal processor technology projects locking the company in 'internecine warfare' and that the Alpha strategy was late.[343] They summarise the situation as follows:

> VAX, driven by its initial design goals and constraints, was a complex architecture and was particularly challenged by the RISC concept that competitively emerged in the mid-1980s. DEC's internal situation in the second half of the 1980s made it impossible to achieve a timely, rational response to the RISC challenge.

In the 1980s DEC had many large projects running that were eventually cancelled without making it into production. Amongst them were:[344]

- Jupiter
- Argonaut
- PRISM
- And many other RISC projects

All of these cost the company time, investment and eventually delayed development of new products.

---

341 Bell published a graph showing the rise and fall of semiconductor technologies. This showed CMOS overtaking ECL in performance around 1990, making the VAX 9000 obsolete. Slide 59 of the presentation.
http://research.microsoft.com/en-us/um/people/gbell/Digital/Minicomputers_The_DEC_aka_Digital_Story.ppt
(accessed: July 6, 2015). Other companies, such as IBM and Cray, also failed to recognise the rise of CMOS.

342 Computerworld Extra, Computerworld, Sep 2, 1987, "A conversation with Gordon Bell".
http://archive.computerhistory.org/resources/text/DEC/dec.bell.beyond_vax_a_conversation_with_gordon_bell.1987.102630347.pdf (accessed July 6, 2015).

343 G. Bell and W. D. Strecker, "Retrospective:What Have We Learned from the PDP-11; What Have We Learned from Vax and Alpha," in *ISCA '98 25 years of the International Symposia on Computer Architecture* (ACM, 1998). The Alpha was DEC's own RISC processor and will be discussed in chapter 6.

344 Argonaut was the next mid-range ECL VAX under development while the VAX 9000 (Aquarius) was being developed. PRISM was the project under which Dave Cutler was developing DEC's RISC architecture in the 1980s.

Finally, in an oral history interview by the Smithsonian Institute, Bell states that:[345]

> If I'd stayed, I believe DEC would have prospered. I would not have let it flip flop in architecture, build the ECL 9000, or fail to be a PC supplier. Not capitalising on its technology to: be a network equipment supplier, be the dominant supplier of web servers, or exploit AltaVista are equal boners.

The VAX 9000 development had impacted DEC's research and development budget for much of the 1980s restricting the funds available for the development of other products.[346] The company had maintained its CMOS program, developing the NVAX chip for its next generation of minicomputers but this still lagged behind the RISC workstations that were being developed by DEC's competition. DEC's RISC development was hampered by the lack of development funds as well as the disarray in its direction.

In the 1960s and 1970s, DEC was full of engineers and managers in their twenties and thirties, dynamic and enthusiastic. By the 1980s, many of these engineers and managers had aged and DEC's business had moved from the environment where the customer was technically astute to one where it was selling into business areas where the customer was not as computer literate as those in the early days. At the same time, in the West Coast around Palo Alto, many companies were starting up with dynamic products, young employees and rapid development times. DEC did not realise the danger of ignoring these new companies and consequently lost their advantage in the developing workstation market, primarily to SUN.[347]

RISC technology in the 1980s came from Berkeley and Stanford, with the main developers being Patterson and Hennessy. Both Patterson and Hennessy spent time at DEC, according to their oral histories. Hennessy worked with Cutler on the MicroVAX I chipset.[348] The following paragraph is a summary of Patterson's oral history.[349]

---

[345] Oral History Interview with Gordon Bell, Interviewer: David K. Allison, Curator, Division of Information Technology and Society, National Museum of American History, Smithsonian Institution, Date of Interview: April 1995. http://americanhistory.si.edu/comphist/bell.htm (accessed July 6, 2015).
[346] E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 216.
[347] SUN grew rapidly to dominate the UNIX workstation market, being the number-one supplier of technical workstations in 1987. Karen Southwick, *High Noon: The Inside Story of Scott Mcnealy and the Rise of Sun Microsystems* (New York: John Wiley, 1999) 66.
[348] John Hennessy, Oral History, Computer History Museum, Ref x4149.2008.
[349] David Patterson, Oral History, Computer History Museum, Ref x4150.2008.

Patterson had been invited by Sam Fuller to spend some time at DEC in 1979 researching microprogramming on the VAX. As a result, he wrote a paper on RISC using VLSI, in which he determined that complex microcode with many bugs was not the way to design computers. The IEEE rejected the paper and this saw the birth of the RISC project at Berkeley. Patterson said that the 'VAX was their competition as VAX was the way computers were heading'. Patterson's paper, written with Dave Ditzel, was sent to Doug Clark at DEC.[350] Clark and wrote a rebuttal which started a discussion on RISC and so indirectly gave it the attention it needed to go forward.[351] This in turn led to SUN approaching Patterson to help build their RISC chip. While there, he advised them to drop their implementation, use the MIPS chip instead and implement the same instruction set. However, this was rejected by SUN, as it did not appreciate the MIPS business model.

There was some dissention at DEC on RISC as a strategy, as illustrated in Strecker and Clark's paper. This might explain the disarray in DEC during the 1980s concerning its RISC research, when Strecker took over from Bell as DEC's chief strategist. Olsen also suggested that RISC technology was irrelevant, in a cover story of *Business Week* May 16th 1988, stating that 'it would be several years before the software existed to make RISC machines as useful to customers as the VAX is now and the network was the system'.[352] Forest Baskett was teaching computer science at Stanford and was Hennessy's mentor during his MIPS research project, which was supported by DARPA. Baskett left Stanford in 1982 to start and direct DEC's Western Research Laboratory; he left in 1986 to join SGI. Hennessy presented a paper to the third CalTech conference in 1983, co-authored with, amongst others, Norman P. Jouppi who was one of the principle architects of Stanford's MIPS processor. Jouppi joined DEC's Western Research Laboratory in 1984 and worked on Micro-Titan, Multi-Titan and BIPS.[353]

[350] D.A. Patterson and D. R. Ditzel, "The Case for the Reduced Instruction Set Computer," *ACM SIGARCH Computer Architecture News* 8, no. 6 (1980): 34-38.
[351] William D. Strecker and Douglas W. Clark, "Comments on 'the Case for the Reduced Instruction Set Computer'," *ACM SIGARCH Computer Architecture News* 8, no. 6 (1980): 25-33.
[352] Photocopy of article supplied to Goodwin by Don Gaubatz, not available in *Business Week* archives, which are only online from 1991.
[353] The Titan project was one of DEC's RISC projects at its Western Research Laboratory in Palo Alto. Begun in 1982, it was cancelled when Dave Cutler took over DEC's RISC program in 1985. Titan is defined in Western Research Labs technical note TN-29 and TN-32 http://www.hpl.hp.com/techreports/Compaq-DEC/WRL-TN-32.pdf and http://www.hpl.hp.com/techreports/Compaq-DEC/WRL-TN-29.pdf (accessed July 6, 2015): BIPS was a single chip ECL microprocessor with a 1ns cycle time

In the early 1980s, Bell recognised that RISC was an important technology and realised that it had a future in the industry. DEC had collaborated with Patterson at Berkeley and the MIPS founders had worked with DEC at their Western Research Laboratory, where a number of DEC engineers were involved in the initial design of the MIPS chip. As was DEC's norm, internally it had four different teams working on four different RISC processors across the country.

Bell was the strategist when DEC began work on RISC processors, but when he left, he counselled Hennessy and Mashey to take their RISC work forward by starting a company and he suggested that Edward P. Stritter should be approached.[354] Hennessy had previously worked at DEC with Cutler on the MicroVAX I and knew of DEC's Titan work. Patterson went back to DEC's Western Research Laboratory in 1990 to write his book with John Hennessy.[355] This was not the end of Bell's involvement with RISC technology. In an article for *Datamation*, he assessed RISC technology and compared it with CISC, concluding that the goal of RISC is 'to make a simple hard-wired processor to carry as many functions as possible with software.'[356] He was at the time the chief scientist of DANA Group, which was designing a personal supercomputer using a RISC chip.

In 1982, DEC began a number of projects to develop RISC processors. According to Bob Supnik, the first was SAFE, a 64-bit design by Alan Kotok.[357] This was an effort by the Large Computer Group and, according to Supnik, it was supposed to run an operating system similar to VMS, but it was only a paper study and he suggested that it had no direct bearing on future development. However, Glorioso talks of the SAFE project in his paper, where he recalls that SAFE was started by Alan Kotok, Dave Orbits and Maurice Wilkes.[358] Wilkes had retired from Cambridge University and had gone to work for DEC from 1980 to 1986. He suggested that SAFE led to Titan. Titan was a system being developed at DEC's Western Research Laboratory in Palo Alto led by Neilsen, Goldberg and Leonard. This was an ECL based system and ran UNIX. The Titan project began in April 1982 and had a logic simulation by March 1983. CPU, memory and I/O were working by June 1985 and a complete system running UNIX was ready in December 1985. There were a few customer shipments

---

[354] John Hennessy Oral History, Computer History Museum, REF x4149.2008; M. S. Malone, *Going Public: MIPS Computer and the Entrepreneurial Dream*, 1st ed. (New York, NY: E. Burlingame Books, 1991).
[355] D. A. Patterson, J. L. Hennessy, and D. Goldberg, *Computer Architecture: A Quantitative Approach* (San Mateo, Calif.: Morgan Kaufman Publishers, 1990).
[356] C G. Bell, "RISC: Back to the Future?," *Datamation* 32, no. 11 (1986): 106.
[357] Personal communication from Bob Supnik December 10, 2010; Subject: DEC History.
[358] B. Glorioso, "The Evolution of DEC: A personal perspective", personal communication to Goodwin, January 25, 2008.

before it was cancelled and a Multi-Titan system was described to the ACM in 1989.[359] According to Supnik, this was a 'big-endian', word addressable system and again he suggested that it had no influence on future developments.[360] However, it was compared with a VAX 8800 and demonstrated that RISC architecture outperformed the VAX architecture by 2:1, using the same technology.[361]

This convinced the internal sceptics that RISC was a valid technology. Cutler said of the Titan project: 'The research group at the Western Research Laboratory in Palo Alto designed and built a research version of Titan with off the shelf logic.[362] A group in Maynard began a project to productise the Titan. When they went to the research group for help they were effectively told: 'we don't do productisation, only research'. Cutler also added that if the Titan had ever been produced it would not have been economically viable; it was completely incompatible with VAX and the researchers were proud of that fact. This is probably linked to their background in West Coast America and the emphasis on UNIX in the area. Fuller and Baskett's group in California was remotely managed by Glorioso who has stated that, when their work was cancelled, many of the group left to form the core of MIPS development at SGI and other Silicon Valley firms, in direct competition with DEC.[363]

In 1984, the DEC Hudson engineers Rich Weitek and Dan Dobberpuhl began work on HR-32, a CMOS RISC processor.[364] Dobberpuhl had presented a paper on fundamental issues in the electrical design of VLSI circuits to the same CalTech conference where Hennessy had presented his paper on the MIPS work, so he would have been aware of Hennessy's work.[365] Norman Jouppi was working on Micro-Titan in DEC Semiconductor (an ECL microprocessor) and Cutler began work on CASCADE (a TTL RISC processor) at DECwest in Bellevue. Jouppi co-authored the paper that Hennessy presented. According to

---

359 Titan manuals are still available for reference on the HP web site. http://www.hpl.hp.com/techreports/Compaq-DEC/WRL-86-1 . WRL-87-8 and WRL-89-9, (accessed July 6, 2015).

360 Big-endian and little-endian refers to the byte significance of multi-byte words in a computer system. In big-endian systems the most significant byte is stored in the lowest address whereas in the little-endian system the least significant byte is stored in the lowest address.

361 Personal communication to Goodwin from Supnik, December 10, 2010; Subject: DEC history.

362 Interview with Dave Cutler in Bellvue, Washington, October 5, 2010.

363 Personal communication from Glorioso, January 23, 2008; Subject: DEC.

364 Rich Weitek worked on VAX, Alpha and StrongARM at DEC and then on PowerPC at Apple. He is now working for Microsoft.

365 J. L. Hennessy et al., "Design of a High Performance Very Large Scale Intergration Processor," in *Third Caltech Conference on Very Large Scale Intergration*, ed. R. Bryant (Pasadena, California: Springer-Verlag, March 1983). D. W. Dobberpuhl, "Fundamental Issues in the Electrical Design of Very Large Scale Integration Circuits," in *Third Caltech Conference on Very Large Scale Integration*, ed. R. Bryant (Pasadena, California: Springer-Verlag, March 1983).

Supnik, SAFE progressed no further than paper studies.[366] None were taken seriously by DEC and they did not receive the funding or manpower resources for adequate development.

Mashey considers RISC instructions and compares the complexity of the compilers with the CISC implementations, examining the many different techniques that are important to the performance of RISC.[367] He suggests that 1986 would be the defining year for RISC systems and concludes that RISC and UNIX have no technical connection, but are closely related in commercial practice. This has been quite prophetic as most RISC systems were sold with UNIX as their operating system.

Having seen its low end sales being eroded, DEC belatedly realised that it needed a serious effort for their RISC strategy and in 1985 Jack Smith named Cutler to lead the project.[368] Cutler cancelled all of the various RISC projects, combined many of the engineers into one development group (with Rich Weitek as chief architect) and the PRISM project was born. The group at DEC's Western Research Laboratory (WRL) in Palo Alto were left isolated from DEC's RISC development, but, as will be shown later, they did influence DEC's RISC programme in a major way. DECwest worked on a high-end ECL implementation called CRYSTAL and the semiconductor group in Hudson, Massachusetts worked on a CMOS version called MicroPRISM.[369] Cutler meanwhile worked on the operating system, Mica, which was a microkernel on top of which both UNIX and VMS were supposed to be able to operate. PRISM was to provide the follow on architecture to the VAX and take DEC into the next few decades.

The plan in 1987 was to supply compute servers, the Glacier range, database servers, the Cheyenne range and workstation products.[370] Glacier was expected to be available in March 1990; Cheyenne was expected to be available in Q2 FY91 and was aimed at IBM and Tandem markets. DEC also talks of Crystal, Jewel and Emerald systems in the literature, aimed at the scientific market and planned to be available in 1989. In 1988, DEC published the PRISM System Reference Manual, stating that the goal of PRISM was to take DEC forward and

---

366 Personal communication from Supnik to Goodwin, December 10, 2010; Subject: DEC history.
367 J. Mashey, "What's All the Fuss about RISC?," *UNIX review*, February 1986. J. Mashey (MIPS).
368 Jack Smith was DEC's vice president for engineering amongst other responsibilities.
369 DECwest was DEC's engineering establishment in Bellevue, Washington. DEC's Western Research Laboratory (WRL) was in Palo Alto.
370 Taken from the Glacier Executive Summary at http://www.bitsavers.org/pdf/dec/prism/Glacier_Executive_Summary_Nov87.pdf (accessed July 6, 2015).

to counteract the difficulty of building cost-effective, high-performance VAX processors.[371] There was confusion in DEC's senior engineering group over direction and, in 1987, PRISM was ordered to be 64-bit only, closely followed by another edict that it should be both 32-bit and 64-bit. These changes in direction severely hampered the development and introduced many delays. It is clear however that DEC was still on the curve at this point as it was developing the follow on systems using RISC technology.

It is relevant to look at MIPS at this point, as the chip caused a number of problems for DEC and its RISC strategy. Hennessy left Stanford in 1984 to co-found MIPS Computer Systems after a suggestion by Bell.[372] After 1987, it had a business model where it used semiconductor partners to fabricate chips under license and therefore did not have the overhead of semiconductor manufacturing; a similar model to ARM today. It sold its systems through OEMs and VARs (value-added resellers), with manufacturing also being outsourced under licence. Finally, it created another company, Synthesis, to write compilers, etc. for the company. Compilers were effectively the 'microcode' of RISC systems and pivotal to their speed. CISC systems required a great deal of microcode to be hard wired and so the testing time was long and correcting bugs was complex. RISC, on the other hand, had a very simple instruction set and therefore could be designed and fabricated quickly. The intelligence was added by the compilers which, being software, could be modified very easily to correct bugs and enhance the operation.

In 1988 MIPS was a small start-up with a few hundred people in two small buildings in Sunnyvale California.[373] It had designed the MIPS chip on two VAX 11/780's. A major opportunity arose for MIPS in 1988, when DEC bought the rights to MIPS technology and a 5% stake in the company for $15 million, together with warrants for 15% more.[374] By 1989 MIPS was spending 20% of its revenue on R&D and had only a single source for its top end R6000 chip. DEC placed Sam Fuller, its vice-president of research, on to the MIPS board, so that

---

[371] Available at
http://www.bitsavers.org/pdf/dec/prism/Prism_System_Reference_Manual_3.0_Apr88.pdf
(accessed July 6, 2015).
[372] J. Mashey, "Oral History of John Hennessy", Computer History Museum, REF x4149.2008: relates Bell's encouragement in starting MIPS,
http://archive.computerhistory.org/resources/access/text/2012/04/102658153-05-01-acc.pdf
(accessed July 6, 2015). John Mashey was also a co-founder of MIPS and he is now at the Computer History Museum. A number of Mashey's email conversations have been saved on
http://yarchive.net/comp/index.html , including those concerning the VAX and MIPS. (accessed July 6, 2015).
[373] J. Mashey article at http://yarchive.net/comp/vax.html, (accessed July 6, 2015).
[374] M. S. Malone, *Going Public: MIPS Computer and the Entrepreneurial Dream*, 59.

DEC would be able to have some control over the company. When MIPS became a public company, their financial performance was questioned, and it did not make good reading.[375] SG&A was at 50%, R&D was at 30% and revenue dependent solely on licensing did not guarantee the company's long-term future. DEC had been persuaded to invest in MIPS by Joe DeNucci, who worked for DEC in Palo Alto. Malone states that DeNucci was the person who had engineered the deal with DEC that radically improved the situation at MIPS.[376]

DeNucci had joined DEC in 1971 and spent 18 years with the company, finishing as U.S. workstation sales manager. Some DEC engineers, James Billmaier, Mario Pagliaro and Armando Stettner in Palo Alto were working on a MIPS R2000 microprocessor and thought it would fit into a VAXstation box. Frustrated by the lack of a credible RISC workstation, DeNucci decided that he would to meet eleven DEC Vice-presidents to persuade them of the advantages of a MIPS-based workstation. He began with Shields. Shields liked the concept so much that he sent DeNucci straight to see Olsen, who immediately gave it his approval for an investigation. DeNucci then had a meeting with Hennessy and Stritter to discuss details. There was a great deal of discussion and disagreement within DEC about using MIPS technology in the workstations and the message that this might give to customers. There was also an issue concerning the future of VMS, which, it was believed at the time, could not be ported to the MIPS chip. Supnik was sent to Palo Alto to look at the proposal and he reported to the 'infamous building 10 meeting'.[377] Much to the consternation of many within DEC, he said that the company could build a competitive workstation much faster if it adopted MIPS, rather than wait for PRISM. Glorioso said 'Bob Supnik, the champion of PRISM, stood up before the executive committee and stated that we should go with MIPS.'[378] Cutler indicated that 'Supnik was not a great supporter of PRISM; he was not included in its architecture team and was a constant critic even though the PRISM chip was being produced in his organisation.'[379]

---

[375] Ibid. Ch.10.
[376] Ibid.
[377] As quoted by Dave Cutler in private meeting in Bellvue, WA, October 5, 2010. There are only verbal accounts of the meeting which was pivotal in the future of RISC in DEC. It was at this meeting that PRISM was cancelled and consequently Cutler moved to Microsoft. The executive meeting was held on 9th June 1988 and the resulting memo from Cutler is available on the bitsavers site https://archive.org/stream/bitsavers_decprismmed_109800/880617_PRISM_killed#page/n1/mode/2up , (accessed July 6, 2015). Bhandarkar gave a presentation to the meeting in which he recommended aggressively pursuing the PRISM program to ship as soon as possible. Memo https://archive.org/stream/bitsavers_decprismmegy_595438/880609_RISC_Strategy#page/n0/mode/2up , (accessed July 6, 2015).
[378] Private communication January 23, 2008.
[379] Private communication August 3, 2010 subject: Electronic Introduction.

PRISM prototypes were in production six months after the cancellation. Supnik later admitted that adopting MIPS was a mistake; he stated that the company should have completed PRISM and ported VMS to it.[380] PRISM had the potential to be Alpha, but available three years earlier, which would have given DEC the momentum it needed to return to the S-curve and move ahead of its competitors. Bhandarkar suggested that, once the decision to use MIPS had been made, the company should have continued with the strategy.[381] He said that DEC had the rights to develop their own chips and modify the architecture and so porting VMS would not have been an issue. Bhandarkar also wrote that internal politics, led by Supnik, prevented this from happening. DEC announced the MIPS workstation in 1989; DeNucci left DEC and joined MIPS later in 1989.

In June 1988, Bhandarkar sent a memo to senior management about DEC's RISC strategy, commenting on how critical PRISM was to the company and advising against a MIPS-only strategy. Cutler gave a presentation on PRISM versus MIPS at the 'infamous building 10 meeting' and clearly identified issues with the MIPS architecture that made a MIPS-only strategy an issue for DEC.[382] He argued for more funding for PRISM to ensure that workstation systems were shipped on schedule and pointed out that there would be customer perception issues and long term strategy issues, if DEC were to follow any other course. The PRISM project was near completion when the executive decided to employ MIPS technology and to cease PRISM development. This decision was based, amongst other things, on the promise from MIPS that it would soon have a 64-bit version running. Later DEC's decision was reversed, and the Alpha chip, which was developed internally using some of the knowledge that had been gained' from PRISM, was selected as the company's future technology path. The cancellation of the PRISM project caused the resignation of Cutler and a number of his team in DECwest. They left and went directly to Microsoft to work on their new operating system, Windows NT, which was to become a dominant player in the OS world and lead to a loss of sales of VMS.

DEC, it was reported, had the opportunity to sue Microsoft. Cutler has stated that he was personally named in the complaint and was required to sign a waiver every month so that DEC would not sue. He indicated that DEC accused him of stealing the design of Mica, which he said was absurd: DEC had cancelled

[380] Private communication to Goodwin from Supnik, March 9, 2009 subject: DEC History.
[381] Private communication to Goodwin from Bhandarkar, August 10, 2009; subject: Electronic Introduction.
[382] Available at http://www.bitsavers.org/pdf/dec/prism/memos/880530_Cutler_PRISM_vs_MIPS.pdf (accessed July 6, 2015).

PRISM and was never really interested in Mica.[383] Eventually, Cutler said, Microsoft offered some joint marketing money to appease DEC. Strecker was deeply involved in this activity but declined to answer any questions when interviewed.

It is important to discuss Cutler at this point as his departure from DEC and subsequent hiring by Microsoft was pivotal to the modern computer age, and could easily have been avoided by DEC with correct management.[384] When interviewed, Cutler suggested that Schein had only written one side of the story – that of Olsen, Supnik and Glorioso.[385] He indicated that DEC was the best place he had worked and the worst. It was best from 1971 to 1981 and worst from 1985 to 1988. He also mentioned that VMS was the best project he had worked on, VMS was completed in record time (two years), whereas Windows NT took five years to complete. He said that when DEC first started long-range planning, the process was two years in the future. At some time in the 1980s, this decreased to six months and nothing was completed. Cutler commented that Bell was a visionary and he would probably have stayed if Bell had still been at DEC.

In an email, Cutler suggests that the decline began when Bell left, as he was the arbiter of DEC's strategy and could stand up to Olsen.[386] When Bell left no one adequately filled the void. Cutler stated that he had not wished to leave, but had no choice when the company cancelled every product it had asked him to build for several years. He did not really have anything good to say about DEC's technical management, suggesting that Olsen had Glorioso and Supnik telling him 'fairy tales' – Glorioso convincing Olsen that he was saving the company by developing the VAX 9000, and Supnik convincing Olsen that DEC should abandon PRISM and go with MIPS shortly before 'slinking off' to start the Alpha project.

Cutler said that DEC was an engineering company and when it tried to become a sales and marketing company it was unable to do so. He mentioned that DEC was at the beginning of the Internet and had a core competency of networks, but

---

383 Personal communication to Goodwin from Dave Cutler, October 6, 2010. Subject: Re Bhandarkar – Goodwin electronic introduction.

384 Dave Cutler was pivotal in DEC's operating systems development having contributed to both RSX-11M and VMS development. He resigned in October 1988 after the cancellation of the PRISM project and joined Microsoft to develop Windows-NT which was to become a major competitor to VMS. The internals of Windows-NT resemble the internals of VMS as described in Helen Custer's book Inside Windows NT. Helen Custer left DEC at the same time as Cutler and worked on technical documentation at DEC and Microsoft. Helen Custer, *Inside Windows NT* (Microsoft Press, 1993).

385 Interview with Dave Cutler in Bellevue, Washington, USA, October 5, 2010.

386 Email to Goodwin from Dave Cutler, August 2, 2010 Subject: Bhandarkar-Goodwin electronic introduction.

never leveraged it. He also suggested that DEC had better technology and systems than PCs, but again could not exploit these. Zachary's book discusses Cutler and the development of Microsoft's Windows NT.[387] Cutler thought that the book was written in the style of the '*The Soul of a New Machine'* and was a little embellished, being 65% factual and 35% unclear.[388] The following quotations summarise what it has to say about Cutler:

> P8 Cutler joined in 1971 and took DEC by storm being ranked amongst the company's software stars.
>
> P19 Bureaucracy made things much harder, everyone wanted a piece of VMS. Cutler left VMS team and threatened to quit. Bell offered him funding and autonomy. Cutler moved to Seattle in spring 1981. 1985 won approval, narrowly, for PRISM. In 1988 he was told PRISM was cancelled. Cutler quit and word got to Microsoft. Cutlers exit triggered an exodus of his trusted colleagues. Within a week Microsoft had hired seven top code writers.
>
> P37 Cutler and colleagues were asked to sign employment contracts but objected to the clause that barred an employee from joining a competitor for at least a year. They didn't have this clause in their DEC contract.
>
> P46 Perazzoli, who was in charge of Mica for DEC joined Microsoft.

Cutler suggested that engineering large machines was a mistake for DEC. In his time at Bellevue, Washington, he said that he was involved in the development of about four different machines, none of which reached production status. He spoke of PRISM, stating that it was an architecture and an implementation. The ECL version was the same technology as the cancelled Argonaut and was under Demmer's group (the PRISM chip being from Hudson), and was actually produced but not sold.

Cutler then went on to talk about 'the infamous building 10 meeting', a result of which was the cancellation of PRISM and the decision to build a workstation

---

[387] G. P. Zachary, *Show-Stopper!: The Breakneck Race to Create Windows NT and the Next Generation at Microsoft* (New York, Toronto: Free Press; Maxwell Macmillan Canada; Maxwell Macmillan International, 1994).
[388] T. Kidder, *The Soul of a New Machine*.

based on the MIPS chip.[389] Cutler said that DEC started Alpha almost immediately and initially called it AXP, which he suggested, stood for 'Almost eXactly PRISM' and that it had a few features that were better than PRISM. He went on to suggest that Olsen did not understand modern technology and that Smith was 'out of his league'. According to Cutler, the engineering meetings were 'unbelievable', not to the company's benefit, with the 'fiefdoms' of Glorioso and Demmer each with its own agenda. As Smith was not technically oriented, Strecker kept him constantly confused. Cutler suggested that Strecker should share the blame with Glorioso and Supnik for DEC's demise. He also mentioned that Strecker offered many alternative courses of action, but would not put his support behind anything and changed his mind frequently.

In an email to Bell, commenting on Schein's book, Cutler mentions that PRISM was delayed due to internal approval processes.[390] He said that it took almost two years for architectural approval and that if he had done it as a 'skunk works project', DEC could have delivered PRISM much earlier and avoided the MIPS excursion. Cutler also said that Alpha was a moderate success, and great technology, but the VAX 9000 was a disaster, and that he believed DEC bought most of them back. He also indicated that when he left, four of his team joined Microsoft at the same time, followed by six software and four hardware engineers. He suggested that, in total, about forty of DEC's best engineers joined his team at Microsoft.

6.4.1 *Alpha*

Even as it was signing the deal with MIPS to use the MIPS chip in its workstations, DEC began a research program to develop its own RISC chip. This was the Alpha and was to become one of the fastest chips in the world for a number of years and was designed for a twenty-five year lifetime. The Alpha ran VMS, DEC's implementation of UNIX, LINUX and Windows NT. DEC released a number of systems covering its whole product range from PC's to the High-end. DEC had designed its final VAX systems to be plug compatible with the Alpha and VMS also supported both VAX and Alpha so customers had a cheap upgrade path built-in.

---

[389] The meeting was attended by Olsen, and senior engineering VPs – Jack Smith, Cutler, Supnik, Fuller, Demmer, Strecker and Palmer amongst others. It was a discussion about PRISM and MIPS. Olsen apparently liked Supnik's slides, as they provided the arguments that he wanted to hear. Cutler mentioned that at the 'building 10' meeting, Palmer sat in the corner 'all slicked up in a three piece suit' and said nothing. Cutler went on to suggest that Palmer exhibited the same behaviour in most other meetings.

[390] Personal communication to Gordon Bell from Dave Cutler September 3, 2003.

After committing to MIPS and cancelling PRISM, Olsen spoke to Supnik asking him to consider how to make VMS more competitive against RISC-based UNIX systems.[391] Olsen was aware that the VAX was nearing the end of its life and that VMS would become obsolete if there was not a new platform to run it on. He believed, as did many in DEC, that VMS could not be ported to a RISC architecture. However, Supnik took this as authorisation to start up another internal RISC project, the Alpha, in September 1988. The team reviewed the issue of VMS on RISC and concluded that VMS macrocode could be recompiled to RISC code, allowing VMS to be ported to a suitable RISC architecture.

The Alpha team used the PRISM specification and turned it into a system that could run VMS in 64-bits. Thus, Supnik effectively gained PRISM and Cutler left for Microsoft unaware that the PRISM project continued. MIPS did not keep their promises and DEC continued RISC development with the Alpha program.[392] This series of U-turns slowed the development and, although Alpha was far ahead of competitors in performance, with PRISM, DEC could have been three years ahead of the release of Alpha. A PRISM prototype was running before the cancellation of the project and, according to Dobberpuhl, it ran at 50Mhz, faster than the fastest RISC chip in existence at the time.[393] Cutler believed that Mica was about a year away from field test at cancellation.[394]

Had DEC followed the engineers' preferred option of continuing with PRISM and Mica for VMS and MIPS for UNIX, the computing environment today could be very different. Cutler and his team took much of their OS development knowledge with them, to such an extent that, as mentioned above, DEC threatened to sue Microsoft. However, DEC accepted a cash settlement and technology swap as compensation.

As mentioned, DEC did not have sufficient faith in MIPS delivering their product roadmap and, at a meeting of senior personnel; DEC executives were informed that their fears were correct.[395] DEC's workstation market share was badly affected by delays of MIPS R4000 in 1991.[396] Systems based on the R6000 were cancelled in 1990, after Bipolar Integrated Technology failed to deliver sufficient volumes of the ECL microprocessor, because of fabrication

---

391 http://simh.trailing-edge.com/semi/ev4.html (accessed July 6, 2015).
392 The 64-bit MIPS chip, R4000, was not available until October 1991.
393 Email from: Dobberpuhl, to: STF, Oct 21, 1988, Subject: uPRISM – The Final Chapter. Available from http://bitsavers.informatik.uni-stuttgart.de/pdf/dec/prism/memos/881021_uPRISM_charcterization.pdf (accessed July 6, 2015).
394 Personal communication and conversation with Dave Cutler, October 2010.
395 A product roadmap is used to define the stages of development and shipment of future products and put timescales around them.
396 L. Curran, "The Workstation Race Heats Up," *Electronics magazine*, April 1991.

problems.[397] In 1991, MIPS was in trouble because of the costs associated with the R6000.

In a recently recorded interview at the Computer History Museum, the founders of MIPS spoke of the error they made with the R4000 by being distracted by ECL when they should have stayed with CMOS.[398] This, it said, was the cause of the delay and ultimately the reason why DEC dropped its plans for MIPS and implemented Alpha across its full range. The decision delayed availability of the R4000 for one year from 1991 to 1992. DEC's move away from MIPS had a number of additional consequences, the main one being the cessation of the ACE initiative and the end of Windows NT use on MIPS workstations. DEC had been working on delivering Windows NT on its range of MIPS workstations; a DEC workstation was the first system on which Windows NT had operated.[399]

The cancellation resulted in a change in direction for the workstation developers and reconsideration of the primary geographical location for the workstation development. DEC, although known as an East Coast company, had a large presence in Palo Alto, leasing eight buildings totalling 240,000 square feet and a large workforce of development engineers. The choice was between Palo Alto and Maynard; eventually Maynard was selected and 100 engineers were offered transfers to Maynard. The move was not popular with the engineers in Palo Alto, who enjoyed the West Coast lifestyle and technology environment; therefore, most accepted the option of redundancy. Olsen ensured that their redundancy package was generous, and many of them now occupy senior roles in West Coast corporations. Ironically, DEC had to move some of its Alpha design team back to Palo Alto in 1993 to engage with the Silicon Valley semiconductor community.[400]

Initially, DEC had promised to port MIPS Ultrix to OSF Alpha, but later reneged on this to save costs. This led to the consequent loss of customer confidence in the investment in MIPS-based workstations. DEC was, at one time, the number two in worldwide shipments of workstations with its MIPS systems. MIPS was acquired by SGI in 1992 for $230 million, after a series of difficulties. At the time, it had fourth quarter profits of $2.5 million and $50 million in the bank.

---

[397] "DEC Cancels ULTRIX Workstation Using ECL R6000", *Computer Business Review*, August 14, 1990. http://www.cbronline.com/news/dec_cancels_ultrix_workstation_using_ecl_r6000. (accessed July 6, 2015).

[398] Computer History Museum interview with John Hennessy, Bob Miller, Skip Stritter and Joe DeNucci. Moderated by Dave House and recorded on July 27, 2011. Published on YouTube: http://www.youtube.com/watch?v=3paiCK3dlK0&feature=plcp (accessed July 6, 2015).

[399] Personal knowledge of Goodwin, who supported NT in the UK for DEC.

[400] M. S. Granovetter and R. Swedberg, *The Sociology of Economic Life*, 2nd ed. (Boulder, CO: Westview Press, 2001).

MIPS had limited resources for development, causing issues in completion of processor projects, and an inability to design 32-bit systems alongside 64-bit systems.

It is pertinent for us to note here that, had the DEC management not been indecisive about RISC technology, they could have purchased MIPS, instead of allowing SGI to take control. DEC could have invested money and resources for development into MIPS, rather than investing in Alpha. DEC workstations based on MIPS with the ability to run Windows NT and UNIX would certainly have been a competitor in the marketplace. DEC could then have maintained its workstation development, and would not have upset a number of its major customers. Again, it is important to note that SGI actually considered implementing Alpha instead of MIPS prior to the purchase.

ARM began in 1983 after its founders read the papers from Berkeley's RISC project and it followed the MIPS business plan of creating the design and licensing fabrication to others. DEC licensed the ARM work and implemented a design called StrongARM (to be discussed later). Others ignored RISC technology and subsequently suffered. In the early 1980s, Motorola had a lead in the UNIX workstation market with its 68000 family, controlling two thirds of the US market by 1987. SUN, Apollo, HP and Silicon Graphics all built systems using RISC. Motorola were dominant until 1988, when companies such as SUN and HP brought out their own RISC workstations, ignoring the Motorola 88000.

An article in *UNIX World* in July 1990 by Andrew Ould summed up the difficulties that Motorola encountered.[401] It suggested that Motorola was late to recognise the significance of RISC in the workstation market and so lost out to competing products. The article also suggested that the 88000 was not a priority within Motorola and was not allocated sufficient money or people for development. It also stated that SUN investigated the 88000 before developing SPARC and decided that there was insufficient commitment within Motorola to the 88000. SGI discussed the 88000 with Motorola and asked: 'where is the team, where are your compiler tools and where is the commitment?' Even Apple looked at the 88000 for its new system, before choosing the PowerPC. Ould concludes on the sombre note: 'At a crucial point in the development of chip architectures, Motorola blinked. And when it opened its eyes, the top names in the UNIX market were gone'. This is a very similar story to DEC's who dithered over RISC for too many years and lost the workstation market as a result.

[401] A. Ould, 'How Motorola Lost the Workstation Market', *UNIX World*, July 1990.

There were a few successful implementations of RISC microprocessor technology over the years but Intel has maintained its lead position by volume. Some of the important RISC microprocessors of the era were:

- ARM: now in most handheld devices;
- PowerPC: the IBM RISC microprocessor;
- MIPS: Hennessy's implementation; now owned by Imagination.
- PA-RISC: HP's RISC system;
- SPARC: from SUN; Now owned by Oracle
- Alpha: from DEC.

Apart from SPARC and PowerPC, those that have not been discontinued have found a market in low power handheld devices and games consoles, with Intel's CISC design currently being dominant in the desktop and server market.

6.5 *UNIX*

UNIX was the sleeping giant that came to haunt DEC. A saying attributed (wrongly) to Olsen was that UNIX was 'snake oil'. What Olsen actually said was that UNIX was 'sold like snake oil'. He was not opposed to UNIX, as is shown in his memos.[402] He wanted to sell a UNIX on the Intel 386 microprocessor and even suggested developing a set of tools to port AIX applications to Ultrix.[403] He continually asked the engineering team why UNIX development was not providing what the company required and also asked why the company missed its commitment for UNIX on the VAX 9000.[404] DEC had many opportunities to dominate the UNIX market. UNIX was designed on DEC computers and optimised for them. DEC was reportedly given the opportunity of the exclusive rights to UNIX for $10,000, as long as it was maintained for multiple minicomputer platforms and made available at no charge to non-profit organisations.[405] Olsen rejected the offer, as he believed that VMS was far superior and was the company's flagship product; he was reluctant to dilute VMS by supporting two major operating systems. DEC did join with IBM, HP and others in the formation of the Open Software Foundation, a consortium set

[402] Various memos regarding UNIX in Ken Olsen archives; for example, Memo June 26, 1992 Subject: UNIX, where Olsen is urging the company to hire the best UNIX engineers, look at HP and IBM, and build a superior product.
[403] Memo in Ken Olsen archives, December 5, 1988 Subject: Ultrix on 386. Memo in Ken Olsen archives, February 15, 1990 Subject: Transporting AIX Applications.
[404] Memo in Ken Olsen archives, August 24, 1990 Subject: System V.
[405] Personal communications from Ed Kramer (January 18, 2008) and Pat Cataldo (June 6, 2008).

up to counter the threat posed by SUN, who had joined its version of UNIX with AT&T's version in 1988.

DEC had a large involvement in UNIX over the years. It was a major partner, along with IBM, in the Athena project at MIT, which was a campus-wide distributed computing environment for educational use. Athena was announced in 1983 and completed in 1991; it was still in use in 2010. Project Athena spawned the X-windows System, Kerberos, and had a significant influence on thin client, LDAP and instant messaging. DEC had many engineers working on project Athena and supported the technology in its offerings, productising the software under the title DECAthena. Digital Press even published a book on MIT's Project Athena.[406] DEC was also heavily involved in the development of Motif windowing system as part of its OSF development. However, until the mid-1990s, DEC's main focus was on VMS, keeping UNIX in the background. Strecker confirmed this when interviewed, remarking that DEC had a policy of *VMS first, UNIX second*, whereas companies such as HP publically stated *UNIX first, proprietary second,* whilst still selling proprietary systems as a stopgap to retain the customer. DEC lost many customers in the late 1980s because it did not have a credible UNIX offering.

UNIX was quite closely tied into the PDP hardware, as it had been written in PDP assembler before being rewritten in C; the C language itself reflected much of the PDP instruction set. DEC did not exploit this, preferring to promote its VMS operating system, because this provided a good income and high margins. In fact, the first UNIX user group was a subgroup of DECUS. DEC had some excellent UNIX engineers (as reported by Bell) but allowing UNIX sales to compete with VMS was not permitted within the company.[407] As with the implementation of RISC technology, Berkeley was influential in UNIX development in the 1970s. Later, DEC upset the original developers of UNIX by refusing to support a VAX version, leading to a late port to VAX by the UNIX community.[408]

AT&T was not allowed to sell UNIX commercially, so it gave it away to universities, thus ensuring widespread use. Dr Kelly, in his talk to the 1995 Spring Unite Conference, stated that the 1984 *Fortune* magazine reported that of

---

[406] G. A. Champine, *MIT Project Athena: A Model for Distributed Campus Computing* (Bedford, MA: Digital Press, 1991).
[407] Smithsonian Oral Interview with Gordon Bell, http://www.cwhonors.org/search/oral_history_archive/gordon_bell/index.asp Transition from VAX to Prism (accessed July 6, 2015).
[408] J. C. Kelly, "The UNIX Industry: A Brief History," http://snap.nlc.dcccd.edu/learn/drkelly/brf-hist.htm (accessed July 29, 2012).

750 universities giving computer science degrees, 80% had UNIX licences.[409] As with RISC, DEC was late into the UNIX market. It tried to sell VMS as 'open' but also invested heavily in the development and implementation of OSF, as it had government contracts that specified OSF.[410] Later the government relaxed this requirement and those that did not go down the OSF route gained market share at the cost of those who did.

In 1980, DARPA needed a team to implement TCP/IP on a VAX under UNIX. The PDP-10s on the ARPANET were aging and DARPA were rightly concerned that DEC might stop PDP-10 development. DARPA considered contracting DEC to conduct the implementation, but were concerned that DEC might not be responsive. Therefore, they asked Berkeley to develop the TCP/IP code instead. Until this point, there was little networking support on UNIX.

DEC's initial version of UNIX, released in 1982 was a proprietary version called Ultrix. It produced Ultrix on the PDP-11, the Professional 350 and the VAX range. It also produced a version on the MIPS workstations. In 1987, DEC's share of the UNIX market was 13%; by 1993 that was reduced to a mere 2%. *Business Wire* on March 21st 1995 reported that, in 1993, DEC's workstations had almost 11% of the market together with IBM, HP had 19%, SGI had 5% and SUN had 38%.

Before the cancellation of the MIPS based machines, DEC had ported OSF to the DECstation but had never produced it commercially, promising the MIPS customers an upgrade path to OSF/Alpha.[411] DEC spent a great deal of time and money on OSF, including features in VMS, as well as ensuring its version of UNIX was compliant, anticipating that government requirements would stipulate OSF adherence. This did not really materialise, but DEC did begin to take UNIX seriously in 1995 and went on to transform its UNIX/OSF offering into Digital UNIX in 1995 and Tru64 UNIX in 1999. Tru64 UNIX was eventually regarded amongst the top UNIX systems, competing against HP's HP-UX. DEC's initial lack of commitment to UNIX led to lost orders, lost customer confidence and a poor position in the workstation market for many years. This commitment was more of a lack of marketing, as DEC's UNIX team was about the same size as the VMS development team. In 1996, a SUN press release suggested that DEC

[409] Unite is the Unisys Users Group. Dr Kelly's talk can be found at http://snap.nlc.dcccd.edu/learn/drkelly/hst-hand.htm (accessed July 29, 2012).
[410] The Open Software Foundation (OSF) was initially proposed by DEC; the group of members included Apollo, HP and IBM. The group was set up to counter the SUN and AT&T alliance, fearing that they would be excluded from UNIX development.
[411] Software porting is the translation of the code such that it can be executed on a different hardware platform.

and HP had all but surrendered the UNIX workstation market, although it is not apparent how it justified this statement, as HP had a 19% share of the market in 1995.[412]

It is argued that although DEC had the ability to implement UNIX on all of its systems, it did not have the internal commitment to do so at the expense of VMS. Olsen questioned the engineering teams on their commitment to UNIX on a number of occasions, but to the customer it was apparent that DEC did not have a sufficiently compelling argument to convince them that it was serious about UNIX support.[413] It is also argued that this lack of an enterprise-strength UNIX affected sales at a time when the company needed to grow, especially in the workstation market where its major competitors were all offering UNIX as the preferred operating system. In the 1990s, DEC was seeing many of its systems being replaced by UNIX offerings from competitors, but was unable to compete with its Ultrix system. Many of these systems were sold into the financial market where price had become more of a priority than reliability in the 1990s.

6.6 *Failing to Develop a Credible PC until the 1990s*

Another disruptive technology that DEC missed – as suggested by Christensen – was the PC.[414] As far back as 1974, Knowles had proposed that DEC build a personal computer, but this went against DEC's engineering culture and the low margins were not attractive to the company.[415] In 1978, DEC released the PDT range of personal computers – well before the IBM PC. Knowles suggested that Bell had transferred all the development people from the PDT to solve issues with the VAX and that this effectively finished the PDT as a product. Bell, in turn, writes in the history of personal workstations, that DEC introduced the PDT-150 at a price of less than $10K. While the DEC marketing department debated price and distribution, the PC industry formed, and DEC discouraged Dan Bricklin from using a PDT-150 to build VisiCalc.[416] Bricklin had been employed at DEC from 1973 to 1976 working on WPS-8 word processing

---

412 http://www.sun.com/smi/Press/sunflash/1997-01/sunflash.9770113.23236.xml (accessed July 12, 2008).
413 Various memos in the Ken Olsen archives.
414 C. M. Christensen, *The Innovator's Dilemma: The Revolutionary National Bestseller that Changed the Way We Do Business*, 126-127.
415 E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 162.
416 A. Goldberg and Association for Computing Machinery, *A History of Personal Workstations*, ACM Press History Series (New York, N.Y.; Reading, MA: ACM Press; Addison-Wesley Pub. Co., 1988).

software.[417] Bricklin had wanted to develop VisiCalc for DEC systems. However, as he did not receive enough support from DEC, he developed it on an Apple II instead.[418]

Many people who were interviewed by email or telephone suggested that the late entry into the personal computer market was a contributory factor to the downfall of DEC. In one interview by David Ahl of the *New York Times* at the 1977 World Future Society meeting in Boston, Olsen is reported as saying: ‘There is no reason for any individual to have a computer in their home’. This is widely quoted even today and is often cited as one of the greatest errors in technology forecasts of the twentieth century. However, Olsen’s comment was taken out of context; he was speaking of the computers of the time and not the personal computer.

In 1977 Heathkit produced the model H-11, which was an LSI-11 based kit system running HT-11, a modified RT-11, and BASIC. This sold for $1295 and was popular with hobbyists, but did not sell well, both because of the price and because it was bound to Heathkit storage.[419] When this was discussed with Gaubatz, he questioned whether DEC could afford to sell a complete system for about one-tenth of the price of its current models. However, by 1980, as the VAX had overtaken the PDP as DEC’s major future source of income, it might have been possible to create volume at the low end without affecting product sales too much.

Gaubatz also recalled that DEC’s PC research was not an enjoyable time for Bell as engineering manager.[420] In 1982, having initially introduced an add-on to the VT100, the VT180 (Robin), that ran CP/M, DEC entered the PC market in earnest with three offerings: the Professional 350 (PRO), the Rainbow and the DECmate word processing system. The Rainbow was an excellent business PC. It had dual processors, the Z80 and the 8080, and ran both 8-bit and 16-bit operating systems simultaneously, sharing peripherals and communicating via memory. The Professional range ran on a micro PDP-11 chip and ran a version of DEC’s RSX-11 operating system with an end user interface on top. Internal sources suggested that the PRO should have implemented DEC’s RT-11 operating system as RSX was high end and resource hungry thus slowed the

---

417 J. Coventry, “Interview with Dan Bricklin, Inventor of the Electronic Spreadsheet,” November 7, 2006. http://lowendmac.com/coventry/06/dan-bricklin-visicalc.html (accessed July 6, 2015).
418 P. E. Ceruzzi, *A History of Modern Computing*.
419 RT-11 was one of DEC’s popular real time operating systems for the PDP-11.
420 Personal communication to Goodwin from Gaubatz, February 24, 2011: Subject: reading chapter 6.

system down. The DECmate ran DEC's word processing software on a PDP-8 chip and was aimed at secretarial use.

In an interview Avram Miller asserted that DEC was not focussed on PCs. Bell had returned and brought some excellent technical people with him, including his PhD student Strecker, but they were focussed on the large systems rather than the consumer market.[421] He said that Olsen did not understand the market and so was frustrated with the development of low-end products. He went on to suggest that Olsen was a power supply person who did not understand software. Miller stated that he was asked supervise hardware engineering at the low end and was drafted into a meeting with Olsen, Bell and Stan Olsen to discuss the low-end business. In that meeting, Olsen was targeting the systems at clerks and clerics, according to Miller. He also stated that Bell did not care about low-end products. Miller suggested that DEC did not know about the IBM PC when it started development of the PRO, but when it dissected one; Olsen said he would sack anyone who designed a system as bad as this. Miller also said that Barry Folsom decided to build a product that would run MS-DOS and started the project behind his back; this caused friction between the development groups.

It was anticipated that the PRO team would port the DECmate software to the PRO, but the group could not find the source code and were unable to do this. As a result, the DECmate group decided to build a system as well. Finally, the three groups came to their senses and went to Olsen to ask him to stop two of the three developments, fearing customer confusion and loss of sales. Olsen refused, suggesting that the customers would decide which was best. Sales, marketing and customers were all confused by the release of three systems at the same time. Moreover, because of the lack of applications, the Professional did not sell well. Had Olsen cancelled two of the systems, the DEC PC might have had a better chance of early success. In reality, it was the workstation, rather than the PC, that was a problem for DEC in the 1980s. Miller commented that the company should have bought SUN; he and Bell had visited SUN when it was starting up, and Bell 'fell in love with' its systems.

The workstation and PC market merged in the 1990s when DEC was in fact gearing up its PC and server presence. Hindsight tells us that the PC market was, and still is, a low-margin, high-volume business; this was not where DEC's mainstream was positioned at the time. DEC's entry into the market was based on its normal process: three systems all over-engineered, 'Rolls Royce' systems

[421] Telephone interview with Avram Miller who ran DEC's Professional System development group in 1983, March 19, 2009.

in a market that was cost driven. Miller left DEC soon after the failure of its PC offerings. When DEC finally re-entered the market, it took some time to gain momentum, but its server products gained market share eventually. DEC had made a serious error when entering the PC market because, rather than embracing the accepted standards, it decided that it would try to impose its internal standards as industry standards.

Without a complete change of business model, manufacturing process and sales process, DEC could not have made money in the PC market unless it spawned a separate company, as IBM had done. At the time, its structure and manufacturing processes were not geared up to volume markets and so (as IBM found out for itself), this was not the market for DEC at the time. IBM had correctly set up a separate company to launch its PC bid for the market, but this stalled when it tried to bring the PC business back into its mainstream business. DEC could have focussed on the workstation market, potentially buying one of the many companies that were to appear in the PC market at a later date. Whilst targeting IBM, DEC was distracted from its traditional market – minicomputers and workstations – and allowed SUN, APOLLO and HP to own it. We suggest that this was another major error in the company's history. According to Supnik, after the debacle with the three models, DEC engineering suggested that the company should build a clone PC: the PC25 and PC50. This was before Compaq was even formed and again Olsen rejected the proposal. He declared that 'DEC wasn't a copycat company', even though DEC, by this time, had the facilities for building in volume, due to its terminal and printer business and a form of business model to succeed.

In April 1991, Olsen recognised that to succeed in the PC industry the Dell model was the one to emulate. He proposed that Palmer plan a factory to make PCs and workstations to order and deliver within 24 hours, including preinstalled software. It is unclear what happened to this proposal but it is evident that it never materialised.[422]

6.7 *Conclusion*

This chapter set out to show that DEC missed the curve in terms of technology advances and the failures of its RISC strategy rather than lacking the 'money gene' as Schein proposed. It has shown that the company was being attacked on most fronts by competitors with disruptive technologies and dormant

[422] Memo in Ken Olsen archives, April 29, 1991: Subject: A factory to make PCs and Workstations to order.

technologies. DEC was at the forefront of research into RISC technology, but indecision at a senior level led it to change its mind a number of times thus relinquishing the market to others. It has been argued that DEC's RISC strategy could have been achieved by either continuing with PRISM and accepting the delay to its workstation product or developing the MIPS chip to be the new architecture to replace the VAX architecture that was reaching its limits. However at the meeting on 9th June 1988 the executive committee were indecisive in leading the company and set a dual architecture path, later revising it to the confusion of the customers. This led to Cutler moving to Microsoft and developing competitive software to VMS. DEC also tried to make a 'Rolls Royce' PC when the market wanted cheap PCs.

It has also been argued that DEC invested in highly technical products such as the VAX 9000 when the market for them was disappearing and again ignored the need for a viable UNIX operating system. The VAX 9000 was almost immediately superseded by the much cheaper NVAX based systems which implemented much of the developments of the VAX 9000 into silicon. This reduced the development finance for DECs RISC efforts and delayed their implementation.

It is apparent from the facts recorded in this chapter that DEC's misfortunes started around 1983 with the loss of Bell. He had been the company's visionary, and he had foreseen the coming of VLSI and CMOS technology in place of ECL and the need to have a replacement for the VAX family in the late 1980s. When he left, there was a void in the technical direction and a lack of decision making that led to the company starting and stopping RISC initiatives, opting for an external vendor and then changing direction again. This delay enabled IBM to take market share from DEC in mid-range computing and SUN capture the workstation market. All of this happened when DEC should have been on the next technology wave. Its VAX/VMS architecture was in need of refresh and UNIX was in the ascendency. It was the arrogance of the management in believing that VAX/VMS was the 'best' architecture and operating system that led to the company not investing in UNIX at an earlier stage.

The most pivotal point at which DECs fate was sealed was the 'building 10 meeting' when PRISM was cancelled and after which Cutler left to join Microsoft. This led to Microsoft developing an operating system that was to challenge VMS and to the rise of Intel based systems in the datacentre.

In fact there was a great deal of indecision in the technical management at DEC with both the STF and Olsen making, then reversing, decisions, leading to delays and cancellations in 'productisation' of projects. There was infighting between the LCG development group and the Maynard-based engineers. This became especially apparent after the cancellation of Jupiter and Titan and affected the VAX 9000 development team. Engineering VPs were said to be parochial and acted only in their own best interests.[423] DEC was ruled by a tripartite group of Olsen, Smith and Shields (until he left) who defined the direction, advised by Strecker on the technology. Many of their decisions were proven to be wrong, even though their technical community had advised them correctly.

It has been shown that Shields pursued the IBM market and Olsen failed to stop the development of the VAX 9000, even though the STF always argued against it.[424] Strecker did not back PRISM and also agreed to the MIPS decision, even though Cutler and Bhandarkar had advised against it. The company missed the workstation market and could also have defined the PC had it had some leadership. All of this left customers confused, application vendors looking elsewhere and Wall Street becoming worried.

Had Bell remained, DEC might have been a very different company by the 1990s and Windows NT, which grew to be DEC's major competitor in the data centre, might never have appeared. Schein assertion that it was the lack of the money gene that led to the demise of DEC does not consider the technology option. We suggest that it was the lack of a visionary such as Bell, as well as a lack of the marketing gene, that caused the downfall rather than the money gene. Cutler in his email to Bell also suggests that it was not a lack of money gene but a lack of any semblance of a decision making process that destroyed DEC and states that 'the important point here is that when you left the seeds of disaster were sown'. Schein looks at the downfall of DEC in organisational and cultural terms, building on his many years as an organisational consultant with the company.[425] He assigns very little of his book to the technical issues that beset the company in its later years and that ultimately led to its failure. This chapter has identified the technical decisions that led to the failure.

In summary, it has been argued in this chapter that the major mistakes that DEC made, thus missing the technology curve, were:

- Continuing to invest in the VAX 9000 even though it could not make money;

[423] Personal email from Dave Cutler August 20, 2010.
[424] Comment to Goodwin from Gaubatz October 5, 2011.
[425] E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*.

- Indecision over its RISC strategy;
- Failing to offer a competitive PC;
- Failing to develop an enterprise UNIX early enough.

It is difficult to comprehend why Olsen maintained the work on the VAX 9000 and failed to develop the low cost RISC architecture, when his initial motivation in founding the company was to deliver low-cost computing to a broader audience.

7 The Impact of Downsizing on DEC

7.1 *Introduction*

Schumpeter's creative destruction theory proposes that evolution in technology streamlines processes and thus increases productivity. This leads to either a reduction in staff or an enhanced output that utilises the current workforce. Schumpeter theorized that as technologies progressed, productivity increased and so the manpower required reduced. DECs culture was that a job at DEC was a job for life. This coupled with the company hiring for an assault on IBM meant that when the newer technology arrived and margins decreased it was vastly overstaffed (fig. 2) and reluctant to reduce its staff due to the company culture.[426] The advent of CMOS technology meant that computer manufacture and maintenance was simplified and the workforce required to deliver was reduced. DEC was eventually forced into a massive reduction in manpower in the early 1990s. The problem the company faced during this period was that even though it cut the headcount, it could not keep up with the required reduction rate to meet its reduced needs and reduced margins. This led to a never ending spiral of layoffs which had a serious impact on the company culture and the relationship of the workers to the company. This chapter sets out to show that the negative impact of downsizing on the company which was one of the major contributory factors in the failure of DEC to recover. For this purpose, the effect of the downsizing activity at DEC is analysed. This chapter concludes that the manner and severity of the downsizing restricted the company's ability to recover and negatively affected morale to such an extent that company loyalty was also lost. It also posits that many operational errors occurred as a result and that managers did not deliver the downsizing they promised at the beginning, thus causing a stronger reaction from the board.

DEC was affected in the late 1980s, as were all other computer manufacturers, by the worldwide recession. However, DEC also suffered from an aging senior management population in a dynamic industry. Although the company had streamlined its manufacturing capabilities, and was a role model for the industry at the time, it was not organised for volume manufacturing and had too many diverse manufacturing facilities across the world.[427] This was the beginning of

[426] Peter de Lisi in an e-mail on 19-Feb-2008 stated that the additional manpower hired between 1986 and 1988 to go up against IBM was 26,800.
[427] B. Arntzen et al., "Global Supply Chain Management at Digital Equipment Corporation." Also Robert Palmer Oral Interview by Craig Addison, in Dallas, Texas. Craig Addison, "SEMI Oral History Interview: Robert P. Palmer," November 18, 2004, Transcript available at: http://silicongenesis.stanford.edu/transcripts/SEMI/palmer.htm (accessed July 6, 2015).

the rise of the West Coast revolution in computing which took DEC by surprise. The new companies were unhindered by the size and overheads of the established firms and so were agile in their product development. DEC was hindered by its sheer size and its traditional values. It had implemented a set of core company values that were defined by Olsen. These values were documented in the *Corporate Philosophy and Organization* paper and defined by the Operations Committee in 1974.[428] The corporate values dictated that the company was oriented towards its employees and customers and can be best summarised by the 'First Rule' which states 'When dealing with a customer, a vendor or an employee do what is 'right' in each situation'. DEC culture was opposed to job cuts; it was believed to be a job for life when anyone joined DEC. Critically, Olsen could not agree to wholesale cuts in 1992 and so lost his job.

7.2 *Downsizing in DEC*

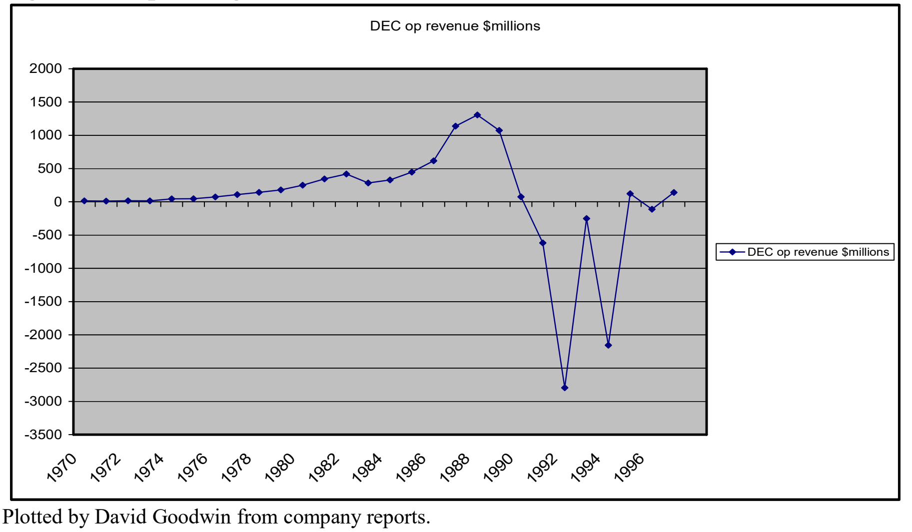
As mentioned above, a job at DEC had always been considered a job for life, particularly at the lower levels of the company, as evidenced in many of the comments from interviews and the survey[429]. However, Olsen finally agreed to a voluntary round of layoffs in the mid-1980s. The methodology used in this round of downsizing is aptly described in the paper *Employment Security at DEC: Sustaining Values Amid Environmental Change* in which Kochan discusses the values that were apparent within the corporation and how it designed a policy of downsizing in the mid-1980s which maintained this core set of values whilst delivering the desired reduction in numbers of employees.[430] Although this was a worldwide headcount reduction, the majority of it was in the manufacturing areas, primarily in the US.

At DEC, this programme of redundancies was a forced reaction to the sudden decline in the stock market value of the company in 1983, when the value of the stock dropped by 29% in three weeks. It was undertaken over a three-year period. The initial stages involved an analysis of where reductions were needed, followed by training and counselling. The result was minimal disruption to the operation of the company and also minimal reduction in the morale of the employees because the downsizing was implemented according to the corporate values. This began to change in the late 1980s and early 1990s when DEC was once again in crisis mode. As discussed in chapter 5, DEC had mistakenly

[428] Currently located in the Ken Olsen archives; also available on the web on Gordon Bell's web site at http://research.microsoft.com/en-us/um/people/gbell/Digital/Dig_Corp_Philos_and_Org_7704.pdf (accessed July 6, 2015).
[429] The results of the survey are detailed later.
[430] T.A. Kochan, J.P. MacDuffie, and P. Osterman, "Employment Security at DEC: Sustaining Values Amid Environmental Change," *Human Resource Management Journal* 27, no. 2 (1988): 121-143.

increased its workforce by between 20,000 and 30,000 to focus on the IBM market, believing that this was its future growth area. The recession, changing market and changing technology proved this to be incorrect, leaving DEC with too many employees for its income. Olsen, as observed in multiple management memos, tried to get the company to realign its personnel for growth rather than to resort to wholesale downsizing, believing that this was the best course of action for the company but the board and other senior managers disagreed.[431] Shareholder activism was also evident in the wish to downsize during the 1990s.

Figure 16: Operating revenue (1970 – 1997).

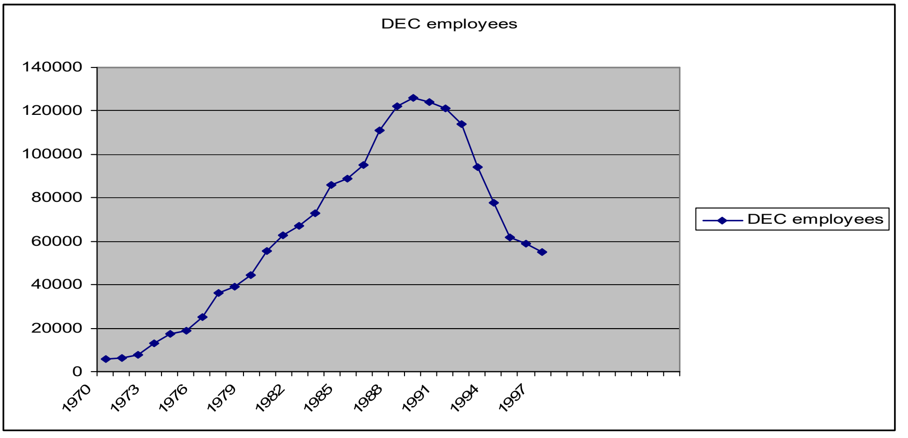


Plotted by David Goodwin from company reports.

As can be seen in Figure 16, DEC's operating revenue was in severe decline, resulting in a substantial loss in 1991 and 1992, briefly returning to profitability in 1995, before posting an annual operating profit again in 1997. Much of the reported losses in the 1990s can be accounted for in the cost of the downsizing that went on during this period to reduce the employee population from 124,000 in 1990 to 55,000 in 1997 (Figure 17). DEC set aside large amounts in 1991, 1992, 1994 and 1996 for restructuring resulting in losses in those years.

[431] Various memos in the Ken Olsen archives (1990-1992). For example, Memo from: Olsen, To: Distribution, Subject: Let's Do Planning Next Year, Date: May 29, 1992. Also Memo: From: Olsen, To: Distribution, Subject: Letter to the Board, Date March 24, 1992.

Figure 17: Employee population (1970 – 1997).



Plotted by David Goodwin.

Initially this was done in order to realign the company population as a reaction to the excess staff that DEC had accumulated during its goal of overtaking IBM. But the downsizing continued much longer than anticipated, as stated by many staff members interviewed in the present study who suggested it was 'death by a thousand cuts' and all they wanted was for the downsizing to be over, so that they could get on with their jobs without the constant worry of who was next to go. Had the senior management looked at the company's operation and focussed the cuts initially where the consequences would be minimal, then there might not have been the need for on-going staff reductions.

In the early 1990s, the redundancies at DEC followed the corporate values and were conducted in a compassionate manner, although voluntary redundancy and early retirement were part of the solution. The early retirement programme was initiated hastily, with little time for deep consideration given to volunteers. It should have been aimed at those actively considering the option (as confirmed within the free text portion of the employee survey) and although attempting to adhere to the company values it was not viewed as such by many respondents. The voluntary redundancy scheme was the first mistake the management made in its downsizing. It led to a number of people with key skills deciding to leave the company, thereby not only creating problems for those who were left behind, but also giving a distinct advantage to the competing companies they joined. Although, initially, this had minimal effect on the morale of those left behind as the downsizing was deemed to have been carried out fairly and generously, it did have a detrimental impact on the skills that the company had for recovery, as well as giving rise to a growing resentment as the value of the redundancy package declined. At a special operations committee meeting, frustration was expressed at the engineering department's inability to meet headcount reductions when all others were on target.[432] This is an example of the 'DEC nod' where engineering management agreed headcount reductions in management meetings but failed to deliver. In another meeting, the FY91 headcount reduction target was set at 7,150.[433] In a Jack Smith memo, he notes that the forecast headcount reduction for FY92 was 15,550.[434] In a further memo, Jack Smith reported that the FY93 reduction target was 13,215.[435] In fact, DEC achieved only about an 8,000 reduction in the workforce for the first two years. However, as the cuts became larger and deeper in the Palmer era, the core values were lost, as was any focus on who should go. In many cases, the compensation deteriorated, as confirmed by the results of the survey later and the minutes of a Strategy Committee meeting.[436] Particularly evident in the case of DEC was that the employer-employee relationship moved from stable to short-term, after there had been an extremely strong company culture up until the resignation of its founder Olsen. DEC's stock price initially rose when Palmer was appointed and he outlined his plans for a company recovery, but as the downsizing continued, the price once again fell, as illustrated in the *Wall Street Journal*, causing recurring rounds of redundancies.[437]

Where DEC should have been involved in a process of retrenchment downsizing in the early 1990s, it finally turned to downscoping in the mid-1990s, to such an extent that by 1997 it had sold off so many of its business lines (printers, database products, training, networks, semiconductors) that it ended up as a take-over target.[438] DEC initially focussed on reducing headcount and followed this with a consolidation of manufacturing plants. It was only in the later years that it resorted to asset retrenchment. Cascio's theory of a strategy focussing on people rather than on downsizing is in agreement with Olsen's approach and

---

[432] Special operations committee meeting minutes October 4, 1990, Digital Equipment Corporation records, Lot # Y2675.2004, box #21364262 Computer History Museum.
[433] Special operations committee meeting minutes September 27, 1990, Digital Equipment Corporation records, Lot # Y2675.2004, box #21364262 Computer History Museum.
[434] Jack Smith memo June 13, 1991, Digital Equipment Corporation records, Lot # Y2675.2004, box #21364262 Computer History Museum.
[435] Jack Smith memo June 17, 1992, Digital Equipment Corporation records, Lot # Y2675.2004, box #21364262 Computer History Museum.
[436] Strategy Committee meeting minutes October 13, 1992, Digital Equipment Corporation records, Lot # Y2675.2004, box #21364262 Computer History Museum.
[437] *Wall Street Journal* stock quotes for the period.
[438] W. F. Cascio, "What Do We Know? What Have We Learned?.", *Academy of Management Executive*; W. F. Cascio, "Strategies for Responsible Restructuring," *Academy for Management Executive*.

diametrically opposed to that of Palmer and the board.[439] We suggest that Cascio's theory should have been followed, as this worked for IBM and HP.

Richardson suggested that technology was not the cause of a company's downfall, but people were.[440] This could be argued either way. DEC was behind the technology curve in the 1990s, but that was because its people had not seen the technology change coming. In the case of DEC, this was management's failure to understand that technology had changed and the future demanded a leaner organisation and a lower margin business. Olsen finally agreed to a headcount reduction in 1991, which his management team failed to deliver whereupon the board insisted on more drastic reductions, but Olsen would not be moved. This disagreement was the root cause of the board requesting Olsen's resignation in 1992.[441] As mentioned, analysts at the time suggested that DEC needed to reduce headcount by at least 30,000, a view that would appear correct given that HP was of a similar size, with a similar product set at the time, and had 30,000 fewer employees.

Once Palmer took over, the rounds of redundancy occurred frequently, with the company management promising each time that this would be the last one. Reducing the staff to achieve financial goals became the target, rather than building the business, as shown in the income figures that were stable whilst headcount was reducing. Meeting the staff reduction numbers and the timescales dictated that no analysis of where and whom to cut was undertaken. Olsen identified this as an issue shortly after he was replaced by Palmer, and flagged to the management team in August 1992, but nothing was done.[442] Morale started to suffer and the customers began to question the ability of the company to recover, and so did Wall Street, as reported in many of the US newspapers of the time. Tomasko, in his book on downsizing, characterises this as 'body count mentality', where the primary objective is short-term cost reduction with a primary tool of across the board, untargeted, fast redundancies.[443] This method quite often has unwanted consequences, such as resentment towards management and loss of focus.

---

[439] W. F. Cascio, "Strategies for Responsible Restructuring," *Academy for Management Executive*.
[440] C. Richardson, "Computers Don't Kill Jobs, People Do: Technology and Power in the Workplace," *Annals of the Academy of political and Social Science* 544 (1996). Charley Richardson was the director of the Technology and Work program at the University of Massachusetts, Lowell in 1996.
[441] Statement from board member at the time 2008. Also Memo: September 25, 1992 From: Ken Olsen, Subject: Press release, located in Ken Olsen archives.
[442] Identified in memos in the Ken Olsen archives July/August 1992.
[443] R.M. Tomasko, *Downsizing: Reshaping the Corporation for the Future*, Expanded & updated. ed. (New York, NY: AMACOM, 1990).

DEC also had a problem in EMEA with across the board cuts. France, Germany and certain Benelux countries had regulations making it difficult to reduce headcount. In fact, in France, even if people were made redundant, they still had to be paid a salary. This led to the greater cuts being made in the easier target countries, such as the UK, and provoking even more resentment in the workforce. A senior manager recalled the time he had to make a husband and wife redundant, even though someone else had volunteered, just because they were on a list prepared by the human resources department.[444] He also mentioned that it was also 'normal' behaviour to get rid of 'difficult' or 'controversial' staff in the process, without taking into account their value to the company. This was evident in London, where management made the database and network support engineers redundant, even though there were important customers dependent on their skills.[445] The *Wall Street Journal* reported that:[446]

> In the 1994 reorganisation, Palmer eliminated hundreds of sales and marketing jobs in the healthcare sector. This group had been bringing in $800 million dollars of revenue selling to hospitals etc worldwide. Palmer had suggested that DEC had to act fast as its cost of sales was too high in comparison with its rivals. The result was that the longstanding ties between customer and salesperson were broken. Customers complained about not having seen a sales rep for nine months. Many customers turned to competitors and many laid-off workers went to HP and took their DEC clients with them.

Pre-1992, DEC had a number of powerful, independent managers who tried to hold on to their power base by maintaining that their organisation was lean and suggesting that other parts of the organisation should downsize. This frustrated Olsen, impeded the recovery and development of the company and stifled innovation.[447] Glorioso recollected that the powerful STF blocked much of the innovation that he and other engineering managers tried to instil, thus hampering DEC's growth.[448]

The term 'rightsizing' was used in the initial stages, after which it was deemed to be 'downsizing' and finally 'redundancy' with the termination packages being reduced in many countries along with the terminology. In the case of DEC, trust in management diminished after Olsen left, which led to a number of key people also leaving. It was left to the personnel in the HR department to tell those

[444] Personal recollection of a senior finance manager to Goodwin; asked to keep name confidential.
[445] Interviews with London engineers July, 2008
[446] A. Markels and M. Murray, "Call it Dumbsizing: Why Some Companies Regret Cost-Cutting," *Wall Street Journal*, May 4, 1996.
[447] As illustrated in memos in the Ken Olsen Archives, Gordon College (1988-1992).
[448] Private correspondence with Goodwin by Glorioso, January 25, 2008. Glorioso was a DEC Vice President until 1993.

selected that they were being downsized, in many cases thus relieving the line managers of the problem and in effect enabling them to distance themselves from dealing directly with the people involved. Peter DeLisi wrote of the plummeting morale, falling productivity, and people updating their resumes after Palmer took over.[449] He comments that Palmer brought in external managers to replace DEC's senior managers, many from IBM. This led people within DEC to question why the corporation was bringing in executives who had not been able to keep IBM out of trouble. As mentioned, many of these managers were quick to leave the company when they realised that it was very different from IBM, some lasting less than a year. Palmer also brought in Crawford Beveridge to manage the HR function and he changed the company culture[450] from one that respected employees to one that treated them as property and so destroying the morale of the employees (as exemplified by various Notesfile entries and the survey reported later in this chapter).

Shah looked at the loss of social networks and the consequences for a company, but there were also implications in the technical networks, particularly in the case of DEC.[451] The entries in the Digital Notesfile carried news of the downsizing worldwide within the company, including the way it was being implemented, adding to the resentment of those remaining. As more people were laid off, much of the technical network dried up as those in engineering responsible for responding to field engineer questions disappeared without warning. This led to a sense that the company was losing its technical expertise.

It was not only the employees who felt this loss. A fax sent to Olsen from the Ford account in September 1992 expressed concern that its experienced engineer had been laid off without prior notification, resulting in its being offered an inexperienced replacement.[452] This had a direct consequence for future sales to Ford and the renewal of its maintenance agreements. In August 1992, DEC's Ford account manager wrote to Olsen and Palmer complaining that he had to downsize two of his team. This was in spite of the fact that the team had brought in $32 million, which suggested that his team should be increasing rather than decreasing.[453]

---

[449] P. DeLisi, 1998. A modern day tragedy: The Digital Equipment story. *Journal of Management Inquiry* 7 (No 2 June): 126.
[450] http://www.thesunalsosets.com/editorials.html October 11, 2004 (accessed June 7, 2011).
[451] P. P. Shah, "Network Destruction: The Structural Implications of Downsizing."
[452] Fax to: Thomas Smith, Ford Corporate Account Executive, dated September 2, 1992. Located in Ken Olsen archives.
[453] Memo: August 12, 1992 From: Thomas Smith, To: Ken Olsen and Bob Palmer, Subject: Ford Account Update. Located in Ken Olsen archives.

DEC provides many examples of where the downsizing had unexpected results, confirmed by accounts from employees at the time. DEC reduced its headcount from 124,000 to 55,000 over a seven-year period, removing positions from all departments and thus affecting every aspect of the company. Olsen also expressed concern that the cutbacks were not being focussed on areas that were overstaffed, such as marketing and engineering, but were being carried out across the company and across the divisions.[454] This was in fact the downscaling position that DeWitt mentioned, where he suggests retrenchment involves downsizing but with a goal of productivity improvements from rationalisation, whereas downscaling involves permanent employee cuts and asset reduction, and downscoping involves reduction in a firm's output and focus, vacating competitive space.[455] Robbins and Pearce recommend that firms should retrench regardless of severity, firstly focussing on cost control and reduction and then, if an assessment of financial health indicates possible insolvency in the future, it should be supplemented with asset retrenchment.[456] Olsen was in favour of retrenchment, maintaining the DEC culture, but the board differed and DEC implemented downscaling rather than retrenchment. HP and IBM had succeeded with retrenchment, whereas DEC failed with downscaling.[457]

In May 1992, Olsen wrote of his concern that DEC was hiring marketers, when it already had too many marketers, whilst laying off productive staff.[458] In July 1992, he wrote of his concern that there was little or no 'fat in the field' but this was ignored in the downsizing that followed.[459] Also in the same month, he cautioned Palmer to 'soft pedal' the staff cuts when meeting the board, as it was conscious of DEC's problems and was aware that staff cuts alone could not fix them.[460] He also voiced concern in late 1992 that the company was cutting staff to reduce costs rather than restructuring to build market share and profit.[461] Again, this was highlighted in Lesly and Light's *Business Week* article, mentioned previously.[462] On 15th April 1994, concern was raised at an

---

[454] Memo: May 6, 1992 From: Ken Olsen, Subject: Business plans. Located in Ken Olsen archives.
[455] R. DeWitt, "Firm, Industry and Strategy Influences on Choice of Downsizing Approach," *Strategic Management Journal* 19, no. 1 (1998).
[456] K. D. Robbins and J. A. Pearce II, "Turnaround, Retrenchment and Recovery," *Strategic Management Journal* 13 (1992).
[457] See chapter 9.
[458] Memo: May 18, 1992 From: Ken Olsen, To: John Simms, Subject: Marketers Located in Ken Olsen archives.
[459] Memo: July 29, 1992 From: Ken Olsen, To: Executive Committee, Product Committee, Board of Directors, Subject: Fat in the field. Located in Ken Olsen archives.
[460] Memo: Jul 30, 1992 From: Ken Olsen, To: Jack Smith, John Simms, Board of Directors, Subject: Advice on due diligence meetings. Located in Ken Olsen archives.
[461] Memo: August 19, 1992 From: Ken Olsen, Subject: Who is crazy. Located in Ken Olsen Archives.
[462] E. Lesly and L. Light, "When Layoffs Alone Don't Turn the Tide," *Business Week*.

engineering staff meeting that headcount reductions were disrupting the organisation and that engineers were doing managers' jobs.[463] On 22nd April 1994, at the next engineering staff meeting, it was reported that a number of product releases had slipped due to resourcing issues in engineering.[464] Towers and Perrin conducted a survey of staff regarding the 1993 redundancy programme and presented the results to senior DEC management.[465] They found that the 1993 redundancy programme was poorly managed and did not achieve its objectives. It was significantly worse than the 1990 exercise under Olsen. The following results were obtained:

Table 10: Excerpt from Towers Perrin report on the 1993 redundancy programme

	Current Employees		Redundant Employees	
	Intended to	Actually did	Intended to	Actually did
Achieve company's objectives	83	28	76	17
Communicate the overall purpose	77	28	64	13
Communicate with employees affected	77	30	64	12
Construct appropriate severance package	74	54	73	55
Select the right people to leave	70	9	63	2
Support employees affected	71	30	60	11
Administrate effectively	71	20	68	10
Conduct a fair process	69	14	66	11

(percentage of responses).

Towers and Perrin reported that the redundancy process was perceived as a cost-cutting exercise, rather than a skills-rebalancing process, and that the selection process was questionable and inconsistent, with a belief that poor performers often managed to survive the redundancy process. It is therefore proposed that the redundancy process was repeatedly mismanaged within DEC, having a negative impact on the company and impairing any future recovery, rather than solving the problems of the company.

[463] Minutes of engineering staff meeting in DEC archives at the Computer History Museum, April 15, 1994.
[464] Minutes of engineering staff meeting in DEC archives at the Computer History Museum, April 22, 1994.
[465] Report results presentation by DEC strategy group, donated to Goodwin by member of DEC strategy group.

In the 1980s and 1990s, DEC made a number of acquisitions, buyouts and divestitures. Bowman and Singh looked at corporate restructuring and its link with downsizing activity, where corporations reconfigure their business to increase its efficiency and there is a resultant period of downsizing.[466] They conclude that restructuring is multidimensional and most of the gain from such an exercise comes from asset sales, rather than from efficiency gains. In DEC's case, there were a number of acquisitions in both America and Europe that were intended to add to the company portfolio, followed in the later years by selling off various parts of the business considered non-strategic. Unfortunately, there was no coordination in the acquisitions nor did there appear to be any corporate plan behind them. This led Olsen to question in a memo exactly why the company had bought certain organisations in Europe and how they were to be assimilated into the company.[467]

DEC, after Olsen, first attempted downsizing and only after a number of years decided on restructuring and sold off a number of once-core competencies. During its period of downsizing, DEC maintained its R&D expenditure and did not reduce its asset size until it had been downsizing for a number of years.[468] The commitment to learning, for which DEC had been renowned, disappeared after 1992, when budgets for travel and education were severely curtailed. This in turn had a detrimental effect on the technical health of the company that had always had a reputation for excellence in its engineers. Drew suggests some guidelines for success in downsizing. He discusses the need for strategic planning, commenting that this is often neglected, as is the need to build organisational learning capabilities.[469] He even quotes DEC as an example of a company that is cited for its commitment to learning. If DEC management had read Drew, then the downsizing process that they implemented might not have been as painful for the company or its employees.

7.2.1 *Key Indicators*

A number of key indicators in 1994 indicated there was a problem with the redundancy process.[470] The voluntary termination rates amongst employees rated number 1 was running at 6.2%, where a 1 is the highest of five ratings given to

[466] E. H. Bowman and H. Singh, "Corporate Restructuring: Reconfiguring the Firm," *Strategic Management Journal* 14, Special Issue, Summer (1993).
[467] Ken Olsen Archives, Gordon College, January 6, 1992.
[468] Referenced in company reports in Ken Olsen Archives (1992–1997).
[469] S. A. W. Drew, "Downsizing to Improve Strategic Position," *Management Decision* 32, no. 1 (1994).
[470] Internal DEC 'Critical Path' report 1994, supplied to Goodwin by a member of the DEC internal strategy group.

employees based on performance. In network engineering (one of the core competencies of the company) it was 17%; sales specialists volunteered at 9.2%. Employee litigation costs were $1.93 million in fiscal year 1993. A management presentation at the time stated that a 5% loss in productivity would cost the company $113 million per year. The redundancies at DEC not only reduced morale but also reduced productivity, which compounded the losses the company incurred. Discussions with a senior HR manager from the UK, and later EMEA, confirmed the details of the redundancy process that had been followed. In the early rounds, the redundancies were driven bottom up, with the different countries examining their operations and identifying opportunities for reducing headcount by streamlining and outsourcing. However, in the later rounds they were dictated from above and, in EMEA, the UK was seen as an easy target due to the legal difficulties in other countries with letting people go. This was not an issue in America, where work legislation was not as restrictive.

Two employee surveys conducted for the company by Gallup in 1994 and 1996 show that matters did not improve over the years.[471] In 1994, the Gallup Poll noted that concerns were voiced that the company had become a 'management by numbers', an over-controlled organisation, no longer customer or employee oriented. There was a concern that the redundancies were taking too long and organisations had reduced headcount without adjusting the workloads. The employees believed that the company was too focussed on the short term, solely concerned with the current quarter. Salary increases at senior level were not well received by employees whose salaries had been frozen. A Securities and Exchange Commission filing of the time shows that five of the senior executives received 10% of the stock options granted by the company at the time.[472] Palmer's salary increased from around $740,000 to $900,000, Charles Christ had an increase from $290,000 to $315,000 in two years and Strecker had an increase from $305,000 to $427,000 in the same period. In 1996, the Gallup poll showed job security was still a major concern and the company was still deemed to be too focussed on the short term. Voluntary turnover was still higher than normal and re-engineering the work during redundancies was not performed consistently, leading to poor morale. Employees believed that reaching headcount goals seemed more important than reducing costs. This was evident in the feedback from the employee survey discussed later.

[471] Copies were received confidentially by Goodwin from an internal corporate strategist.
[472] SEC filing, Schedule 14A, September 14, 1994.

7.3 *Results of Employee Survey*

In 1994, Bryan King surveyed the information systems professionals at DEC and presented his results as a part of his first-degree submission.[473] He looked at how the downsizing of 1990 to 1993 affected the productivity and morale of those that remained with the company. His hypothesis was that within the Information Services (IS) function within DEC there had been an adverse effect on productivity and morale, and that, had the downsizing been implemented differently, there might not have been as great an impact. This was a survey of one department within DEC and for a two-year period at the beginning of the downsizing process. He also noted that the management in IS appeared to escape the downsizing intact.

In order to confirm the situation at the whole of DEC throughout the 1990s, a web survey was carried out using the worldwide DEC Alumni organisations to contact ex-employees. The survey was conducted to discover whether the issues discussed previously were present in DEC and if they had a potentially detrimental effect on the corporation. The methodology used was an Internet survey to ensure the reach was to the whole of the employee population, because the respondents were spread across the world and this was the only practical way of gaining a complete picture of the company. This was a random survey, in as much as it targeted all ex-DEC employees worldwide, but there is an aspect that could give a degree of bias in that the respondents were all members, or friends of members, of DEC Alumni societies, and as such might have a degree of affection for the company; they were also all self-selecting.

There were over 1,000 responses to the survey. About 50% of the respondents had left the company because of the downsizing process and 50% remained with the company which provided a good comparison point, after the purchase by Compaq.[474] In the 40 years that DEC existed, 350,000 people were employed.[475] A sample of 382 was required to give an error rate of less than 5% and a 95% confidence rate. The survey achieved a return of 947, which gives a precision of 3.5%. Given that it was 10 years since the company was sold to Compaq and 20

---

[473] Project submitted to the school of management at Lesley College, Massachusetts in August, 1994. "The Effects of Workforce Downsizing on Employee Productivity and Morale in the Computer Industry".
[474] 1,800 attempted the survey, but only 947 completed it fully.
[475] Figure stated by Peter Koch of the DEC Alumni Association at the memorial service for Ken Olsen at Gordon College May 14, 2011.

years since the downsizing started, this was a better than expected response, giving confidence in the data. The ethical aspects of surveys were adhered to, with the survey being completely anonymous by all participants, apart from those who elected to give details in the free text field for further follow up. The first two questions on the survey were to ascertain the geographical spread of the respondents and the area of work to ensure an even distribution of data. The analysis of the responses is as follows.

As is illustrated in Table 11, the responses to the survey were spread across the globe in approximately the same ratio as the company income, with about 50% in EMEA and 40% in America. This gave a degree of confidence that the responses would cover an accurate cross section of the workforce and give a reasonable picture of the company at the time, as well as an accurate view of the employees' feelings.

Table 11: Geographical distribution of respondents.

	Answer	Count	Per cent
1.	Americas	381	41%
2.	EMEA	476	51%
3.	GIA (General International Area)	30	3%
4.	Other	55	5%
	Total	**942**	**100%**

The results indicate a reliable cross section of the functions that were represented in the company at the time.[476] The ratios of the responses followed the numbers in the departments with a reasonable degree of accuracy. Customer Services, Software Service and Sales were the main field-based units. Engineering and Manufacturing were based in a small number of locations, with Human Resources and IT/MIS being country based.

The year of leaving of the respondents was also requested so that it could be verified that all the periods of downsizing were represented, as well as a number of people who survived the layoffs and progressed to work for Compaq.[477] This was so that the change in attitude could be established, both by those downsized but also by those who remained.

[476] Appendix A-3 table 13
[477] Appendix A-3 table 14

The next set of questions was used to ascertain the downsizing methods, their influence on attitudes to work and management, and on morale in the company. The method used was investigated to see which of the models previously discussed were evident. DEC used almost all of the methodologies identified in the academic papers in their effort to reduce headcount.[478] This signifies a company that has lost direction and one that did not understand the reason it was downsizing. There appeared to be little focus on how the company could increase profits and income after 1992, merely a focus on reducing the headcount, ignoring the advice of Olsen.[479]

The next question attempted to understand whether attitudes to management and the company changed after Olsen resigned. This was the period where the company values were being questioned and senior management were trying to differentiate between 'old' DEC and 'new' DEC. The changes were in the way management interacted with employees. It became a much more top-down organisation after Olsen left and the employee attitude reflected this.

Two thirds of those that responded felt their attitude to the company worsened, although 50% replied that this had no bearing on their work.[480] When asked the effect on their work ethic, 50% answered 'yes' with 39% of those saying that its impact increased as the number of rounds increased. This implies an increasing influence on the work ethic, as the rounds appeared to be reactions to Wall Street and the quarterly figures. In staff surveys of 1994 presented to the DEC management team, supplied by a corporate strategist, there was an overwhelming agreement that people were anxious for the downsizing to end, rather than being repeated every time that the quarterly figures were poor.

The influence on morale was even more apparent, with 88% saying that morale was affected by the downsizing. While almost 50% of the respondents reported that the compensation package worsened. This would be guaranteed to create resentment from those who survived the first rounds as, even though they would have been regarded by the company as needed more than those who had been released, when it came to their turn, they received a worse package. This was more evident in the Americas, as employment rules in EMEA guaranteed many of the packages in the employee's contracts.

[478] Appendix A-3 table 15
[479] Ken Olsen Archives at Gordon College (September 28, 1992; May 6, 1992; July 29, 1992; July 30, 1992; August 19, 1992).
[480] Appendix A-3 table 16

Hallock looked at the empirical evidence linking rounds of layoffs and top executive pay, concluding that there was no conclusive correlation between the two, and that executive compensation did not tend to increase in the year after a major layoff was implemented.[481] However, in the case of DEC, entries in the Digital Notesfile warned that raising senior managers pay whilst the rest of the company had a pay freeze was having a detrimental effect on morale in the company, suggesting that DEC was rewarding those at the top, whilst ignoring the majority of the workforce. This was certainly born out in the Gallup employee survey and the SEC filings of the time.

When asked about how their departure was handled, the majority found it was handled well, which implies the company culture had not been completely forgotten.

The final part of the survey was a free text field for additional feedback. Many of the comments were critical of management, although there was an underlying feeling of nostalgia for the company itself. However, most felt that the company had changed in the 1990s and was no longer the same company they joined. A number spoke of the percentage cuts across the board without reference to how it would affect the business. There were stories of people sitting in their cars with customers, being phoned and told they were being released. There were also stories of survivors having increased workloads left by those made redundant and the toll on morale by the endless rounds of redundancies. The political aspect of the downsizing was also highlighted by employees who spoke of the loss of passion, stagnation and the walking wounded. A number spoke of having fifteen minutes to clear their desks before being escorted out of the building.

Orlando debates one of the ethical issues of downsizing that the philosophical community had ignored, namely that of its human cost.[482] DEC had intentionally opened manufacturing plants in the poorer areas of America and helped the people of those areas into useful employment. Closing these plants had a major effect on these communities. One of the most disturbing comments in the survey was from an employee who recalls seeing 'stacks of business cards left by psychiatrists' at the Marlborough offices because of the numbers of employees suffering mental problems from the downsizing. One senior UK employee tells of suffering from almost terminal clinical depression, never having recovered from his loss of employment with the company.

---

[481] K. F. Hallock, "Layoffs, Top Executives Pay, and Firm Performance," *The American Economic Review* 88, no. 4 (1988).
[482] J. Orlando, "The Ethics of Corporate Downsizing," *Business Ethics Quarterly* 9, no. 2 (1999).

All of the above reactions support our conclusion that the downsizing was handled poorly by the company, as described by Tomasko.[483] He discusses 'demassing', where greater than 10% are laid off, and the consequences for the company. In particular, he comments on companies that shift attention from gaining market share to their stock price as an indicator of performance. This is exactly what DEC did in the 1990s.

7.3.1 *Downsizing conclusions*

It has been shown that DEC was forced into downsizing by recruiting for an unproven market in the 1980s and being caught by the recession and change in direction of the industry. The downsizing at DEC began in a compassionate manner with regard to the employees. Many have commented that the package offered was very generous, some going so far as to say that it was too generous, given the financial problems of the company. Analysing the company reports adds weight to this theory: the reduction in staff and facilities resulted in a cost to the company of $550 million in 1990, $1.1 billion in 1991, $1.5 billion in 1992, $1.2 billion in 1994 and $420 million in 1996. This amounted to a total of almost $4.8 billion in six years, covering a reduction of staff of over 50%. A simple calculation puts this at a cost of around $80,000 per employee. It has been shown that the first rounds offered voluntary redundancy and early retirement, and were extremely generous as evidenced by feedback from employees who volunteered. A number of ex-employees have recalled their joy at being able to volunteer in 1992-1994. It has been argued that this led to a loss of valuable skills, as the company did little to categorise those who were able to volunteer, as shown in the Towers and Perrin report. Later rounds were across the board cuts with no regard to business requirements for growth; whole departments were sold off to erstwhile competitors, together with the staff. This left a gap in the support of products for customers, as the technical escalation path was no longer available for the service arm of the company. This, in turn, led to a loss of confidence in the company's ability and future, and badly affected sales. Sales departments stagnated while they waited for reorganisation as a result of downsizing. At the same time, they changed from non-commission to commission-based sales. Unfortunately, the commission structures were not in place, which again led to demoralisation of the workforce.

Part of the DEC downsizing included the closing of manufacturing facilities and consolidation of these facilities. Although this might have appeared a sensible and prudent move on the part of the company, in practice some facilities that had

---

[483] R. M. Tomasko, *Downsizing: Reshaping the Corporation for the Future*.

just geared up to produce product, and were achieving best in class, were suddenly relocated to another manufacturing facility, resulting in a gap in production as well as the loss of experienced production workers. Bob Glorioso in a private communication tells of the VAX 8600 manufacturing base being moved twice, each time just as the facility had perfected its manufacturing process. This would suggest that medium-term planning had not taken place in relation to the closure of manufacturing facilities, and that the impact on production had not been considered. This was one of a series of errors that DEC made during its downsizing. Olsen was against the wholesale downsizing that went on during the 1990s at DEC, cautioning that the company should be concentrating on building for growth rather than cutting to reduce costs.[484]

As Cascio suggested, the benefits of downsizing did not materialise at DEC in the first few years after 1990 due to its influence on morale and productivity.[485] Management distanced itself from the downsizing by employing HR to implement the cuts and did not communicate with the employees, as feedback from the employees surveyed indicated, as well as the Gallup feedback. This is in line with McKinley and Scherer's findings on cognitive order. In fact, at one time or another in their period of downsizing, DEC appear to have made all of the ten mistakes that Cascio identified as ones to avoid.[486] Palmer attempted to change the culture at DEC whilst changing the top management and downsizing the company. As Hickok comments, this cultural and management change altered the employer-employee relationship from a family relationship to a confrontational one.

It is the considered conclusion of this thesis that the way the downsizing was handled, the people who were targeted and the loss of focus on gaining market share all had adverse consequences for the company and contributed to its demise. This, together with the use of $4.8 billion to fund the downsizing and the lack of strategic planning, added to DEC's problems when it was trying to regain market share and direction. It has been argued that this significantly delayed any recovery for the company and eventually led to the senior management considering a merger, rather than continuing as an independent company. Many papers have been written on the subject of staff reductions and most detail the pitfalls of incorrect downsizing. It has been shown that DEC did not take any of these into account when reducing its headcount, although a number of managers

[484] Various memos in Ken Olsen archives (1991-1992); for example, Memo: July 29, 1992 From: Ken Olsen, To: Bob Palmer, Subject: Fat in the field.
[485] W. F. Cascio, "What Do We Know? What Have We Learned?," *Academy of Management Executive*.
[486] W. F. Cascio, "Strategies for Responsible Restructuring," *Academy for Management Executive*.

made significant efforts to release the right people. The management created stagnation in the sales force by the poor introduction of a compensation scheme which left the sales personnel unsure what their compensation would be or how they could achieve the required results. This, together with the impact on morale and company loyalty, was a significant impediment to recovery.

7.4 *Conclusion*

Olsen's approach to the need for downsizing was, in our opinion, mostly correct, although he did not perceive the extent to which downsizing was required. The error that he made, however, was to look for early retirement volunteers for the initial rounds. This meant that people with needed skills would be lost, as they could easily find employment elsewhere. He did however recognise the need to plan for growth, as well as removing those employees who were underemployed. Palmer, on the other hand, had only cut staff in the semiconductor manufacturing division before his promotion and even then many commented that he had cut too deeply. The board wanted deep cuts and Palmer did just as it asked. In doing so, it has been argued, he made a number of mistakes. Firstly, he cut indiscriminately without regard to required skills. Secondly, he did not cut quickly enough and continued the cuts for many years. Finally, he did not plan for growth. All of this is clearly against the scholarly wisdom as published in many papers, as has been indicated. Schumpeter and Christensen both argued that new technology would require fewer personnel. DEC failed to build its business over the 1990s and so had to continue with its manpower reductions.

We propose that the company, once the board had decided that Olsen should relinquish his position, should have analysed the areas that were overstaffed and those that were not core to its growing business, and should then have implemented an appropriate staff reduction in those areas, whilst maintaining the core functions. This should have been a one-off heavy reduction of staff, which would have resulted in a more balanced revenue versus expense scenario for the company, more confidence in Wall Street and a company that was able to focus on growth as Olsen had wanted. HP had executed this action, as had IBM, both successfully as indicated in Chapter 4. DEC would have had more time to analyse their position, rather than reacting to Wall Street. Morale would not have suffered, as many recognised the need to reduce numbers of employees and they would have seen a company that was growing, rather than stagnating.

8 Financial Analysis over the Years

8.1 *Introduction*

Schein proposed that DEC's decline was due to the 'lack of money gene' in its management.[487] It is therefore important that we examine the financial performance over the years to determine the extent of its impact on the company and also determine whether this was due to management's lack of financial cognisance or external influences. The company's finances have been analysed to identify a number of the issues facing DEC during the 1990's and also to identify whether there was a lack of money or a lack of product creating the problems. The accounts are presented and the reasons for the losses are discussed in order to understand the actions of the management. The Wall Street crash of the 1980's had hit DEC's share price along with everyone else in the market. However, whilst others recovered in the late 1980's DEC's share price continued to decline and the reasons for this will be explored. One of the major factors that provoked the financial problems at DEC was the hiring of around 30,000 personnel to attack the IBM market at a time when that market was declining as discussed earlier. It will be argued that DEC had the finances to refocus on growth in the 1990s but instead it concentrated on maintaining its cash reserves and reducing costs. The company had a problem with declining margins which they didn't handle well in the late 1980's. Senior managers are accused of not implementing Olsen's restructuring directives, budgetary directives and downsizing directives. Argument is presented to support the assertion that the board should have appointed a successor to Olsen sooner rather than waiting until there was a crisis and they should have taken more time in selecting a successor. Palmer was selected mainly on a video presentation to the board, against Olsen's opinion, and left in charge to preside over many years of losses when it might have been prudent to replace him sooner.

DEC was always conservative in its handling of finances, maintaining an extremely low borrowing rate and relatively high reserves of cash. For many years it did not pay a dividend, relying on the increasing share price to satisfy investors whilst maintaining its growth. Whilst rebuffing any attempts at being taken over, DEC often resisted the temptation to buy many dynamic young companies such as SUN, Microsoft, MIPS, Compaq and Apple, a policy that, it will be argued, was to have severe repercussions later. This financial restraint had helped to maintain the company's extremely good credit rating and stock

[487] E. H. Schein, *DEC is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 1st ed. (San Francisco, CA: Berrett-Koehler, 2003). 86

value for many years but cost it dearly in its future strategy. It is argued that buying and developing small dynamic companies could, potentially, have offset the attacks on its product space in later years. For example, SUN had grown as a result of buying smaller companies, as had HP, IBM, Microsoft and Compaq, yet DEC maintained a policy of internal development, shunning anything that was not developed in-house. When the company did invest in external organisations it made many mistakes, often losing money in later years. Palmer, as will be shown, maintained the cash balance, mainly due to the sale of profitable product lines, but increased the long term debt of the company and focussed on profit rather than growth.

8.2 *Finances*

Up until 1990 DEC's finances were looking very healthy with annual profits in the billions, and revenue itself was also healthy, but not growing, up to 1997. Kotter and Heskett (Kotter and Heskett, 1992) reported that of 207 leading US firms surveyed, DEC was number 11 in the long term economic performance index over eleven years with HP at 18. They also reported that for the average yearly increase in stock price for 1977 to 1988 they were number 33 with HP at 47 and IBM at 146. In the early 1990's DEC's problems hit customer confidence and hence sales flattened out. But DEC started to pick up again from 1994 to 1996, revenues were fairly flat but taking the sale of 8% of its product offering to third party vendors, flat equated to a growth in real terms. Its financial problems can be traced to:

- The high cost of sales at a time when margins were reducing.
- Too many employees compared to similar sized organisations in the same business sector in the late 1980's.
- Delayed product releases, in particular the VAX 9000 and RISC systems.
- An overly generous redundancy package in the beginning of the company downsizing in the early 1990's.

All of this was widely reported in the press at the time. In one of the many comments by ex-DEC employees it was stated that 'Ken saw profit as a natural outcome of doing the right thing for customers, not an end in itself', although as mentioned above, profitability was the second rule in the company beliefs. DEC was an ethical company that didn't focus purely on profit, rather it focussed on technical excellence in its product to enable profit. This was one of the reasons that DEC salesmen were not commission based as Olsen believed they would only sell what the customer needed by not being financially rewarded for sales.

Schein argued that the root problem at DEC was, in his words, the lack of the 'money gene' in its management.[488] There are a number of definitions of 'the money gene' but they basically all come down to the desire to generate money. We believe that this has not been proven to be the root of the problems at DEC. In fact DEC's management tried to hold on to its high margin business thus maximising its income when it should have foreseen the move towards open systems replacing proprietary systems and thus reducing margins. Hence we suggest that it was clearly a lack of business acumen rather than a lack of money gene that caused the problems at DEC. Analysis of the company's products and technologies also point towards more of a lack of the marketing gene than the money gene which will be shown in the next chapter. In Bell's appendix to Schein he states that he refuses to believe that DEC lacked the money gene and in fact, as mentioned, the second rule in the company was profitability.[489] Olsen preferred the comfort of DEC's VAX systems, believing that they were superior to any open systems and did not see the change coming or prepare the company for it. DEC's problems in the 1980's were not just technical but also financial as a result. They went from healthy profits to substantial losses in a few years.

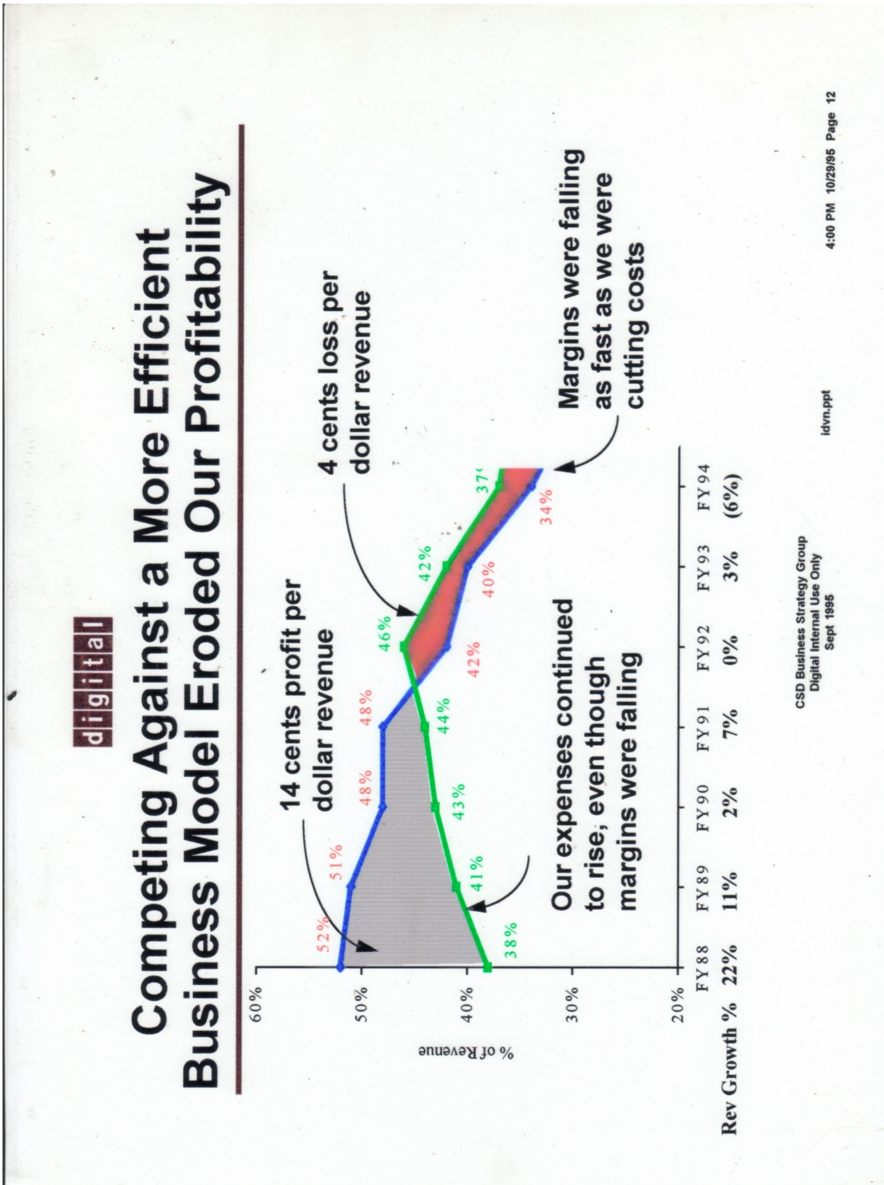
It does not necessarily follow that not focussing on profit implies that DEC management lacked the money gene. However it is clear that DEC realised too late that sales and more importantly profits per employee were lower than comparable companies as shown in Table 12 and that margins were falling as expenses rose and even when expenses were cut through downsizing and rationalisation margins still fell faster as can be seen from Figure 18.

Table 12: Sales/profits per employee from internal mail reporting research in 1991

Company	Sales/employee	Profits/employee
Apple	$440,000	$37,400
Compaq	$379,000	$47,900
IBM	$185,000	$16,100
SUN	$217,600	$9,650
HP	$139,000	$7,780
Digital	$104,000	$600

488 E. H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 1st ed. (San Francisco, CA: Berrett-Koehler, 2003)
489 Ibid. 292

Figure 18 Expense versus margin

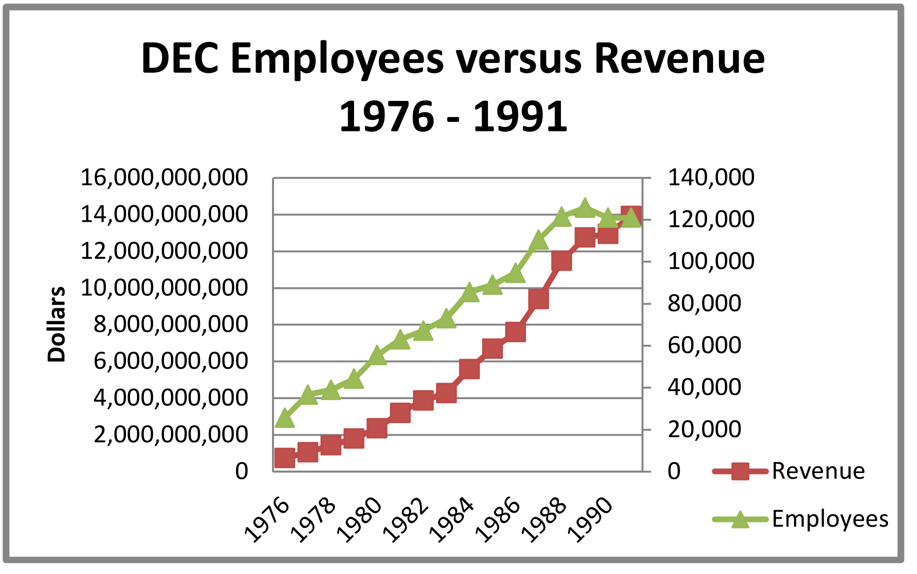


(Supplied privately by member of DEC corporate strategy group)

DEC also invested heavily in its research facilities, having a number of labs across the world working on advanced technologies and producing many scientific papers. These establishments, as will be shown later, produced a number of technologies that could have assisted DEC during its troubled times but conflict with engineers at the corporate headquarters hampered the productisation of these technologies. Examples of these are DEC's RISC systems which began with Titan in Palo Alto, also AltaVista, again out of Palo Alto. Palo Alto was regarded with suspicion in Maynard and Palo Alto had a number of ex-LCG (PDP-10) engineers who had a distrust of management in Maynard.

DEC's financial problems could have been managed without the focus of Wall Street had it not increased its manpower from 1986 to 1990 by around 30,000. The company had hired, prematurely, for an assault on the IBM market with the VAX 9000. This increased the salary bill by up to $1 billion per annum at a time when a world recession was beginning. The VAX 9000 was late and the IBM mainframe market was declining, leaving DEC with an unnecessarily large wage bill. The cost to the company was considerable. DEC was also slow in recognising the move to server based computing in the mid 1980's and consequently, as Schumpeter predicted, the reduction in the manpower required by computer manufacturers for the new paradigm. This, together with a stated goal of overtaking IBM resulted in a large excess of manpower when it was not needed, which, when coupled with a company culture that created a reluctance to cut headcount, led to DEC having far too many employees for the income the company was generating by the late 1980's given the reducing margins as shown in Figure 19. This is one of the clearest examples of a company attacking the wrong market and investing in manpower without a clear view of the financial penalties of doing so. It is argued that the board must share the responsibility for these actions along with the senior management.

Figure 19 Employee population versus revenue (1970 – 1991) plotted from data in company reports.



A number of internal and external commentators put this manpower excess at 30,000 as mentioned above. In fact Peter Moyes in a chapter of an unpublished book stated that: [490]

> *"a colleague and a friend, Nicola Renshaw, did a comparison of the performances of Digital, Hewlett Packard and IBM as part of her MBA studies.....and she concluded that Digital was seriously overstaffed."*

He went on to say that she estimated that DEC needed to cut staff by about 50,000 to compete on level terms. Olsen struggled with this for some time, many memos in his archive relate to his attempts to get his senior management to set realistic budgets for a number of years as well as memos relating to the need for the senior management to realise the manpower reduction targets they had set themselves.[491] When DEC eventually resorted to redundancies, the redundancy payments were generous and very costly to the company, amounting to around $5 billion over six years from 1991 to 1997. There was also a continuing management failure to deliver the required redundancies in a timely manner prolonging the expense even further. The board itself was concerned with the overgenerous redundancy that DEC was offering as witnessed by DEC director Tom Philips[492]. In fact, DEC's redundancy payments almost completely account

[490] Personal communication from Peter Moyes (ex-DEC) 17th March 2008
[491] Ken Olsen Archives, Gordon College, Massachusetts
[492] Interview with Ben Strout.

for the losses they incurred during the six year period of downsizing. Of course this does not take into account the employee costs that were saved by the downsizing. During the period 1993 to 1997, under Palmer, DEC decided to focus on core competencies and divest a number of product ranges and associated employees resulting in a reduction in ongoing revenue of 8%, a reduction in headcount of around 5000 and generating an income of around $1 billion[493]. In real terms this was a reduction in revenue of $1 billion per year for a one off income of $1 billion by selling off profitable product lines whilst maintaining a number of non-profitable products. As Ann Jenkins put it "Palmer sold the crown jewels when we needed the income they generated". [494] Many ex-DEC personnel, including senior management, interviewed suggested that in the later years Palmer was selling product lines in order to make the company a takeover candidate. However, Strecker suggested that DEC had too many product lines for the money available for R&D investment which led to a dilution of product development and that DEC needed to refocus. [495] It is apparent that some divestment was necessary as the company could not afford to invest sufficiently in its vast range of products but it is also apparent that the ones sold in later years were not the correct option.

Palmer, when he took over, recognised the need to get costs under control and so instituted a number of measures aimed at achieving this. He started a salary freeze for most of the company but left out the senior managers, many of whom were recruited externally by Palmer himself. These managers received large increases and share options, causing extreme resentment from the majority of the employee population as indicated in memos from Ken Olsen and employee feedback in the Digital Notes file.[496] He also started the headcount reductions in earnest to remove the excess that had been hired over the 1988 – 1992 period. However he acted hastily and did not do a full analysis of who should be removed, rather he implemented across the board cuts. It is suggested however that the downsizing could have been handled differently. It is asserted that Palmer could have taken six months to look at the organisation, decided what products were core and focussed the downsizing on the excess staff in non-core activities, thus maintaining growth whilst reducing staff instead of stagnating growth. Palmer, in fiscal year 1995 implemented a 40% cut in sales and marketing due to a move towards more indirect channels for sales. This was a policy put forward by Pesatori according to Business Week and should have

[493] Data from annual reports for Digital Equipment Corporation
[494] Interview at Gordon College 2009.
[495] Interview 7/Feb/2011.
[496] Various memos in Ken Olsen archives at Gordon College.

resulted in large savings for the company. [497] However in October 1996 there was an unexpected loss for the quarter which Palmer attributed to the fact that DEC had cut its direct sales force too deeply to focus on 1000 accounts worldwide and he would now expand that workforce. This is clearly another example of acting without looking at the consequences.

In looking at the impact of the downsizing on the company's financial performance it proved difficult to calculate the exact cost of the excess employees due to different employees being reported via different lines of the SEC filing. Selling, General and Administration expense (SG&A) is normally held up as a measure of employee costs although DEC bundled the costs of some employees into other reporting lines. Over the period 1986 to 1989 DEC's SG&A went up from 21.94% of revenues to 28.56% of revenues and their employee population went up by 30,000 (Scott, 1994). Average employee salary was therefore used to get a rough estimate of savings. In the UK in 1983 the average cost of an employee in DEC was £11,000. By 1987 that had increased to £13,300 according to the UK Annual Reviews. The average salary for employees in the Boston area in 1991 was $28,500 per year.[498] From this it can be estimated that the annual cost of the 30,000 excess staff at DEC was around $850 million. Obviously the company could not carry this cost for an extended period and so the board were correct in requiring staff cuts. The alternative proposed by Olsen was to grow the company to meet the employee population. The assertion is however that DEC did not have the products at the time to grow significantly so the best course of action was an immediate headcount reduction followed straight away by a strategy for growth.

By 1994 the company reports suggested that there was actually a reduction in overall operating expense of $4 billion, which should have resulted in healthy profits but didn't because the company's margin was declining just as rapidly as the cost reductions. An internal report by Bain and Company, one of the many strategy consultancies brought in by Palmer to advise on company direction, on the 'Digital Turnaround' suggested that DEC had a near-death experience in 1994 when there was a surprise loss for the third quarter of $183 million and there was only 90 days of cash remaining.[499] SG&A was out of control at 53% of sales compared to HP's 24% but by 1995 DEC had turned it around to about 30% of sales and DEC had a 6% revenue growth compared to IBM's -7%. Bain and Company also reported that their effort was now focussed more on strategy

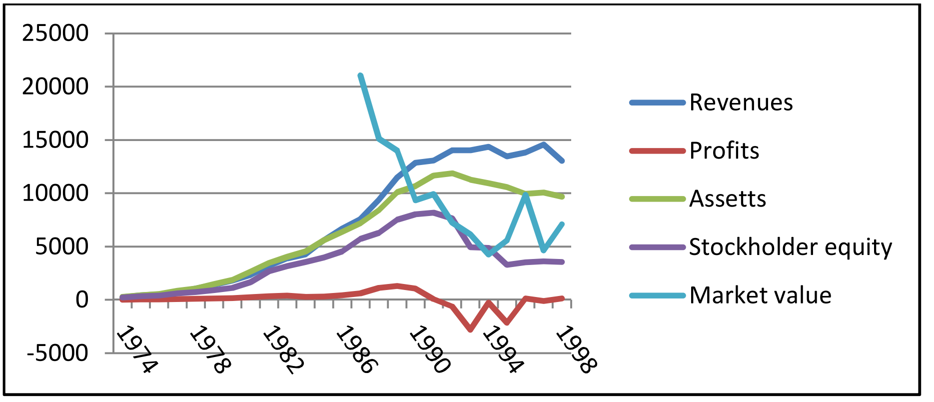
---

[497] Article on "Digital's Turnaround: Time for Phase Two" by Mark Maremont 19/Jun /1995
[498] Taken from Heinonline.org last accessed 9/Sep/2009
[499] Donated to Goodwin by Kathy Hornbach of Corporate Strategy.

and operations rather than implementation. However, Palmer's response to this loss was yet another round of headcount reductions.

8.2.1 *Fortune 500 data*

Figure 20 Fortune 500 data for DEC



The figure 20 shows that the company's market value dropped significantly from 1987, well before the profits tumbled, halving in four years and halving again over the next three. From 1990 the market value was below the asset value and in December 1989 DEC adopted a stockholder rights plan[500] as a 'poison pill' to ensure no hostile takeover bid was attempted. This was very important in 1995 where the market value was $3.279 billion and the asset value was $10.579 billion. The poison pill clause was revoked at the 1997 stockholders meeting, just before the Compaq takeover in 1998. Shareholder equity peaked in 1991 before dropping dramatically. After the four years of dramatic downsizing, profits began to recover slowly.

8.2.2 *General Analysis of Company Data (1986 to 1996)*

The Security and Exchange Commission filings submitted by the company and the company reports were studied and the data for the twelve years up to 1997 extracted.[501] DEC's finances up to 1986 gave no real cause for concern to the board as it was growing year on year and its products returned high margins. The market was however changing and so the senior management and the board

[500] Los Angeles Times article 12/Dec/1989
[501] Shown in Appendix.A-4

should have been planning for this change. After 1986 DEC's financial position declined rapidly from one of high profit to negative income by 1991. DEC found it very difficult to track its costs due to its multiple interrelated product lines which saw costs being assigned to different groups and sales revenue being reported by more than one product line for the same sale. When Palmer introduced a commissioned sales force the situation worsened due to lack of clarity on the basis of the commissions. DEC also introduced a SAP system for, amongst other things, order processing which was a troublesome implementation in the early years, losing booked sales and sometimes shipping duplicate orders to customers. SAP was also blamed in part for a loss of product revenue immediately after the Compaq merger.[502]

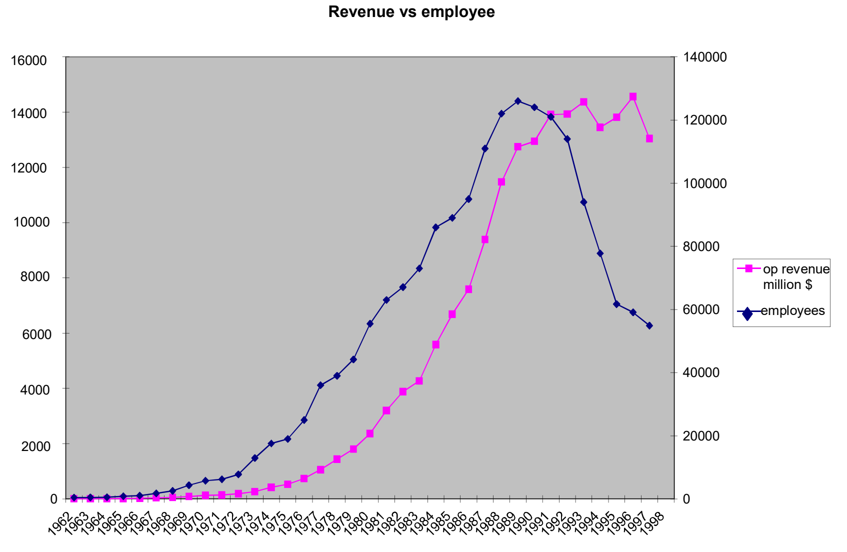
From the company reports it is clear that DEC was in financial trouble by the early 1990's. Cost of sales had almost doubled in the five years from 1987. Selling and general admin charges went up almost three times in the same period. R&D costs were up by 75%, accounts receivable were up 75%, employee population went up almost 50% and working capital had halved. The balance between product sales and service revenue also altered in this period with services becoming a much bigger factor in the company's revenue stream. This was clearly a company whose finances were out of control. It is understandable why the board were concerned in 1992, but the problem had been building for a number of years before that and it could be said that their action was too late and hurried. This is clearly an example of a board that was not performing.

DEC had always invested heavily in R&D but in the 1980's this level of investment became unsustainable as DEC implemented a number of technologies that proved to be both costly and problematic. DEC's first product involving a large investment in product development was the RA90, a thin film technology disk which will be covered in the next chapter and is often quoted by Christensen when he discusses innovation. The company then followed this up with the VAX 9000 which, according to those involved cost between \$2 billion and \$4 billion to develop. Finally the Alpha chip required a great deal of investment in plant for manufacturing. All of these cost the company many billions of dollars at a time when their margins were being eroded. It took Palmer some time to get the finances under control. The R&D investment dropped significantly from 12.5% of revenue in 1992 to 7% in 1996. However, inventory peaked in 1994 due to the back filling of the channels, mainly in the PC area by Bernhard Auer, DEC's Personal Computer Business Unit VP, a strategy that was to prove costly due to low PC sales. Every quarter DEC was putting in 30 to 50 percent more PC's into

[502] As reported in the Digital Notes file note number 3300,40

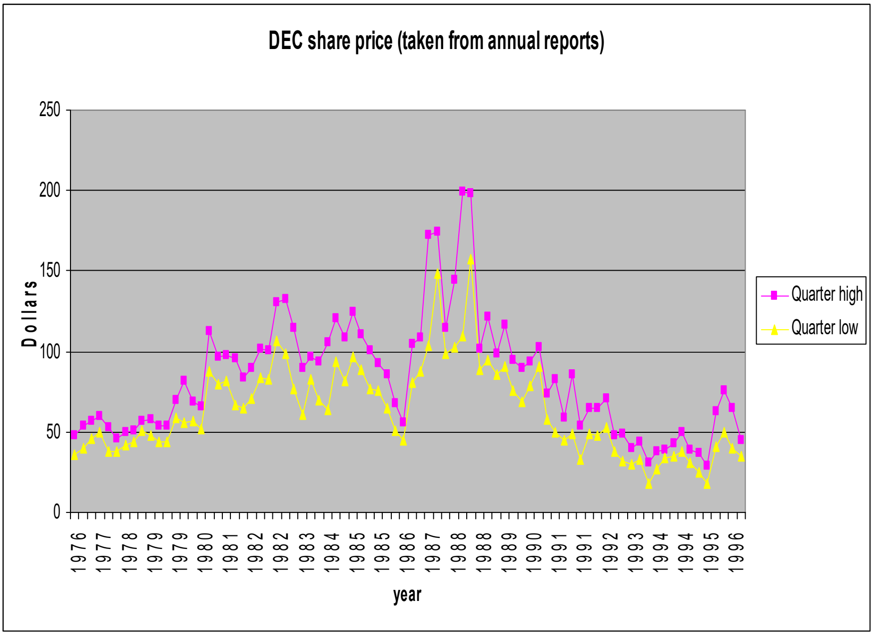
the channel than were being sold.[503] This was identified by Claflin after he was hired from IBM to replace Auer in 1995. Auer himself had been promoted by Palmer to replace Pesatori in 1994. DEC's long term debt policy altered as soon as Palmer took over, going from $42 million to $1 billion in his first year. The effect of selling manufacturing plants can clearly be seen in the property assets, peaking at around $3.8 billion under Olsen and reducing to $2.2 billion after Palmers cutbacks.

Figure 21 Revenue vs employee sourced from company annual reports.



[503] The New York Times 25/May/1997 business section article by Laurence Zuckerman 'For Digital's Chief, A Last Grab for Glory'

Figure 22 DEC share price by quarter



DEC's share price dropped back to 1977 levels and revenue per employee doubled by 1997 as can be seen from Figure 21 and Figure 22.

8.2.3 *Financial Analysis of the 1990's from the Company Reports*

The following analysis is based on data from DEC's annual reports and comments in the company's SEC filings.

By the 1990's DEC had moved from a position where over 60% of its business was US based to one where 66% was from overseas, bringing with it issues around foreign exchange fluctuations and on the technology side issues with voltage and frequency differences to be addressed. Service revenue had grown during the 1980's from \$2.4 billion in 1985 to around \$5 billion by 1990. During the 1990's this income was flat at around \$6 billion, reflecting the move towards commodity computing and IBM's entry into the services market. Product sales dipped in the first half of the 1990's but were on the increase by 1996, bringing almost \$8.5 billion to the company.

The following paragraphs are summaries of the annual company reports for the years 1990 to 1997.

In his 1990 company report[504], Olsen says that 3000 jobs were eliminated by voluntary separation, the costs of which were absorbed by the company. He also focuses on mainframe style computing and fault tolerant systems as the future. He reports on DEC's commitment to client server computing, emphasising DEC's commitment to RISC based workstations. DEC sold over 560,000 terminals during the year and Olsen commented on DECWORLD in Boston which included the QE2 as a floating hotel. This, although a very costly business extravaganza, brought in sufficient business to warrant the cost. Product sales were flat due to a weakness in the US market and customers waiting for the new high end VAX 9000 that had been preannounced. Service revenue also slowed during 1990. R&D was now 12.5% of revenue, Olsen believing that such investment was needed to maintain the company position as a leader in its field. The company tax rate was 40%, up from 25% due to the lack of profitability in the US making it impossible to utilise all of the foreign tax credits.

In the 1991 company report Olsen is much more downbeat. He comments on the challenging times for the computer industry, improvements in technology and the dramatic increase in productivity. He laments the need to downsize but comments that it is a result of the technology that DEC worked hard to develop. The company reported a loss of $617 million mainly due to a downsizing charge of $1.1 billion. During the year, he reports that DEC shipped 330 VAX 9000 systems. In his memos, Olsen suggests that departments had been slow to downsize and had not, in many cases, delivered the numbers they had committed to.[505]

In the 1992 company report DEC reported a loss of $2.1 billion which seemed disastrous for such a stable company and shook Wall Street and depressed the share price. However when this is analysed, there was a $500 million charge for implementation of a new accounting standard for postretirement benefits, $1.5 billion for restructuring charges and a tax bill of almost $250 million due to profitable foreign operations, leaving what would have been a small operating profit on revenues. Also in 1992, 3700 took the very generous early retirement package, DEC losing some very valuable skills, and even though the headcount was reduced by 23,000, some poor acquisitions in Europe added 11,000 employees and cost the company about $500 million. These were the acquisition

[504] DEC company reports are available at Gordon College in the Ken Olsen archives.
[505] Also in internal memos held at the Ken Olsen archives.

of the Philips and Kienzle operations, followed by the purchase of a stake in Olivetti which was to cost $287 million in FY93. Also investment in the Hudson semiconductor plant, which Palmer promoted, was to cost DEC $425 million over four years. Investment in R&D increased to 12.6% of revenue. This was Olsen's last report and in it he announces that Alpha had shipped and that DEC was the fastest growing personal computer company in the industry. He also talks of modular computing enabling processor and storage additions when needed, which was an initiative that he began at DEC and urged Palmer to continue. Palmer subsequently killed off modular computing research at DEC.

In the 1993 report, Palmer's first full year, it stated that SG&A expense was hit due to Philips/Kienzle but the tax bill reduced to $27 million. Service margin was running at around 40%, cash reserves increased to $1.6 billion, up from $1.3 billion in the previous year but debt was up to $1.04 billion, up from $42 million in 1992. Operating income showed another loss of $237 million and the company's assets totalled almost $11 billion. Palmer eliminated around 20,000 people in his first year taking the employee population down to 94,000, reduced R&D to the equivalent competitor's investment and eliminated 3.3 million square feet of manufacturing space. He also talks of attracting professional, experienced talent to head up sales and marketing as well as the consulting and new business divisions. Many of these were ex-IBM and they were to prove problematic for the company in terms of compensation and performance.

By the 1994 report, margins were down 6% to 34%, European revenue was down partly due to issues with the Kienzle business. In 1994, Palmer took another restructuring charge of $1.2 billon, $679 million for separations and $527 million for plant closures. This resulted in another $2 billion reported loss for the company. He reported that during 1990, 1991, 1992 DEC eliminated approximately $2.5 billion in operating expense and 1994 restructuring, when complete (20,000 people), should eliminate a further $1.5 billion. During the year DEC also wrote off $194 million for Kienzle and sold Olivetti stock for $148 million ($150 million loss). Long term debt was stable at $1 billion and cash reserves had reduced to $1.18 billion. In the 1994 company report, Palmer talks of a year of progress and frustration, eliminating 12,000 personnel and 5.2 million square feet of manufacturing space, eliminating DEC's inefficient matrix management system and shipping over $1 billion of Alpha systems since 1992. He talks of the move to indirect channels and refining product and service costs but the bottom line is still red for DEC. In the Q&A there are questions about divestment and employee morale for the first time.

In his 1995 report, Palmer says that Alpha based sales had increased to 22% of product sales, up from 13% in 1994 and 3% in 1993. Intel based sales were 26%, up from 19% in 1994 and 9% in 1993. VAX revenues were 10%, down from 19% in 1994 and 34% in 1993. Margin had reduced to 32% and cash reserves were up to $1.6 billion. During the year, the Queensferry semiconductor manufacturing plant was sold, including 530 employees, for $128 million, Contract manufacturing was sold for $75 million, including 700 employees, the disk business was sold for $360 million including 3100 employees and DEC's relational database product RdB was sold for $107 million including 250 employees. In Palmer's president's letter in the company report, he is more upbeat after three consecutive quarters of profit. DEC's market value increased by $3 billion in 1995 and he reported that DEC was one of the few multinational companies to maintain revenue whilst downsizing. DEC eliminated a further 16,000 positions in 1995. Even though signs[506] were appearing that DEC had turned the corner in terms of performance, Palmer continued to downsize and sell off profitable products. Many DEC employees questioned whether Palmer was trying to take DEC back to a hardware company.[507]

By the 1996 report, cash reserves were up to $1.8 billion, software development costs were running at about $100 million per year and long term debt was still around $1 billion. Alpha based system sales had increased to 29% of product sales, Intel sales were at 26% and VAX had reduced to 5%. Research and development costs were down to $1.1 billion from a high of $1.75 billion in 1992. Margin had stabilised at 33%, although this was a drop in services margin of 4% and an increase in product margin of 5% representing a reduction in service income, moving towards lower-margin multivendor service offerings and increased product reliability. Learning services were sold for $80 million including 600 employees although development was kept in house. DEC still managed to post a loss of $112 million on operating revenues of $14 billion even though employees were 59,000, thus employee costs had halved since 1991, and margin had reduced by 15%. This was due to yet another restructuring charge of $500 million to cover more redundancies and plant closures. Also in 1996, AltaVista filed a registration statement with the Securities and Exchange Commission for the registration of shares in its Class A common stock in an initial public offering, the significance of which will be covered in the next chapter. In 1996 the adjusted revenue was the highest in the company's history even after the sale of 8% of its business.

---

[506] Alpha sales were growing, revenue per employee was at or above industry norms, market value had increased and the company was profitable.
[507] Digital notesfile entries

In the 1997 report, DEC once again made an operating profit but revenue was down 10%, mainly due to reduced product sales. This was due to the discontinuance of the PC consumer range and anticipated reduction in inventory as a result. Alpha sales were at 33% but this was a decrease of 4% in revenue. Intel-based sales were up to 28% due to an increase in server sales. Other products accounted for 40%, down from 52%, in 1995 due to the divestment of various product lines. 1997 also saw the filing of a lawsuit against Intel alleging infringement of DEC's intellectual property in its microprocessors. This was an action that many, internally and in the media, suggested was primarily aimed at inducing Intel to purchase DEC's semiconductor manufacturing facilities.

1998 was DEC's final year and so only 9 months of data is available. In its final SEC filing, DEC talks of the strong US dollar having an adverse impact on revenue growth but it was still showing a profit. In this period DEC sold its network product business to Cabletron for $233 million and it announced a deal with Sequent to establish Digital UNIX as the leading IA-64 computing architecture. It also granted Samsung Electronics Co. Ltd. an Alpha architectural license, strengthening their existing agreement. Margin had increased to 34.3% and revenue in the US was up 8%. Windows NT server growth was 43% and UNIX AlphaServer revenue was up 11%. DEC's lawsuit against Intel had been finalised but was not included in the filing. DEC's merger with Compaq had been announced but had not been completed.

8.2.4 *Financial Summary*

As can be seen, DEC's financial position, although in trouble, was far from critical throughout the 1990's. The financial markets didn't agree, moving DEC's credit rating from AAA to CCC in the mid 1990's. All through the 1990's they had a very healthy cash balance, considerable assets and very little debt. This suggests that redundancy costs had been almost completely covered by operating profits, plant closures and divestments without impacting DEC's overall financial position. Palmer concentrated on DEC's finances, particularly cash on hand, rather than trying to invest for growth. In spite of this lack of investment, by 1997 DEC's sales were increasing, headcount had reduced dramatically, possibly too far and they were leaders in Microsoft technology services. This appears in contrast to the impression on Wall Street that DEC was near collapse in 1992 and Ceruzzi's statement that DEC in 1992 'was heading towards bankruptcy', although things were approaching critical at the time.[508]

[508] P. E. Ceruzzi, *A History of Modern Computing*, 2nd ed. (London, Eng. ; Cambridge, Mass.: MIT Press, 2003)

Customers, looking at the financial reports, however, were reluctant to buy DEC products in the 1990's due to worries about DEC's position and press reports about the company. These worries, plus concerns over redundancy policy and product strategy had led the board to look closely at Olsen and their concerns resulted in their asking him to relinquish his position to Palmer. By 1993 DEC's SG&A percentage was running at 30.94 and cost of product sales had hit a high of 58.83% as a result of the lower margins available.[509] Revenue per employee had increased to $153,000 in 1993 from the 1991 figure of $100,000 closing the gap on its competitors.[510]

---

[509] G. Scott, *Digital Equipment Corporation: R.I.P. Or Future Lean and Mean Competitior?* Scott Consulting, 1994).
[510] ibid

9 Discussion and Conclusions

9.1 *Discussion*

This thesis has examined the reasons behind the decline of DEC from a technology perspective with a view to proving whether Schein or Christensen was correct in their assertions or whether there was another factor behind the failure. Schein's theory of the 'money gene' has been considered by analysing the finances of the company and also the technologies that were critical to the future. DEC's handling of innovation was considered to determine whether the PC was the disruptive innovation responsible for the fall of the company as proposed by Christensen amongst others. The downsizing of the company has been compared with Cascio's and Budros's theories on how downsizing should be handled as a part of continuous improvement rather than in isolation. Product cycles are of paramount importance to technology companies as considered by Utterback, Anderson and Tushman, Christensen and Schumpeter in their dominant design and S-curve theories. Christensen had criticised the conclusions of Tushman and Andersen that firms were most at risk when innovation destroys competence. However he, in turn, was criticised by Danneels, Lepore and Gans who argued that Christensen cherry-picked his examples and that many did not conform to his theories.

We have shown that DEC grew rapidly in the 1980s, its pinnacle being in 1988 when profits and sales peaked. It's major and minor product cycles maintained a consistent period agreeing with the theories of Schumpeter, Anderson and Tushman and Utterback. The company's troubles started in 1983 with the departure of Bell and continued through the 1980s, culminating in the departure of Cutler and the subsequent replacement of Olsen by Palmer. The departure of Bell resulted in a sustained period of confusion for DEC's engineering groups with constant indecision over its RISC strategy, the debacle of its PC strategy and its lack of focus on workstations and UNIX. Olsen realized that the company was in trouble and tried to deal with it, but did not have his management's consensus, each having their own fiefdom, which they protected. We have also highlighted the part the 'DEC nod' played in some of those decisions even at senior level.

Schumpeter proposed that restrictive practices could steady the ship in the face of creative destruction but in the end evolutionary technologies will win. IBM found this out with RISC and DEC found this out with VMS. Both companies tried to maintain their high margins for too long. The problems at DEC worsened in the mid-1980s when the VAX/VMS product range started to be too slow and too expensive compared with the newer UNIX based systems that offered portability and compatibility. The company failed to invest seriously in UNIX until the 1990s, even though it ran on all of the DEC systems. UNIX was a dormant technology that DEC did not recognise until it had become a disruptive technology in the 1980s. DEC had also recruited to compete in the IBM market and so had about 30% too many staff on its payroll at a time when its margins were shrinking. In order to attack the IBM market, DEC had embarked on the ECL VAX 9000 project. This was late and the company was unable to recoup its development costs. The VAX 9000 was almost immediately overtaken by the lower cost disruptive VLSI/CMOS technology. DEC always had a number of parallel research projects going on so were developing CMOS systems alongside the VAX9000 but the main research funding was taken up by the VAX9000.

We have identified that DEC's market was being eroded by the low cost UNIX workstations in the mid to late 1980s and as a result it made the fatal decision to implement a third party technology in the form of MIPS chips in its workstations and cancel its own RISC development, the PRISM. This indecision resulted in Cutler moving to Microsoft and developing Windows NT, which looked very much like VMS and Mica. This in turn led to Microsoft developing an operating system that was to challenge VMS in the datacentre. However, had DEC extended the architecture of the MIPS chip and brought VMS compatibility to it, the company might have had the product set to succeed, but DEC changed direction once again and dropped the MIPS technology in favour of a resurrected PRISM program in the form of Alpha. This managerial indecision is proposed as the main cause of the company's failure along with a failure of technological leadership after the departure of Bell.

Finally, the board's patience was exhausted with Olsen and it asked for his resignation. The board reacted hastily instead of giving due consideration to Olsen's replacement and appointed Palmer who, many believed, did not have the capabilities to run such a large, diverse organization.[511] Palmer took over a company that was failing and in need of drastic action. He struggled for a strategy whilst downsizing indiscriminately, causing a state of stagnation in the company for a number of years. The downsizing led to a major reduction in morale, due to the way it was handled and the length of time over which it was implemented. The downsizing also had an impact on the company's technical resources, due to the lack of focus on which personnel should leave. These issues

[511] Feedback from many ex-DEC personnel and reports at the time.

agree with Cascio’s conclusions as identified in chapter 2. As Saxenian commented, the company had conservative East Coast management that could not compete with some of the tactics of the newer companies. There was also protectionism by senior managers of their turf and conflict between the Large Computer Group and the West Coast development labs leading to a failure to embrace the newer technology.

DEC just about had the potential to survive on its own in 1997, had it not been in negotiations with Compaq. VMS was a steady source of income which, even after a lack of investment by Compaq and a lack of marketing by HP, is still selling and still runs many of the world’s stock markets and telecommunications industries because of its stability and security. The Alpha was starting to gain market share, as the Intel rival ‘Itanium’ was late and did not perform as well as suggested. DEC had a hold on the Internet market with its powerful Digital Unix-based Alphas providing the performance required by e-commerce. Furthermore, had the company not been distracted by the merger negotiations, a Google-AltaVista combination could have been dominant today. DEC’s GIGAswitch Ethernet product was a leader and the company was about to invest heavily in the networking arm of the company when Palmer sold it.[512] DEC’s cluster technology was an asset that the company never marketed correctly and the company let VMS be portrayed as ‘old’ by its competitors even though it ran many mission critical systems worldwide.

As John Harty of the University of Florida put it in early 1998, just before DEC was sold:

> DEC has played a major role in the creation of the Internet. DEC’s research & development division was given unlimited time & resources to promote DEC’s commercial status on the Web; as well as their continuing commitment to education. DEC’s most well known contribution to the Internet is their search engine: AltaVista.
>
> The commercial applications of AltaVista have resulted in new software technology and services that include: firewalls, tunnelling, email, conferencing, and directories.
>
> DEC has one of the world's largest libraries of free software, accessible by anyone to download via the Internet. DEC has been a corporate pioneer on the Internet, as it was:

[512] Notesfile entry from networking group.

1) The first major corporation to establish a public Web site.
2) The first company on the ARPANET.
3) The first organization to have two separate geographical gateways.
4) The first computer company to register an Internet domain, mail gateway, and commercial print server.
5) A founding member of the WWW consortium.
6) One of the first computer companies to utilize public Usenet Newsgroups.

AltaVista is just part of DEC's continued train of contributions to the Internet, as they have decided to promote & expand the services of the Net, instead of thinking about sales & profits.

The Net has created new business opportunities for DEC in the areas of marketing and sales, in both the private & public sector. In the long run, these efforts have brought huge profits for DEC.

It has been argued that the company made many mistakes including the following:

- The loss of key technical people, Bell and Cutler at a critical time for the company with no one taking their place with the same vision.
- Missing the technology wave with the failure to implement RISC technology early enough, including the multiple changes of direction and failing to embrace UNIX.
- Continuing with the VAX 9000 when advised against it and hiring excessively for an assault on IBM, resulting in financial loss.
- The timing and manner of the removal of Olsen and the subsequent promotion of Palmer without due diligence.
- Failure to invest in companies that had technologies that DEC did not (e.g. Microsoft, Compaq, Apple).
- Extremely poor implementation of the downsizing process.
- Stagnation for two years while external consultants were paid to develop a strategy, and not implementing that strategy correctly.
- Lack of marketing of Alpha and lack of applications.
- Selling the semiconductor fabrication facilities too late.
- Not recognising the potential of the products the company had for the Internet wave.

The causes of which were:

- Indecision at a senior management level brought about by a lack of technological leadership.
- A board that was out of touch, weak and static.

- Management fiefdoms and a 'not invented here' attitude to technology.
- Management tensions, especially between the Large Computer Group and the rest.

A comparative study of competing companies has shown that IBM and HP survived by:

- Moving to RISC technology early.
- Hiring the right CEO.
- Stopping downsizing after the initial round.
- Embracing UNIX early.
- Focussing on customers rather than internally.

DEC and Data General failed by:

- Focussing internally instead of on customers.
- Being late with RISC and UNIX.
- Spending on a technology that was expensive and late into service.
- Continuing rounds of downsizing and killing morale.

By 1996 DEC had got back onto the S-curve with Alpha, and later with the Internet. Microsoft was committed to 64-bit Windows NT on Alpha until the Compaq buyout. DEC was still cash rich and had stopped the constant annual losses. Intel-based business systems were selling well and VMS was still providing reasonable margins, but needed more sales focus. Services were a growing part of the company's revenue, especially in the Microsoft space. DEC had a solid strategy with Windows NT, UNIX and VMS as the software platforms, and a full offering of Alpha and Intel hardware platforms, as well as massively parallel systems, and Alpha in the supercomputer class systems. DEC was providing service to both DELL and Compaq's Intel business and DEC was also ahead in the Internet business. DEC's enterprise storage products, Storageworks, were amongst the best and are still selling well under the HP name, bringing in about $4 billion in 2007.[513]

In researching the downfall of DEC I have learned a number of things about the importance of senior management decisions on the future of companies. Even large diverse technology companies need a focus on the developments around them. It is not satisfactory to sit back whilst you have a dominant product set as there will always be someone developing a product that will impact your business. Sometimes it will be a dormant product that suddenly finds a market. Other times it will be a new technology that might open markets that compete.

[513] HP quarterly earnings report for Q3 FY07.

RISC systems were initially disregarded by DEC because the senior management believed VAX/VMS was a superior product set and customers would obviously select it above RISC. DEC's indecision was at the heart of the failure. It didn't see the workstation market becoming dominant, the VAX systems needing a refresh and focussing on staff reductions at a time when it needed to grow its business.

9.2 *Conclusion*

The research question we aimed to answer was 'what caused a company the size and reach of DEC to fail?' Was Schein correct in his theory of the money gene or was it mismanagement, indecision in innovation, Schumpeter's creative destruction, Christensen's disruptive innovation of the PC or the cumulative effect of all of them coming together in a catastrophic clash?

This thesis proposes that the PC was not the cause of the company downfall as suggested by Christensen nor was it Schein's money gene but it was management indecision in the 1980s that caused it to miss the disruptive innovations brought about by UNIX, VLSI and CMOS technology, especially in the workstation market that DEC were late to enter.

In chapter 6 we looked at the company's products over the period of interest, concluding that the PC was not the crucial innovation that brought the company down. In fact, by the time the PC was in the datacentre, DEC had made significant inroads with its Prioris range of PC servers. It also had gained many of the corporate desktops with its Celebris range of PCs and its support of Microsoft Exchange. Christensen had proposed that the PC was the disruptive innovation that killed DEC, whereas in the case of the major computer companies it was the workstation and the advent of client server technology that was the major influence. Timesharing was replaced by client server and the dumb desktop terminal was replaced by the workstation and then the PC. First UNIX and Microsoft's Windows NT provided the server component. DECs indecision at its critical meetings around RISC technology in 1988 caused confusion amongst its customers and led to Cutler leaving the company and developing Windows NT for Microsoft. Without Cutler and his team Windows NT would not have been the operating system that it became, utilising many of the features of DEC's VMS. DEC had been following the S-curves until the failure of the VAX9000 and the indecision over its RISC architecture and only got back on the technology curve when it released its Alpha product. This was three years too late so the company was behind its competitors in the 1990s.

In chapter 7 we considered the methodologies employed by DEC in its efforts to reduce staff numbers. This added to the confusion within the company as sales staff were focussing on keeping their jobs rather than selling, morale was reduced and personnel were scared of doing anything outside of their normal job role for fear of being laid off. This effectively killed innovation in much of the company for a number of years as much of it was as a result of 'skunk works'. The majority of studies of the downsizing process were undertaken after DEC had embarked on its reduction process, many prompted by what was the biggest downsizing of a company to date. It is clear that DEC made many of the mistakes that are identified in the studies.

In chapter 8 we determined that the company was cash rich for most of its existence and Palmer maintained this cash balance at the expense of growth. In the early years the margins were such that there was no need to have tight expense control whilst DEC had the majority of the market. When VLSI technology appeared margins were eroded and manufacturing costs reduced. This was an example of Schumpeter's disruptive innovation that, he predicted, would increase efficiency and thus reduce costs and margins. DEC were slow to realise the margins were reducing and slow to reduce the manpower as a result.
This caused financial issues for DEC as they used billions of dollars in the reduction of manpower and facility consolidation. The share price also suffered as Wall Street lacked confidence in DECs management. Schein theorises that DEC management lacked the money gene. This was potentially true when margins were great but as they reduced DEC management controlled spending and manufacturing costs. There was no evidence to suggest that DEC managements handling of financials had any influence in the downfall of the company. When the management finally realised that the company was overstaffed and that the margins of the 1970s were not sustainable it was slow to remove excess personnel and ended up in a spiral of expensive redundancies affecting staff morale. This scenario mimics Schumpeter's theories almost exactly.

DEC had the opportunity to purchase a number of the companies that were to become major competitors – SUN, Microsoft, MIPS, Compaq and Apple among others – as well as a number of technologies, including UNIX, Google and VisiCalc. It made limited external investments and most of those that it did make proved to be incorrect.

This thesis is based on company reports and interviews with senior people involved at the time. It is clear that memories can become clouded after time and also by peoples focus at the time. The company reports gave the detail reported externally but the lack of minutes from the management meetings and the board meetings made some of the assertions hard to corroborate. Information on internal discussions would have added much to the analysis. We had no success in finding the minutes of the meetings but there is still the potential for someone to locate them in secure storage and add value to this thesis.

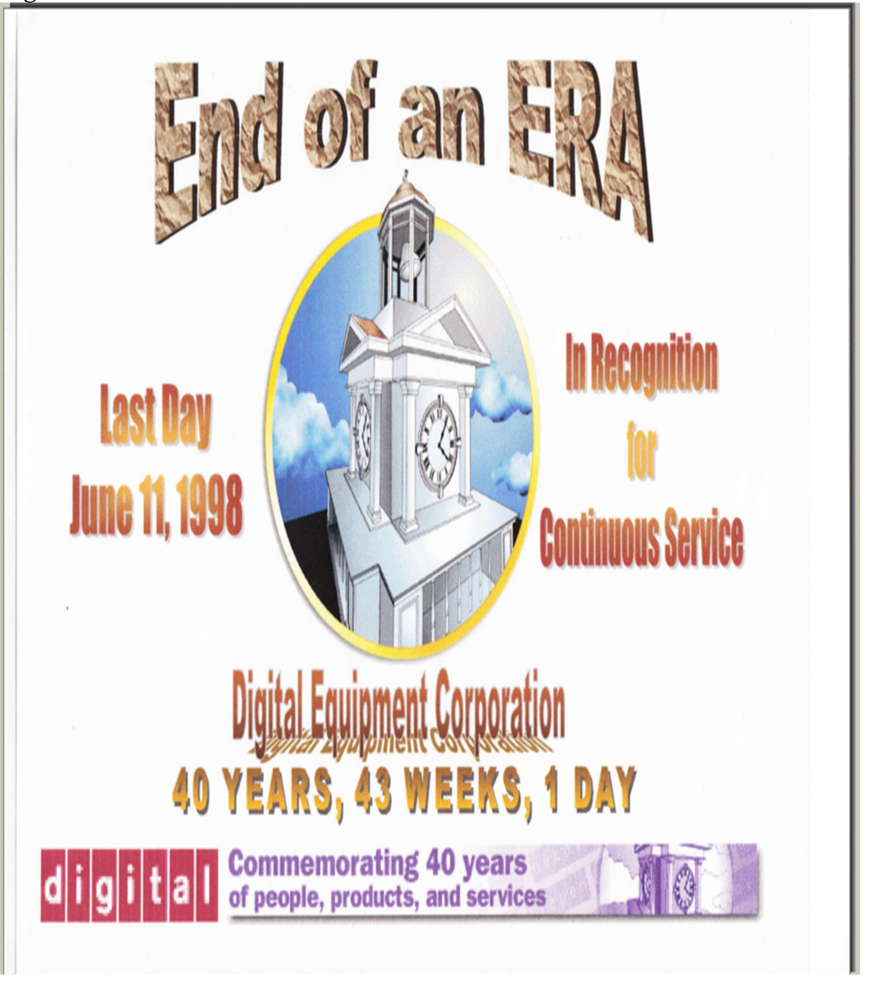
Moving forward there is a number of directions that could prove interesting for researchers. It would be an interesting project to look at DEC's influence on the computer industry in terms of technology and personnel. DEC was involved in a great deal of research in its laboratories and developed innovations such as the hard drive mp3 player that apple benefitted from. Many of its technologies have found their way into Intel and AMD microprocessors. During DEC's final years and for a number of years after, DEC's technologists spread out through the industry taking their skills with them. Many went to Microsoft, Intel, ARM, others started their own technology companies to varying degrees of success. Many of Microsoft and Intel senior technology positions are now occupied by ex-DEC personnel. It would be interesting to plot the distribution and influence of DEC through its dispersion of skilled personnel.

9.3 *The End of DEC*

The DEC culture lives on through many of its alumni both in their current careers and in their on-going association with other DEC employees. There are DEC alumni associations in many countries of the world, continuing the comradeship that was instilled into the company by Olsen. These have now branched out into LinkedIn with 11,000 in the worldwide DEC Alumni group (as of January 2011). In the UK, the DEC Alumni association has over 1,000 members, whereas in the United States there are a number of different alumni groups ranging from Storage through Workstations to the main group in Maynard. There is even a Facebook section for DEC employees. These groups have provided a valuable insight into the workings of the company, as well as feedback on the morale and work ethic during the troubled times.

Finally, six years after Olsen was ousted, DEC was sold to Compaq and the employees each received an 'End of an Era' certificate and the bell at the firm's old headquarters in the Mill at Maynard was rung 41 times, once for each year of the company's existence.

Figure 23: DEC's 'End of an Era' certificate.



10 References

Abbate, Janet. 1999. *Inventing the internet*. Inside technology. Cambridge, Mass: MIT Press.

Acee, Hap. 2001. *Disruptive technologies: An expanded view.* Massachusetts Institute of Technology.

Addison, Craig. 2004. *SEMI oral history interview: Robert P. Palmer*. Computer History Museum, 1-16.

Akera, Atsushi. 2007. *Calculating a natural world: Scientists, engineers, and computers during the rise of U.S. cold war research*. Inside technology. Cambridge, Mass.: MIT Press.

Alarcon, Rafael. 2004. *Migration between States and Markets,* August. Ed. H. Entzinger, M. Martinello, and C. Withol de Wenden, Ashgate Publishing, Burlington VT. 28-41.

Allan, Roy A. 2005. *A bibliography of the personal computer: The books and periodical articles*. 1st ed. London, Ont.: Allan Pub.

———. 2001. *A history of the personal computer: The people and the technology*. 1st ed. London, Ont.: Allan Pub.

Allen, Thomas J., and Michael S. Scott Morton. 1994. *Information technology and the corporation of the 1990s: Research studies*. New York: Oxford University Press. 499-516.

———. 1994. *Information technology and the corporation of the 1990s: Research studies*. New York: Oxford University Press.

Amidon, Debra, ed. 1990. *Global innovation strategy: Creating 'value add'*. Austin: IC2 Institute, University of Texas at Austin.

Amidon, Debra M. 2003. *The innovation superhighway: Harnessing intellectual capital for sustainable collaborative advantage*. Boston: Butterworth-Heinemann.

———. 1997. *Innovation strategy for the knowledge economy: The Ken awakening*. Boston: Butterworth-Heinemann.

Anderson, Harlan E. 2009. *Learn, earn & return: My life as a computer pioneer*. 1st ed. Redding, CT: Locust Press. 114-115.

Anderson, Philip, and Michael L Tushman, 1990. Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change, *Administrative Science Quarterly* 35: 604-633.

Anklam, Patti. 2001. The camelot of collaboration. *Knowledge* Management Magazine, 5 (2). 1-12.

Ante, Spencer E. 2008. *Creative capital: Georges Doriot and the birth of venture capital*. Boston, Mass.: Harvard Business Press. xiii, 149, 151, 179.

Arntzen, Bruce C., Gerald G. Brown, Terry P. Harrison, and Linda L. Trafton. 1995. Global supply chain management at Digital Equipment Corporation. *Interfaces* 25 (Jan-Feb 1995): 69-93.

Arthur, Michael B., and Denise M. Rousseau. 1996. *The boundaryless career : A new employment principle for a new organizational era*. New York: Oxford University Press.

Asthana, Praven. 1995. Jumping the technology S-curve. *IEEE Spectrum* (June): 49-54.

Auerbach, Jon G. 1997. After settlement, Digital CEO is expected to rejuvinate firm. *Wall Street Journal, western Edition*, October 30, 1997.

Austin, Robert D., and Richard L. Nolan. IBM Corporation Turnaround. *Harvard Business School Case 600-098,* March 2000. (Revised November 2000.)

Babbage, Charles, and Martin Campbell-Kelly. 1989. *The works of Charles Babbage* [Works.]. New York: New York University Press.

Bardhan, Ashok, and Cynthia A. Kroll. 2003. *The new wave of outsourcing*. Fisher center for real estate & urban economics research report series no. 1103.

Barker, Vincent L., and Mark A. Mone. 1994. Retrenchment: Cause of turnaround or consequence of decline? *Strategic Management Journal* 15 (5): 395-405.

Barwolff, Matthias. 2010. *End-to-end arguments in the internet: Principles, practices, and theory*. Technical University of Berlin.

Bashe, Charles J. 1986. *IBM's early computers*. MIT press series in the history of computing. Cambridge, Mass.: MIT Press.

Battelle, John. 2005. *The search: How Google and its rivals rewrote the rules of business and transformed our culture*. New York: Portfolio.

Bauer, Roy A., Emilio Collar, and Victor Tang. 1992. *The Silverlake Project: Transformation at IBM*. New York: Oxford University Press. 158.

Beard, Henry, and Roy McKie. 1999. *Computing: A hacker's dictionary*. New York: Workman Pub.

Bell, Gordon C. *Fate of US minicomputer corporations*. Available from http://ed-thelen.org/comp-hist/G-Bell-91-US-mini-1968-to-1982.html (accessed April 4, 2015).

———. in Gordon Bell - Microsoft [database online]. Available from http://research.microsoft.com/en-us/um/people/gbell/CGB%20Files/Mini%20and%20Micro%20Industries%20Computer%208410%20bw%20c.pdf.(accessed April 4, 2015

———. Appendix for Edgar H. Schein "DEC is dead, long live DEC". Available from http://research.microsoft.com/en-us/um/people/gbell/CGB%20Files/DEC_Is_Dead_Bell_Appendix_Schein_Book.pdf (accessed April 4, 2015).

———. A list of minicomputers. Available from http://ed-thelen.org/comp-hist/GBell-minicomputer-list.html (accessed April 4, 2015).

———. Mini and micro industries. Available from http://research.microsoft.com/en-us/um/people/gbell/CGB%20Files/Mini%20and%20Micro%20Industries%20Computer%208410%20bw%20c.pdf (accessed April 4, 2015).

Bell, Gordon C. 1986. RISC: Back to the future? *Datamation* 32 (11): 96-108.

Bell, Gordon C., J. Craig Mudge, John E. McNamara, and Digital Equipment Corporation. 1978. *Computer engineering : A DEC view of hardware systems design*. Bedford, Mass.: Digital Press.

Bell, Gordon C. 1986. *Toward a history of (personal) workstations*. Proceedings of the ACM conference on the history of personal workstations. New York.

Bell, Gordon C. 2008. Bell's law for the birth and death of computer classes. *Commun. ACM* 51 (1): 86-94.

———. 1980. *Digital Equipment Corporation PDP tree*. Artifact, Computer History Museum,

———. 1962. *Programmed Data Processor - 4 technical specification*. Artifact, Computer History Museum.

Bell, Gordon, and William D. Strecker. 1998. *What have we learned from the PDP-11; what have we learned from VAX and Alpha.* Paper presented at ISCA '98 25 years of the International Symposia on Computer Architecture.

Bender, Ruth Frances. 2004. *The determination of directors' remuneration in selected FTSE 350 companies*. University of Warwick.

Berkun, Scott. 2007. *The myths of innovation*. 1st ed. CA: O'Reilly Media.

Berners-Lee, Tim. 1989. *Information management: A proposal*. http://faculty.georgetown.edu/irvinem/theory/Berners-Lee-HTTP-proposal.pdf (accessed Sep 30,, 2015), 1-21

Berners-Lee, Tim, and Mark Fischetti. 2000. *Weaving the web: The original design and ultimate destiny of the world wide web by its inventor*. 1 pbk ed. New York: HarperCollins Publishers.

Bernstein, D., Brown J. F. III, R. L. Stamm, and G. M. Uhler. 1992. *NVAX and NVAX+: Single-chip CMOS VAX microprocessors*. Paper presented at Computer Design: VLSI in Computers and Processors, 1992. ICCD '92. Proceedings., IEEE 1992 International Conference on, .

Beyer, Kurt. 2009. *Grace Hopper and the invention of the information age*. Lemelson center studies in invention and innovation. Cambridge, Mass.: MIT Press.

Bhandarkar, Dileep. 1997. RISC versus CISC: A tale of two chips. *ACM SIGARCH Computer Architecture News* 25 (1) (March 1997): 12.

Bhandarkar, Dileep P. 1996. *Alpha implementations and architecture: Complete reference and guide*. Boston, Mass.: Digital Press.

Bhandarkar, Dileep, and Douglas W. Clark. 1991. *Performance from architecture: Comparing a RISC and a CISC with similar hardware organization.* Paper presented at ASPLOS-IV Proceedings of the fourth international conference on Architectural support for programming languages and operating systems, Santa Clara.

Bianco, Anthony. 2010. *The big lie: Spying, scandal, and ethical collapse at Hewlett-Packard*. 1st ed. New York: Public Affairs.

Blackford, Mansel G. 2003. *A history of small business in America*. The Luther Hartwell Hodges series on business, society, and the State. 2nd ed. Chapel Hill: University of North Carolina Press.

Blank, Steve. 2010. The secret history of Silicon Valley, http://www.computerhistory.org/core/secretvalley/.

Bower, Joseph L., and Clayton M. Christensen. 1995. Disruptive technologies: Riding the wave. *Harvard Business Review,* (January-February): 43-53.

Bourne, Philip E., Richard Holstein, and Joseph McMullen. 2003. *UNIX for OpenVMS users*. 3rd ed. Boston: Digital Press.

Bowman, E. H., and H. Singh. 1993. Corporate restructuring: Reconfiguring the firm. *Strategic Management Journal* 14 (Special Issue, Summer): 5-14.

Brandt, Richard L. 2009. *Inside Larry and Sergey's brain*. New York: Portfolio.

Brennan, Niamh. 1995. *Disclosure of profit forecasts during takeover bids*. University of Warwick.

Bresnahan, Timothy F., and Shane Greenstein. 1999. Technological competition and the structure of the computer industry. *The Journal of Industrial Economics* 47 (1): 1-40.

Bricklin, Daniel. *Dan Bricklin biography*. http://www.bricklin.com/bio.htm, (accessed Sept 30, 2015).

Brockner, J., S. Grover, M. N. O'Malley, T. F. Reed, and M. A. Glynn. 1993. Threat of future layoffs, self-esteem, and survivors' reactions: Evidence from the laboratory and the field. *Strategic Management Journal* 14 (Summer): 153-166.

Brockner, J., M. Konovsky, R. Cooper-Schneider, R. Folger, C. Martin, and R. J. Bies. 1994. Interactive effects of procedural justice and outcome negativity on victims and surviviors of job loss. *Academy of Management Journal* 37, No. 2 (April). 397-409.

Bruno, Albert V. and Joel K. Leidecker, 1988. "Causes of New Venture Failure: 1960s vs. 1980s," *Business Horizons,* November–December.

Bruton, G. D., J. K. Keels, and C. L. Shook. 1993. Downsizing the firm: Answering the strategic questions. *The Academy of Management Executive* 10 No.2 (May): 38-45.

Budros, A. 2002. The mean and lean firm and downsizing: Causes of involuntary and voluntary downsizing strategies. *Sociological Forum* 17 No.2 (Jun): 307--342.

———. 1999. A conceptual framework for analysing why organizations downsize. *Organizational Science* 10 No.1 (Jan-Feb): 69-82.

Burrows, Peter. 2003. *Backfire: Carly Fiorina's high-stakes battle for the soul of Hewlett-Packard*. Hoboken, N.J.: J. Wiley & Sons. 15.

Bygrave, William D., Michael Hay, and Jos B. Peeters. 1999. *The venture capital handbook*. Harlow England: Financial Times Prentice Hall.

Bygrave, William D., and Jeffry A. Timmons. 1992. *Venture capital at the crossroads*. Boston, Mass.: Harvard Business School Press.

Campbell-Kelly, Martin. 2003. *From airline reservations to sonic the hedgehog: A history of the software industry*. History of Computing. Cambridge, Mass.: MIT Press.

———. 1989. *ICL: A business and technical history*. Oxford; New York: Clarendon Press; Oxford University Press.

———. 1980. *Foundations of computer programming in Britain*. Sunderland Polytechnic.

———. 1978. *The computer age*. Hove: Wayland.

———. 1973. *An introduction to macros*. Computer monographs, 21. London; New York: Macdonald and Co.; American Elsevier.

Campbell-Kelly, Martin, William Aspray, Nathan Ensmenger, Jeffrey R. Yost, and William Aspray. 2014; 2014. *Computer: A history of the information machine*. The Sloan technology series. Third ed. Boulder, CO: Westview Press, A Member of the Perseus Books Group. 114.

Campbell-Kelly, Martin, Michael R. Williams, and Moore School of Electrical Engineering. 1985. *The Moore School lectures: Theory and techniques for design of electronic digital computers*. Charles Babbage Institute reprint series for the history of computing. Vol. 9. Cambridge, Mass.; Los Angeles: MIT Press; Tomash Publishers.

Cascio, W. F. 2002. Strategies for responsible restructuring. *The Academy of Management Executive* 16, No. 3 (Aug.): 80-91.

———. 1993. What do we know? What have we learned? *The Executive* 7, No. 1 (Feb): 95-104.

Castilla, Emillio J. 2003. Networks of venture capital firms in Silicon Valley. *Int. J. Technology Management* 25 (Nos. 1/2): 113-135.

Caves, Richard E., Matthew B. Krepps, and Michelle J. White Henry Farber. 1993. Fat: The displacement of nonproduction workers from US manufacturing industries. *Brooking Papers on Economic Activity. Microeconomics* 1993 (2): 227-288.

Ceruzzi, Paul. 2010. When dreams become real. *Technology and Culture* 51 (3): 675-679.

Ceruzzi, Paul E. 2003. *A history of modern computing*. 2nd ed. London, Eng.; Cambridge, Mass.: MIT Press. 198, 205-205, 238

Champine, George A. 1991. *MIT project Athena: A model for distributed campus computing*. Bedford, MA: Digital Press.

Chandler, Alfred D. 1977. *The visible hand: The managerial revolution in American business*. Cambridge, Mass.: Belknap Press.

Chandler, Alfred D., and Takashi Hikino. 1990. *Scale and scope: The dynamics of industrial capitalism*. Cambridge, Mass.: Belknap Press.

Chandler, Alfred D., Takashi Hikino, and Andrew Von Nordenflycht. 2005. *Inventing the electronic century: The epic story of the consumer electronics and computer industries: With a new preface*. Harvard studies in business history. Vol. 47. Cambridge, MA: Harvard University Press. 146

Charan, Ram. 1998. *Boards at work: How corporate boards create competitive advantage*. The Jossey-Bass business & management series. 1st ed. San Francisco: Jossey-Bass.

Cheney, Scott, ed. 1998. *Excellence in practice*. Vol. 2. Alexandria: American Society for Training & Development.

Chesbrough, Henry. 2003 *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, Mass.: Harvard Business School Press.

Chesbrough, Henry, and Richard S. Rosenbloom, 2002. *The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-off Companies*, Industrial and Corporate Change, Vol. 11, no. 3. 529-555.

Chposky, James, and Ted Leonsis. 1988. *Blue magic: The people, power, and politics behind the IBM personal computer*. New York: Facts on File. 9.

Christensen, Clayton M. 2000. *The innovator's dilemma: The revolutionary national bestseller that changed the way we do business*. 1 Harper Business ed. New York: Harper Business. xviii, 44, 126-127,

———. 1999. *Innovation and the general manager*. Boston, Mass.: Irwin/McGraw-Hill.

Christensen, Clayton M., and Joseph L. Bower, 1996. Customer Power, Strategic Investment and the Failure of Leading Firms*. Strategic Management Journal* 17, no.3: 199.

Christensen, Clayton M., and Michael E. Raynor. 2003. *The innovator's solution: Creating and sustaining successful growth*. Boston, Mass.: Harvard Business School Press.

Christensen, Clayton, Thomas Craig, and Stuart Hart. 2001. The great disruption. *Foreign Affairs* 80 (2 March/April): 16-80.

Clayman, Michelle. 1987. In search of excellence: The investor's viewpoint. *Financial Analysts Journal* 43 (3 May-June): 10-54.

Codling, Sylvia. 1995; 1992. *Best practice benchmarking: A management guide*. Aldershot, Hampshire, England; Brookfield, Vt., USA: Gower.

Collins, James C. 2009. *How the mighty fall: And why some companies never give in*. New York: Jim Collins: Distributed in the U.S. and Canada exclusively by Harper Collins Publishers.

Collins, James C., and Jerry I. Porras. 1994. *Built to last: Successful habits of visionary companies*. 1st ed. New York: HarperBusiness.

Cooper, Brad. 1998. Pathworks and NT. *IT Pro.* May 1. http://windowsitpro.com/systems-management/pathworks-and-nt (accessed Sept 30, 2015)

Copeland, B. Jack. 2012. *Alan Turing's electronic brain : The struggle to build the ACE, the world's fastest computer*. Oxford; New York: Oxford University Press.

Cortada, James W. 2008. Patterns and practices in how information technonlogy spread around the world. *IEEE Annals of the History of Computing*(Oct-Dec 2008): 21-24.

Couvering, Elizabeth Jane Van. 2009. *Search engine bias*. London School of Economics.

Coventry, Joshua. 2006. *Interview with Dan Bricklin, inventor of the electronic spreadsheet*. http://lowendmac.com/2006/dan-bricklin-inventor-of-the-electronic-spreadsheet/ (accessed Sept 30, 2015).

Crainer, S., and D. Dearlove. 2002. Excellence revisited. *Business Strategy Review* 13 (1): 13-9.

Cronin, Mary J. 1997. *Banking and finance on the internet*. New York: Van Nostrand Reinhold.

———. 1996. *Global advantage on the internet: From corporate connectivity to international competitiveness*. New York: Van Nostrand Reinhold.

———. 1996. *The internet strategy handbook: Lessons from the new frontier of business*. Boston, Mass.: Harvard Business School Press.

Cronin, Mary J., and Mary J. Cronin. 1995. *Doing more business on the internet: How the electronic highway is transforming American companies*. 2nd ed. New York: Van Nostrand Reinhold.

Curran, Lawrence. 1991. The workstation race heats up. *Electronics Magazine.* April.

Custer, Helen. 1993. *Inside windows NT*. Redmond, Wash.: Microsoft Press.

Darnton, Geoffrey, and Sergio Giacoletto. 1992. *Information in the enterprise: It's more than technology*. Salem, MA: Digital Press.

Danneels, Erwin. 2004. Disruptive Technology Reconsidered: A Critique and Research Agenda, *Product Innovation Management* 21: 246-258.

David B. Fite, Jr, Tryggve Fossum, and Dwight Manley. 1990. Design strategy for the VAX 9000 system. *Digital Technical Journal* 2 (4): 13-24.

Davidow, William H. 1986. *Marketing high technology: An insider's view*. New York; London: Free Press; Collier Macmillan.

Davidson, W. N., D. L. Worrell, and J. B. Fox. 1996. Early retirement programs and firm performance. *The Academy of Management Journal* 39, No 4 (Aug.): 970-984.

Dawson, Christian W. 2015. *Projects in computing and information systems: A student's guide*. Third ed. Harlow, England; New York: Pearson.

DEC. *PDP-11/45 system users manual*.

———. 1998. *Thank you - commemorating 40 years of people, products and services*. Videotape issued by Digital Equipment Corporation

———. 1988. Development of the VAX NOTES system. *Digital Technical Journal* Feb (No. 6): 117-124.

———. 1978. *Nineteen fifty seven to the present*. Digital Equipment Corporation.

———. 1974. "Digital Equipment Corporate Philosophy and Organization Document", Gordon College.

DEC cancels ULTRIX workstation using ECL R6000. 1990. *Computer Business Review.* April.

Deck, Stewart. 1998. Users say microsoft is no bully. *CNN News*, http://europe.cnn.com/TECH/computing/9809/15/msnobully.idg.

DECUS. *DECUS proceedings and publications 1962 to 1992*. Vol. 2010. Minesota: .

DeLisi, Peter. 1998. A modern day tragedy: The Digital Equipment story. *Journal of Management Inquiry* 7 (No 2 June): 112-118. 119-130

Denning, Peter J., and Robert Dunham. 2010. *The innovator's way: Essential practices for successful innovation*. Cambridge, Mass.: MIT Press.

Denzin, Norman K., and Yvonna S. Lincoln. 2003. *Strategies of qualitative inquiry*. 2nd ed. Thousand Oaks, CA: Sage.

Deutschman, Alan. 2000. *The second coming of Steve Jobs*. 1st d. New York: Broadway Books.

DeJong, Jeroen P. J. 2007. *Individual Innovation: The Connection Between Leadership and Employees Innovative Work Behaviour*, PhD thesis, University of Amsterdam, supervisor prof. dr. D. N. den Hartog,

DeWitt, R. 1998. Firm, industry and strategy influences on choice of downsizing approach. *Strategic Management Journal* 19, No. 1 (Jan): 59-79.

———. 1993. The structural consequences of downsizing. *Organizational Science* 4, No.1 (Focused Issue: Organizational Decline and Adaption: Theoretical Controversies (Feb.): 30-40.

Digital Equipment Corporation - takeover by Compaq Computer Corporation. 1997. *Wall Street Journal.* May 5.

Digital and Samsung announce Alpha microprocessor agreement, 1996. http://www.samsung.com/us/news/newsPreviewRead.do?news_seq=34 (accessed Sept 30, 2015)

Dipuppo, Julie. 2012. *Innovating in and out of business: The evolution of business ecosystems and the rise and fall of Digital Equipment Corporation*. London School of Economics.

Dobberpuhl, Daniel W. March 1983. *Fundamental issues in the electrical design of very large scale integration circuits*. Paper presented at Third Caltech Conference on Very Large Scale Integration, Pasadena, California.

Doering, Don S. and Roch Parayre, 2000. "Identification and Assessment of Emerging Technologies," in *Wharton on Managing Emerging Technologies,* ed. George S. Day, Paul J. H. Schoemaker, and Robert E. Gunther (New York: Wiley), May: 75-98.

Dorfman, N. S., and Massachusetts Institute of Technology. 1982. *Massachusetts' high technology boom in perspective: An investigation of its dimensions, causes and of the role of new firms ;* center for policy alternatives, Massachusetts Institute of Technology.

Dormehl, Luke. 2012. *The Apple revolution;* Ebury Publishing.

Drew, S. A. W. 1994. Downsizing to improve strategic position. *Management Decision* 32 (No. 1): 4-11.

Dyer, Jeff, Hal B. Gregersen, and Clayton M. Christensen. 2011. *The innovator's DNA: Mastering the five skills of disruptive innovators*. Boston, Mass.: Harvard Business Press.

Earls, Alan R. 2004. *Digital Equipment Corporation*. Images of America. Portsmouth, NH: Arcadia.

Eckerson, Wayne W. 2010. *Performance dashboards: Measuring, monitoring, and managing your business*. 2nd ed. New York: Wiley.

Edelman, Lawrence. 1990. Can Ron Skates save Data General. *Boston Globe*, December 16, 1990. http://www.highbeam.com/doc/1P2-8206695.html (accessed Sept 30, 2015).

Enck, John, and Dan Blacharski. 1997. *Managing multivendor networks*. Indianapolis, IN: Que.

Estrada, Isabel, Natalia Martín-Cruz and Pilar Pérez-Santana, 2013. Multi-partner alliance teams for product innovation: The role of human resource management fit, *Innovation: Management, Policy & Practice* 15, no. 2: 161-169.

Ettlie, John E., William P. Bridges, and Robert D. O'Keefe, 1984. Organisational strategy and structural Differences for Radical vs. Incremental Innovation, *Management Science*, 10: 682-695.

Evans, Harold, Gail Buckland, and David Lefer. 2004. *They made America: From the steam engine to the search engine : Two centuries of innovators*. 1st ed. New York: Little, Brown.

Fagerberg, Jan, D. C. Mowery and R. R. Nelson, 2005. *The Oxford Handbook of Innovation*, Oxford University Press, 2.

Falvey, Jack, ed. 1999. *Hot negatives; why the media miss the business message,* Intermark.

Favaro, John. 1996. When the pursuit of quality destroys value. *IEEE Software* (May 1996): 93-95.

Ferguson, Charles H. 1999. *High stakes, no prisoners: A winner's tale of greed and glory in the internet wars*. New York: Times Business.

Ferguson, Charles H., and Charles R. Morris. 1994. *Computer wars: The fall of IBM and the future of global technology*. 1st ed. New York: Times Books.

Ferrero, Alexis. 1999. *The eternal ethernet*. 2nd ed. Harlow, England ; Reading, Mass.: Addison Wesley Longman.

Finn, David. 1983; 1969. *The corporate oligarch*. Lanham, MD: University Press of America.

Fiorina, Carly. 2006. *Tough choices: A memoir*. New York: Portfolio.

Fisher, Lawrence M. 2001. Clayton M. Christensen, The thought leader interview. *Strategy and Business.* October 1.

Flavey, Jack. 1999. Hot negative: Why the media miss the business message. Paper presented at Intermark .

Folger, Robert, and Daniel P. Sharlicki. 1998. When tough times make tough bosses: Managerial distancing as a function of layoff blame. *The Academy of Management Journal* 41, No 1 (Feb): 79-87.

Freeman, Sarah J., and Kim S. Cameron. 1993. Organizational downsizing: A convergence and reorientation framework. *Organizational Science* 4 (1): 10-29.

M. Fulbrook, 2002. *Historical Theory: Ways of Imagining the Past* London: Routledge, 12-33.

Gandolfi, Franco. 2009. Phases of cost cutting: Downsizing is dead; long live the downsizing phenomenon. *Review of International Comparative Management* 10 (5): 864-876.

———. 2009. Unravelling downsizing - what do we know about the phenomenon? *Review of International Comparative Management* 10 (3): 414-426.

———. 2008. Learning from the past - downsizing lessons for managers. *Journal of Management Research* 8 (1): 1-17.

Garr, Doug. 2000. *IBM redux: Lou Gerstner and the business turnaround of the decade*. Rev ed. New York: HarperCollins.

Gasse, Jean-Louis. 1987. *The third Apple : Personal computers & the cultural revolution*. 1st ed. ed. San Diego: Harcourt Brace Jovanovich.

Gerstner, Louis V. 2002. *Who says elephants can't dance? Inside IBM's historic turnaround*. New York, NY: Harper Business. 63.

Gibson, Carl S., 1990. VAX 9000 series, *Digital Technical Journal*, volume 2, no. 4, 11.

Gillies, James, and R. Cailliau. 2000. *How the web was born: The story of the World Wide Web*. Oxford: Oxford University Press.

Goldberg, Adele, and Association for Computing Machinery. 1988. *A history of personal workstations*. ACM press history series. New York, N.Y.; Reading, Mass.: ACM Press; Addison-Wesley Pub. Co.

Gompers, Paul A. 1994. The rise and fall of venture capitalism. *Business and Economic History* 23 (No. 2). 1-24.

Goodall, Francis, Terry Gourvish and Steven Tolliday, 2013 *International Bibliography of |Business History,* Routledge.

Goodwin, David T., and Roger G. Johnson. 2010. The demise of Digital Equipment Corporation: Downsizing - cause or cure. *Zeitschrift Fur Unternehmensgeschichte* Nr 1: 82-99.

———. 2010. Recession, S-curves and digital equipment corporation. *World Computer Congress Conference, History of Computing*.

———. 2009. DEC: The mistakes that led to its downfall. *SIGCIS Papers*.

Granovetter, Mark S., and Richard Swedberg. 2011. *The sociology of economic life*. 3rd ed. Boulder, CO: Westview Press.

Gundry, John. 1992. Understanding Collaborative Learning in Networked Organizations, *Collaborative Learning Through Computer Conferencing - The Najaden Papers*, ed. A. R Kaye (Springer).

Hafner, Katie, and Matthew Lyon. 1996. *Where wizards stay up late: The origins of the internet*. New York: Simon & Schuster.

Haigh, Thomas. 2006. Remembering the office of the future: The origins of word processing and office automation. *IEEE Annals of the History of Computing* October - December : 6-31.

Hall, A. Rupert, Norman Alfred Fisher Smith, Ian Inkster, and Angel Calvo. 2007. *History of technology*. London: Continuum Vol 27. 77-99

Hall, Jon 'Maddog'. 1995. Linux on alpha, a strategic choice. *Linux Journal.* October 1.

Hallock, K. F. 1988. Layoffs, top executives pay, and firm performance. *The American Economic Review* 88, No. 4 (Sept.): 711-723.

Hally, Mike. 2005. *Electronic brains: Stories from the dawn of the computer age*. Washington, D.C.: Joseph Henry Press.

Hambrick, Donald C., David Nadler, and Michael Tushman. 1998. *Navigating change: How CEOs, top teams, and boards steer transformation*. The management of innovation and change series. Boston, Mass.: Harvard Business School Press.

Hamel, Gary. 2000. Waking up IBM: How a gang of unlikely rebels transformed big blue. *Harvard Business Review,* (July-August): 12.

Hamilton, Ross. 1997. *Continuous path: The evolution of process control technologies in post-war Britain*. PhD., Warwick University.

Hamilton, Ross. 1995. Despite best intentions: The evolution of the British minicomputer industry. *Business History* 38 (2): 81-104.

Harbrecht, Douglas. 1998. How the Compaq-Digital deal came together. *Business Week.* May 7.

Harris, Seymour Edwin, and Joseph A. Schumpeter. 1969. *Schumpeter, social scientist*. Essay index reprint series. Freeport, N.Y.: Books for Libraries Press.

*Harvard business review on CEO succession*2009. . The Harvard Business Review paperback series. Boston, Mass.: Harvard Business School Pub.

Heil, Karl. *Downsizing and rightsizing,* Reference for Business. Encyclopedia of Business 2nd Ed, n.d. http://www.referenceforbusiness.com/management/De-Ele/Downsizing-and-Rightsizing.html. (accessed Jan 19 2016)

Helfat, Constance E. and Ruth S. Raubitschek, 2000. Product Sequencing Co-evaluation of Knowledge, Capabilities and Products, *Strategic Management Journal* 21: 961-979.

Henderson, Rebecca, M. 1993. Underinvestment and Incompetence as Responses to Radical Innovation: Evidence from the Photolithographic Alignment Equipment Industry, *RAND Journal of Economics* 24, no. 2, Summer.

Henderson, Rebecca M. and Kim B. Clark, 1989. *Generational Innovation: the Reconfiguration of Existing Systems and the Failure of Established Firms*, A. P. Sloan School of Management, Massachusetts Institute of Technology, working paper.

Henderson, Rebecca M. and Kim B. Clark, 1990. Architectural Innovation: The Reconfiguration of Existing, Product Technologies and the Failure of Established firms, *Administrative Science Quarterly* 35, no. 1, Mar: 9.

Hendrie, Gardner. 2007. *Oral history of john T. (Jack) Gilmore jr.* Vol. 2012, Computer History Museum.

———. 2006. *Oral history of Harlan Anderson*. Vol. 2006, Computer History Museum.

Hendrie, Gradner. 2005. *Oral history of Gordon Bell*. Vol. 2012Computer History Museum.

Hennessy, John L., Norman P. Jouppi, Steven Przybylski, Christopher Rowen, and Thomas Gross. 1983. Design of a high performance very large scale intergration processor. Paper presented at Third Caltech Conference on Very Large Scale Intergration, Pasadena, California.

Hennessy, John L., and David A. Patterson. 1998. *Computer organization and design: The hardware-software interface*. 2nd ed. San Francisco, Calif.: Morgan Kaufmann Publishers.

Hennessy, John L., David A. Patterson, and Krste Asanović. 2012. *Computer architecture: A quantitative approach*. 5th ed. Waltham, MA: Morgan Kaufmann/Elsevier.

Hennessy, John L., David A. Patterson, and David A. Patterson. 2003. *Computer architecture: A quantitative approach*. 3rd ed. San Francisco, CA: Morgan Kaufmann Publishers.

Hesselbein, Frances, Marshall Goldsmith, Iain Somerville, and Peter F. Drucker Foundation for Nonprofit Management. 2002. *Leading for innovation and organizing for results*. Drucker Foundation wisdom to action series. 1st ed. San Francisco: Jossey-Bass.

Hickok, Thomas A. 2008. *Downsizing and organizational culture*. www.pamij.com/hickok.html (accessed Dec 12, 2009).

Hickok, Thomas A. 1998. Downsizing and organizational culture. *Public Administration & Management: An Interactive Journal* 3, no. 3.

Hickok, Thomas A. 1999. *Workforce reductions: An annotated bibliography*. Greensboro, N.C.: Center for Creative Leadership.

Hindus, S. 2006. Transparency and there again: Lessons learned at Digital. *Journal of Management Development* 25 (10): 1007-1012.

Hopkins, M. E. 1987. A perspective on the 801/Reduced instruction set computer. *IBM Systems Journal* 26 (1): 107-121.

Hoskins, Jim, and Jack Blackledge. 1995. *Exploring the PowerPC revolution! See where the PowerPC fits into your future with this updated look at the Apple-IBM-Motorola project that's changing the face of computing*. 2nd ed. Gulf Breeze, FL: Maximum Press.

House, Charles H., and Raymond L. Price. 2009. *The HP phenomenon: Innovation and business transformation*. Stanford, Calif.: Stanford Business Books. 327, 337-350, 357, 364, 448

Howard, A. 1988. Who reaches for the golden handshake. *The Academy of Management Executive* 2, No. 2 (May): 133-144.

Hubiak, W. A., and S. J. O'Donnell. 1997. Downsizing: A pervasive form of organizational suicide. *National Productivity Review* 16 (2): 31-36.

Hunt, James. 2000. Organizational leadership and shame. Paper presented at 17th Annual Meeting of the International Society for the Psychoanalytic Study of Organizations, London, UK.

Hunt, James, P. Johnson, P. Johnston, S. Laidman and J. Link, 2004. Clearing the Clouds Surrounding SUN, September 21. Available from Ohio University under SunReport.doc.

Hyatt, Joshua. 2003. The business that time forgot, Data General is gone, but does that make its founder a failure? *Fortune Small Business.* April 1.

Indrajit, Mallick. 2010. Reconstructing corporate business history using accounting data. *Munich Personal RePEc Archive* Paper No 21349 .

Itami, Hiroyuki, Ken Kusunoki, Tsuyoshi Numagami, Akira Takeishi, 2010. *Dynamics of Knowledge, Corporate Systems and Innovation*, Springer Science & Business Media, 10 Mar: 29.

Jarvenpaa, Sirkka, and Blake Ives. *Digital Equipment Corporation - the internet company*. Vol. 2010.

Jeanneney, Jean Noël. 2007. *Google and the myth of universal knowledge: A view from Europe* [Quand Google défie l'Europe.]. Chicago: University of Chicago Press.

Jenkins, Keith, and Alun Munslow, 2003. *Re-Thinking History.* London and New York: Routledge, 40.

Jensen, M. C., and K. J. Murphy. 1990. CEO incentives - it's not how much you pay, but how. *Harvard Business Review* May-June (No. 3): 138-153.

Johnson, H. T. 1975. The role of accounting history in the study of modern business enterprise. *The Accounting Review* 50 (No 3 July): 444-450.

Jones, Clarence B., and Stuart Connelly. 2011. *Behind the dream: The making of the speech that transformed a nation*. 1st ed. New York: Palgrave Macmillan.

Jones, Geoffrey. 2005. *Renewing Unilever: Transformation and tradition*. Oxford; New York: Oxford University Press.

Judge, Paul C., and Andy Reinhardt. 1997. DEC's seething shareholders. *Business Week.* June 9.

Kamdar, Ali and Nazer, Daniel. 2013*. Deep Dive: Software Patents and the Rise of Patent Trolls,* Electronic Frontier Foundation**,** February 28.

Kameda, Mitsuhiro. 2004. *Disruptive innovation: Value change and complementary change.* Massachusetts Institute of Technology.

Kelly, Christopher M. 1995. Regional advantage: Culture and competition in Silicon Valley and route 128 - book review. *Harvard Journal of Law* 8 (2): 521-8.

Kelly, Dr. 1995. *The UNIX industry: A brief history*. Spring Unite Conference.

Kenney, Martin, and Urs von Burg. 1999. Technology, enrepreneurship and path dependence: Industrial clustering in Silicon Valley and route 128. *Industrial and Corporate Change* 8 (1): 67-103.

Kepner, Charles David, and Benjamin B. Tregoe, eds. 1978. *Analytic trouble shooting,* Princeton Research Press.

Kepner, Charles Higgins, and Benjamin B. Tregoe. 1981. *The new rational manager*. Princeton, N.J. P.O. Box 704, Research Rd., Princeton 08540: Princeton Research Press.

Khurana, Anjali. 2010. Marketing Strategy of Digital Equipment Corporation, *Management Paradise*, December 10.

Kidder, Tracy. 1981. *The soul of a new machine*. 1st ed. Boston: Little, Brown.

King, Andrew A. and Baljir Baatartogtokh. 2015. How Useful is the Theory of Disruptive Innovation? MIT Sloan Management Review, Fall.

King, Bryan. 1994. *The effects of workforce downsizing on employee productivity and morale in the computer industry*. Project, Lesley College.

Kochan, Thomas A., John P. MacDuffie, and Paul Osterman. 1988. Employment security at DEC: Sustaining values amid environmental change. *Human Resource Management Journal* (Summer). 121-143.

Kosman, Josh, 2010. *Symantec under pressure to split up?* New York Post. Nov 5.

Kotter, John P. 1990. *A force for change: How leadership differs from management*. New York; London: Free Press; Collier Macmillan.

Kotter, John P., and James L. Heskett. 1992. *Corporate culture and performance*. New York : Free Press ; Toronto; New York: Maxwell Macmillan Canada; Maxwell Macmillan International.

Kronenberg, Nancy P., Henry M. Levy, and William D. Strecker. 1985. VAXclusters: A closely-coupled distributed system. *ACM SIGOPS Operating System Review* 19 (5).

Kuh, Ernest S., ed. 1992. *Multichip modules*. Singapore: World Scientific Publishing Company.

Lavie, Dovev, 2006. Capability Reconfiguration: An Analysis of Incumbent Responses to Technological Change, *The Academy of Management Review* 31, no. 1, Jan: 153-174.

Lavie, Dovev, 2004. The interconnected firm: Evolution, strategy, and performance, *Advances in Mergers and Acquisitions* 5, January 1: 127-141.

Leach, Cliff. 1994. *Alpha: A strategic review*. New York: Prentice Hall.

Lécuyer, Christophe. 2006. *Making Silicon Valley: Innovation and the growth of high tech, 1930-1970*. Inside technology. Cambridge, Mass.: MIT Press.

Lee, Jaewon. 2002. *The determinants of employees' affective commitment to the organisation under downsizing: The case of the banking industry in Korea*. University of Warwick.

Lee, Peggy M. 1997. A comparative analysis of layoff announcements and stock price reactions in the United States and Japan. *Strategic Management Journal* 18, No. 11 (Dec.): 879-894.

Lesly, Elizabeth, and Larry Light. 1992. When layoffs alone don't turn the tide. *Business Week.* December 7.

Lepore, Jill. 2014. The Disruption Machine, what the gospel of innovation gets wrong, *The New Yorker*, Annals of Enterprise, June 23.

Linton, Ian. 2012. *Taking technology to the market: A guide to the critical success factors in marketing technology*. Farnham, Surrey, England; Burlington, Vt.: Gower.

Linzmayer, Owen W. 1999. *Apple confidential: The real story of Apple Computer, Inc.* San Francisco, Calif.: No Starch Press.

Linzmayer, Owen W., and Owen W. Linzmayer. 2004. *Apple confidential 2.0: The definitive history of the world's most colorful company*. Rev 2 ed. San Francisco, Calif.: No Starch Press.

Littler, Craig R. and Gandolfi, Franco. 2008. What happened to downsizing? Organizational continuity, managerial fashion, and signalling. *Academy of Management Conference, Anaheim*, paper presentation.

Livingston, Jessica. 2007. *Founders at work: Stories of startups' early days*. Berkeley, CA; New York: Apress; Distributed to the book trade worldwide by Springer-Verlag New York.

Lloyd, Bruce. 1996. Knowledge management: The key to long-term organizational success. *Long Range Planning* 29 (4): 5-576.

Lohr, Steve. 1993. Present at the transition of I.B.M. *New York Times*, October 26.

Lorsch, Jay W., Joseph L. Bower, Clayton S. Rose, and Suraj Srinivasan. 2009. *Perspectives from the boardroom - 2009.* Harvard Business School: Harvard Business School Press, .

Mahoney, Michael S. 2005. The histories of computing. *Interdisciplinary Science Reviews* 30 (No. 2): 119-135.

Mahoney, Michael S., and Thomas Haigh. 2011. *Histories of computing*. Cambridge, Mass.: Harvard University Press.

Malthus, Thomas R., 1807, *An Essay on the Principle of Population*, 4th ed., 2 vols. (London: Printed for J. Johnson by T. Bensley).

Malone, Michael S. 2007. *Bill & Dave: How Hewlett and Packard built the world's greatest company*. New York, N.Y.: Portfolio.

———. 1991. *Going public: MIPS computer and the entrepreneurial dream*. 1st ed. New York, NY: E. Burlingame Books. 59.

Manes, Stephen, and Paul Andrews. 1994. *Gates: How Microsoft's mogul reinvented an industry and made himself the richest man in America*. 1 Touchone ed. New York: Simon and Schuster. 34.

Maremont, Mark. 1995. Digital's turnaround: Time for phase two. *Business Week.* June 19.

Markels, Alex, and Matt Murray. 1996. Call it dumbsizing: Why some companies regret cost-cutting. *Wall Street Journal.* May 4.

Markoff, John. 1998. Digital employees tell of threats by gates over product. *New York Times*, September 10.

Martin, Ian. 2010. Centring the computer in the business of banking; Barclays Bank and technological change, 1954-1974. University of Manchester.

Mashey, John. 2008. *Oral history of John Hennessy*. Vol. 2012, Computer History Museum. REF x4149.

———. 1986. What's all the fuss about RISC? *UNIX Review.* February.

McGrath, Michael E. 2001. *Product strategy for high technology companies: Accelerating your business to web speed*. 2nd ed. New York: McGraw-Hill.

McKinley, W., and A. G. Scherer. 2000. Some unanticipated consequences of organizational restructuring. *The Academy of Management Review* 25, No. 4 (Oct): 735-752.

McWilliams, Gary. 1994. Desperate hours at DEC. *Business Week.* May 9.

Medearis, John. 2013. *Joseph A. Schumpeter*, New York, Bloomsbury Academic. 45.

Menn, Joseph, and Stuart Silverstein. 2002. IBM CEO to step down; he led big blue's turnaround. *LA Times*, January 30.

Mills, Daniel Quinn, and G. Bruce Friesen. 1996. *Broken promises: An unconventional view of what went wrong at IBM*. Boston, Mass.: Harvard Business School Press. 65-66.

Mishra, A. K., and G. M. Spreitzer. 2002. To stay or go: Voluntary survivor turnover following an organizational downsizing. *Journal of Organizational Behaviour* 23, No. 6 (Sept.): 707-729.

———. 1998. Explaining how survivors respond to downsizing: The roles of trust, empowerment, justice and work redesign. *The Academy of Management Review* 23, No. 3 (Jul.): 567-588.

Modis, Theodore. 2012. *Summary: Conquering uncertainty*, ed. Must Read Summaries. Kindle ed. Amazon Digital Services Inc. 1.

———. 2002. *Predictions - 10 years later*. 2nd ed. Growth Dynamics.

———. 1998. *Conquering uncertainty: Understanding corporate cycles and positioning your company to survive the changing environment*. Business Week Books. New York: McGraw-Hill.

———. 1992. *Predictions: Society's telltale signature reveals the past and forecasts the future*. New York: Simon & Schuster.

Mone, M. A., W. McKinley, and V. Barker. 1998. Organizational decline and innovation: A contingency framework. *The Academy of Management Review* 23 No. 1 (Jan.): 115-32.

Montanaro, J., R. T. Witek, K. Anne, A. J. Black, E. M. Cooper, D. W. Dobberpuhl, P. M. Donahue, et al. 1966. A 160-MHz, 32-b, 0.5-W CMOS RISC microprocessor. *IEEE Journal of Solid-State Circuits* 31 (11): 12-1703.

Morgan, Timothy Prickett. 2011. Profit piranhas want a bite of HP. *Business.* July 1.

Mroczkowski, T., and M. Hanaoka. 1997. Effective rightsizing strategies in Japan and America: Is there a convergence of employment practices? *The Academy of Management Executive* 11(2): 57-67.

Mullins, John W. 2006. *The new business road test: What entrepreneurs and executives should do before writing a business* *plan*. 2nd ed. Harlow, England; New York: Prentice Hall/Financial Times.

Myslewski, Rik. 2011. Intel PC hegemony facing ARMy attack. *Channel Register.* May 5.

Nadler, David, and Michael Tushman. 1988. *Strategic organization design : Concepts, tools & processes*. Management applications series. Glenview, Ill.: Scott, Foresman.

Nadler, David, Michael Tushman, and Nina G. Hatvany. 1982. *Managing organizations : Readings and cases*. Boston: Little, Brown.

Nadler, David, Michael Tushman, and Mark B. Nadler. 1997. *Competing by design : The power of organizational architecture*. New York: Oxford University Press.

National Research Council (U.S.). Committee on Workforce Needs in Information Technology. 2000. *Building a workforce for the information economy*. Washington, D.C.: National Academy Press.

NC allegations fly against Microsoft (current and former) DEC employees sue Microsoft chairman Bill Gates for pressuring the company to stop work on a network computer for businesses. 1998. *Info World.* September 14.

Neate, Rupert. 2008. Interview with Steve Wonziak. *Daily Telegraph*, October 6, 2008.

Norberg, Arthur L. 2005. *Computers and commerce: A study of technology and management at Eckert-Mauchly Computer Company, Engineering Research Associates, and Remington Rand, 1946-1957*. History of Computing. Cambridge, Mass.: MIT Press.

Northrup, Mary. 1998. *American computer pioneers*. Collective biographies. Springfield, NJ: Enslow Publishers. 36.

Olsen, Kenneth H., and Newcomen Society in North America. 1983. *Digital Equipment Corporation, the first twenty-five years*. Newcomen publication. Vol. 1179. New York: Newcomen Society in North America.

O'Neil, H. M., D. J. DLenn, and V. F. Caimano. 1993. Voices of survivors: Words that downsizing CEO's should hear. *The Academy of Management Executive* 9, No. 4 (Nov.): 23-34.

O'Regan, Gerard. 2012. *A brief history of computing*. 2nd ed. London; New York: Springer.

Orlando, J. 1999. The ethics of corporate downsizing. *Business Ethics Quarterly* 9, No. 2 (Apr.): 295-314.

Ornstein, Severo M. 2002. *Computing in the middle ages : A view from the trenches, 1955-1983*. [S.l.]: 1st Books.

Oslin, George P. 1992. *The story of telecommunications*. Macon, Ga.: Mercer University Press.

Ould, Andrew. 1990. How Motorola lost the workstation market. *UNIX World.* July.

Packard, David, David Kirby, and Karen R. Lewis. 1995. *The HP way: How Bill Hewlett and I built our company*. 1st ed. New York: Harper Business. 102,

Palmer, I., B. Kabanoff, and R. Dunford. 1997. Managerial accounts of downsizing. *Journal of Organizational Behaviour* 18 (Special Issue: Computers Can Read as Well as Count: Computer Aided Text Analysis in Organizational Research): 623-39.

Papian, W. N. 1950. A co-incident current magnetic memory unit. Massachusetts Institute of Technology.

Patterson, David A., and David R. Ditzel. 1980. The case for the reduced instruction set computer. *ACM SIGARCH Computer Architecture News* 8 (6): 9-25, 34-38.

Patterson, David A., and John L. Hennessy. 2014. *Computer organization and design: The hardware-software interface*. The Morgan Kaufmann series in computer architecture and design. Fifth ed. Amsterdam ; Boston: Elsevier/Morgan Kaufmann, Morgan Kaufmann is an imprint of Elsevier.

———. 2009. *Computer organization and design: The hardware-software interface*. 4th ed. Burlington, MA: Morgan Kaufmann Publishers.

Patterson, David A., John L. Hennessy, and David Goldberg. 1996. *Computer architecture: A quantitative approach*. 2nd ed. San Francisco: Morgan Kaufmann Publishers.

———. 1996. *Computer architecture: A quantitative approach*. 2nd ed. San Francisco: Morgan Kaufmann Publishers.

Pearson, Jamie Parker. 1992. *Digital at work: Snapshots from the first thirty-five years*. Burlington, MA: Digital Press. 55, 58, 88-89.

Peck, Helen, and Chartered Institute of Marketing. 1999. *Relationship marketing: Strategy and implementation*. [CIM professional]. Oxford ; Boston: Butterworth Heinemann.

Peters, Thomas J. 2010. *The little big things: 163 ways to pursue excellence*. 1st ed. New York: HarperStudio.

———. 2009. *In search of excellence*. New York, NY: MJF Books.

Peters, Thomas J., and Nancy Austin. 1986; 1985. *A passion for excellence: The leadership difference*. Warner books ed. New York, N.Y.: Warner Books.

Peters, Thomas J., and Robert Townsend. 1986. *Excellence in the organization*. Chicago, Ill.: Nightingale-Conant.

Peters, Thomas J., and Robert H. Waterman. 1997. *In search of excellence: Lessons from America's best-run companies*. G.K. Hall large print reference collection. Thorndike, Me.: G.K. Hall & Co.

———. 1984. *In search of excellence: Lessons from America's best-run companies*. Warner Books ed. New York, NY: Warner Books.

———. 1982. *In search of excellence: Lessons from America's best-run companies*. 1st ed., New York: Harper & Row.

Petit, Patrick. 2008. *SUN Microsystems International Human Resources Management Case Study*, Grenoble Graduate School of Business

Pettigrew, Andrew M., Howard Thomas, and Richard Whittington. 2006. *Handbook of strategy and management*. London; Thousand Oaks, CA: Sage Publications.

Pravit, Keith. 1990. *Technology, Management and Systems of Innovation*, California Management Review, 32 no. 3 Spring. 63, 65.

Pugh, Emerson W. 1995. *Building IBM: Shaping an industry and its technology*. History of Computing. Cambridge, Mass.: MIT Press.

———. 1984. *Memories that shaped an industry: Decisions leading to IBM system360*. The MIT press series in the History of Computing. Cambridge, Mass.: MIT Press.

Pugh, Emerson W., Lyle R. Johnson, and John H. Palmer. 1991. *IBM's 360 and early 370 systems*. History of Computing. Cambridge, Mass.: MIT Press.

Rajshekhar, M. 2003. Are innovative firms bound to die? *Business World*(Sept 15th 2003): 15.

Ranft, Annette L., and Hugh M. O'Neill. 2001. Board composition and high-flying founders: Hints of trouble to come? *Academy of Management Executive* 15 (1): 12-126.

Raymond, Eric S. 2001. *The cathedral and the bazaar: Musings on linux and open source by an accidental revolutionary*. Rev ed. Beijing ; Cambridge, Mass.: O'Reilly. 6.

———. 1996. *The new hacker's dictionary*. 3rd ed. Cambridge, Mass.: MIT Press.

Ricciuti, Mike. 2000. SUN CEO: We're "good enough". *CNET News*2000.

Richardson, C. 1996. Computers don't kill jobs, people do: Technology and power in the workplace. *Annals of the Academy of Political and Social Science* 544 (Mar.): 167-79.

Ries, Al, and Jack Trout. 2006. *Marketing warfare*. 20th anniversary ed. New York: McGraw-Hill.

Rifkin, Glen. 1992. Digital, the next generation. *Upside.* September.

Rifkin, Glenn, and George Harrar. 1990. *The ultimate entrepreneur: The story of Ken Olsen and Digital Equipment Corporation*. Updated. Rocklin, CA: Prima Pub. 94-96, 275.

Ristelhueber, Robert. 1998. Compaq's triumph is no accident. *Electronic Business* (March 1st). http://www.highbeam.com/doc/1G1-20354905.html (accessed Sept 30, 2015).

Robbins, K. D., and J. A. Pearce II. 1992. Turnaround, retrenchment and recovery. *Strategic Management Journal* 13: 287-309.

Roberts, Edward Baer. 1991. *Entrepreneurs in high technology: Lessons from MIT and beyond*. New York: Oxford University Press.

Rowlinson, Michael, Charles Booth, Peter Clark, Agnes Delahaye and Stephen Procter, 2010. *Social Remembering and Organizational Memory*, Organization Studies, Jan., Vol 31, No 1, 69-87

Sadler, Graham Vernon. 1999. *Executive compensation & share options in UK quoted companies.* University of Warwick.

Samuelson, Paul A. 1948. *Economics*. 1st ed. New York,: McGraw-Hill Book Co.

Saxenian, AnnaLee. 1994. *The limits of autarky: Regional networks and industrial adaption in Silicon Valley and route 128*. Paper presented at HUD Roundtable on Regionalism.

———. 1994. *Regional advantage: Culture and competition in Silicon Valley and route 128*. Cambridge, Mass.: Harvard University Press. 65, 137

Schaffer, William A. 1999. *High-tech careers for low-tech people*. 2nd ed. Berkeley, Calif.: Ten Speed Press.

Schein, Edgar H. 2003. *DEC is dead, long live DEC: The lasting legacy of Digital Equipment Corporation*. 1st ed. San Francisco, Calif.: Berrett-Koehler. 34, 86, 103-112, 162, 216.

———. 1994. *The role of the CEO in the management of change: The case of information technology*. Information Technology and the Corporation of the 1990s: Research Studies., eds. Thomas J. Allen, Michael S. Scott MortonOxford University Press.

Schumpeter, Joseph A. 2009. *Can capitalism survive*? New York: Harper Collins. 43,

———. 1943. *Capitalism, socialism, and democracy*. London: G. Allen & Unwin ltd. 81-86.

Schumpeter, Joseph. A. 1912/1934/1983. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Translated from the German by Redvers Opie. With an Introduction by John E. Elliott. New Brunswick, NJ: Transaction Publishers.

Schumpeter, Joseph A., and Redvers Opie. 1934. *The theory of economic development; an inquiry into profits, capital, credit, interest, and the business cycle*. Harvard economic studies. [Theorie der wirtschaftlichen Entwicklung.]. Vol. ol. XLVI. Cambridge, Mass.: Harvard University Press.

Scott, Greg. 1994. *Digital Equipment Corporation: R.I.P. or future lean and mean competitior?* Scott Consulting.

Sculley, John, and John A. Byrne. 1987. *Odyssey: Pepsi to Apple--a journey of adventure, ideas, and the future*. 1st ed. New York: Harper & Row.

Seltzer, Richard. 2011. *Internet Business Group (IBG) alumni page*. http://www.samizdat.com/ibg.html, (accessed 19 Jan. 2016).

Seltzer, Richard, Eric J. Ray, and Deborah S. Ray. 1997. *The AltaVista search revolution*. Berkeley, Calif.: Osborne/McGraw-Hill.

Shah, P. 2000. Network destruction: The structural implications of downsizing. *The Academy of Management Journal* 43, No. 1 (Feb.): 101-12.

Shapiro, C. 2002. *The FTC's challenge to Intel's cross-licensing practices (June 2, 2002)*. UC Berkeley competition policy center working paper no. CPC02-29. Vol. 2010.

Sheck, Justin. 2009. Ex-employees file lawsuit against HP over sales pay. *Wall Street Journal* (August 8).

Sheth, Jagdish N. 2007. *The self-destructive habits of good companies: And how to break them*. Upper Saddle River, N.J.: Wharton School Pub.

Smiley, Jane. 2010. *The man who invented the computer: The biography of John Atanasoff, digital pioneer*. 1st ed. New York: Doubleday.

Smith, Merritt Roe, and Leo Marx. 1994. *Does technology drive history?: The dilemma of technological determinism*. Cambridge, Mass.: MIT Press.

Soltis, Frank G., 1940-. 1997. *Inside the AS400: Featuring the AS400e series*. 2nd ed. Loveland, Colo.: Duke Press.

Sonnenfeld, Jeffrey A. 1988. *The hero's farewell: What happens when CEOs retire*. New York ; Oxford: Oxford University Press.

Southwick, Karen. 1999. *High noon: The inside story of scott McNealy and the rise of sun microsystems*. New York: John Wiley. 66, 69.

Spencer, Aron S. and Bruce A. Kirchoff, 2006. Schumpeter and new technology based firms: Towards a framework for how NTBFs cause creative destruction," *International Entrepreneurship and Management Journal* 2, no. 2: 145-156.

Steele, Guy L. 1983. *The hacker's dictionary: A guide to the world of computer wizards*. Colophon books. 1st ed. Vol. CN 1082. New York: Harper & Row.

Steenkamp, Jan-Benedict E.M. Martin G. de Jong and Hans Baumgartner, 2010. Socially Desirable Response Tendencies in Survey Research, *Journal of Marketing Research* 47 (2), 199-214.

Stewart, Matthew. 2009. *The management myth: Why the experts keep getting it wrong*. 1st ed. New York: W. W. Norton & Co.

Stiles, Philip, and Bernard Taylor. 2001. *Boards at work: How directors view their roles and responsibilities*. Oxford ; New York: Oxford University Press.

Stone, Arthur A., Jaylan S. Turkkan, Christine A. Bachrach, Jared B. Jobe, Howard S. Kurtzman and Virginia S. Cain (eds), 2000. *The Science of Self-Report: Implications for Research and Practice* Mahwah, NJ: Lawrence Erlbaum.

Strauss, Daryll, and Wook. 1998. Linux helps bring the titanic to life. *Linux Journal* February (46). http://www.linuxjournal.com/issue/46 (accessed Sept 30, 2015).

Strecker, William D., and Douglas W. Clark. 1980. Comments on "the case for the reduced instruction set computer". *ACM SIGARCH Computer Architecture News* 8 (6) (October): 5-34.

Stross, Randall E. 2008. *Planet google: One company's audacious plan to organize everything we know*. 1 Free Press hbk ed. New York: Free Press.

Swedin, Eric Gottfrid, and David L. Ferro. 2005. *Computers: The life story of a technology*. Greenwood technographies. Westport, Conn.: Greenwood Press.

The big engine that hasn't. 1991. *Business Week.* June 23.

The early hackers. http://www.catb.org/esr/writings/homesteading/hacker-history/ar01s02.html. (accessed 16 Jan. 2016).

The origins of venture capital. 2011. Fall 2011 ed.Life Science Foundation.

Tomasko, Robert M. 1990. *Downsizing: Reshaping the corporation for the future*. Expa & updat ed. New York, NY: Amacom.

Tosh, John. 2010. *The pursuit of history: Aims, methods, and new directions in the study of modern history*. 5th ed. New York: Longman/Pearson. 320.

Tulving, Endel, 1983. *Elements of Episodic Memory*, Oxford University Press.

Tushman, Michael. 1974. *Organizational change: An exploratory study and case history*. ILR paperback. Vol. 15. Ithaca: New York State School of Industrial and Labor Relations, Cornell University.

Tushman, Michael, and Philip Anderson. 2004. *Managing strategic innovation and change: A collection of readings*. 2nd ed. New York: Oxford University Press.

———. 1986 "Technological Discontinuities and Organizational Environments," *Administrative Science Quarterly* 31, no. 3.

Tushman, Michael, and William L. Moore. 1988. *Readings in the management of innovation*. 2nd ed. Cambridge, Mass.: Ballinger.

Tushman, Michael, and Charles A. O'Reilly. 2002. *Winning through innovation: A practical guide to leading organizational change and renewal*. Rev ed. Boston, Mass.: Harvard Business School Press.

Tushman, Michael, Charles A. O'Reilly, and David Nadler. 1989. *The management of organizations: Strategies, tactics, analyses*. Ballinger series on the management of organizations. New York: Ballinger Pub. Co.

Uhler, Michael G., et. al., 1992. NVAX microprocessor, *Digital Technical Journal,* volume 4, no. 3, 10.

Ulrich, David, and Dale G. Lake. 1990. *Organizational capability: Competing from the inside out*. New York: Wiley.

Unknown. 1987. Setbacks for data general. *New York Times - Business Days Section*, July 24.

Usselman, Steven W. 1993. IBM and Its Imitators: Organizational Capabilities and the Emergence of the International Computer Industry, *Business and Economic History* 22, no. 2: 1-35.

Utterback, James M. 1994. *Mastering the dynamics of innovation: How companies can seize opportunities in the face of technological change*. Boston, Mass.: Harvard Business School Press. 124.

Utterback, James M. and Happy J. Acee, 2001. *Disruptive Technologies: An Expanded View,* SM Thesis, Management of Technology, Massachusetts Institute of Technology .

Utterback, James M. and William J. Abernathy, 1975. A Dynamic Model of Product and Process Innovation, *Omega* 3, no. 6: 639-656.

Vance, Ashlee. 2007. *Geek Silicon Valley*. 1st ed. Guilford, Conn.: Globe Pequot.

Verhulst, Pierre, (1838). "Notice sur la loi que la population poursuit dans son accroissement". *Correspondance mathématique et physique* 10: 113–121. (Accessed July 6, 2015):

Vise, David A., and Mark Malseed. 2005. *The Google story*. New York: Delacorte Press.

Von Neumann, John, William Aspray, and Arthur W. Burks. 1987. *Papers of John von Neumann on computing and computer theory*. Charles babbage institute reprint series for the history of computing. Vol. 12. Cambridge, Mass.; Los Angeles: MIT Press; Tomash Publishers.

Waite, Charles. 2000. *Done Deals: Venture Capitalists Tell Their Stories*, ed. Udayan Gupta, Harvard Business School Press. 225

Walden, David, and Raymond Nickerson, eds. 2011. *A culture of innovation: Insider accounts of computing and life at BBN,* Waterside Publishing.

Waldrop, M. Mitchell. 2001. *The dream machine: J. C. R. Licklider and the revolution that made computing personal*. The Sloan Technology Series. New York: Viking.

Walker, James. 2005. *Determinants of the decline of British Leyland: The roles of product quality, advertising and voluntary export restraints (1971-2002).*London School of Economics.

Walsh, Ian J. 2009. *The Role of Organizational Identification in Post-Death Organizing*, Wallace E. Carroll School of Management, Boston College, March 23 (2009). PhD dissertation. Supervisor J. M. Bartunek.

Watts, Reid McRae. 2001. *The slingshot syndrome: Why America's leading technology firms fail at innovation,* Writers Club Press.

Wheeldon, Richard. 2003. A web of trails. Birkbeck College, University of London.

Where is 64-bit going. 2004. *Computer Times*, June 30, 2004.

White, Roger Bourke. 2010. *Surfing the high tech wave a history of Novell, 1980-1990* Authorhouse.

Wikes, Maurice V. 1952. *Pure and Applied Programming*. Paper presented at Proceedings of the ACM Toronto Meeting, Toronto. 121.

Wilkes, Maurice V. 1985. *Memoirs of a computer pioneer*. MIT press series in the history of computing. Cambridge, Mass.: MIT Press.

Willett, Shawn. 1992. Giants downsize: DEC regroups, IBM cuts jobs. *Info World.* October 5. 8.

Williams, Kathleen Broome. 2004. *Grace Hopper: Admiral of the cyber sea*, Library of Naval Biography, Annapolis, Md.: Naval Institute Press. 172.

Williams, Michael R., and Martin Campbell-Kelly. 1989. *The early British computer conferences*. The Charles Babbage institute reprint series for the history of computing. Vol. 14. Cambridge, Mass.; Los Angeles: MIT Press; Tomash Publishers.

Wilson, John F. 2000. *Ferranti: A history ; building a family business, 1882-1975*. Lancaster: Carnegie Publ.

Yang, Kisuk. 2003. *Fundamentals of divestiture as a restructuring method: Case study of LG demergers in terms of shareholders value and corporate governance in the context of Korean practice*. Massachusetts Institute of Technology, Sloan School of Management.

Yates, JoAnne. 2005. *Structuring the information age: Life insurance and technology in the twentieth century*. Studies in industry and society. Baltimore, Md.: Johns Hopkins University Press.

Young, Jeffrey S. 1998. *Forbes greatest technology stories: Inspiring tales of the entrepreneurs and inventors who revolutionized modern business*. New York: John Wiley & Sons.

Yovanof, Gregory, and George Hazapis. 2008. Disruptive technologies, services, or business models? *Wireless Personal Communications* 45 (4): 569-83.

Yuen, Albert, ed. 2006. *Bill & dave's memos*. Palo Alto: 2DaysOfSummer Books.

Zachary, G. Pascal. 1994. *Show-stopper!: The breakneck race to create windows NT and the next generation at Microsoft*. New York : Free Press ; Toronto; New York: Maxwell Macmillan International.

Zollo, Maurizio, and Sidney G. Winter, 2002. Deliberate Learning and the Evolution of Dynamic Capabilities, *Organizational Science* 13: 339-351.

Zoltners, Andris A., Prabhakant Sinha, and Sally E. Lorimer. 2006. *The complete guide to sales force incentive compensation: How to design and implement plans that work*. New York: American Management Association.

Zuckerman, Laurence. 1997. Shareholders discuss challenges facing digital. *The New York Times*.

Appendix.A.1 Biographical Notes

The following is a brief biography of the people that had the greatest impact on the company.

Harlan Anderson – Born 1929, received a Master of Science degree from the University of Illinois. He went on to work at Lincoln Labs with Olsen. Anderson was DEC's second employee and co-founder. He left in 1966 after being sidelined by Olsen.

Gordon Bell - Born: August 19, 1934, Kirksville, Missouri. Received his Masters from MIT Worked on the TX-0 at Lincoln Labs. Joined DEC in 1960 from MIT and in 1966 took a leave of absence for a number of years to rejoin academia at Carnegie Mellon University. Once DEC's chief architect and main designer of the VAX architecture that was to keep DEC at the front for many years. Left in 1982 after suffering a heart attack, reportedly brought on by the stress of his job and working with Olsen. He kept in touch with Olsen over the years and offered advice which was not always listened to.

Dileep Bhandarkar – Educated at the Indian Institute of Technology, Bombay, where he received his B. Tech in Electrical Engineering in 1970. He also has a Masters and Ph.D. in Electrical Engineering from Carnegie Mellon University. He was elected an IEEE Fellow in 1997 for contributions and technical leadership in the design of complex and reduced instruction set architecture and in computer system performance analysis. Prior to joining Intel in 1995, he spent almost 18 years at Digital Equipment Corporation, where he managed processor and system architecture, and performance analysis work related to the VAX, PRISM, MIPS, and Alpha architectures. Dr. Bhandarkar is currently a distinguished engineer at Microsoft.

Edson deCastro - Designer of the PDP-8 and PDP-X which, when cancelled, caused him to leave DEC and start up a rival company Data General. This in turn caused DEC to hurriedly design a 16-bit product which turned out to be one of the most successful minicomputers ever built. Olsen never forgave him.

Dave Cutler - Born in Lansing in 1942, author of RSX and major contributor to VMS, left DEC after the PRISM/Mica program was cut in favour of the MIPS architecture. Immediately joined Microsoft with many members of his team and was the prime developer of Windows NT. It was rumoured that code from DEC found its way into the new operating system although this never came to court and DEC formed an alliance with Microsoft.

Bill Demmer – Was the programme manager for the VAX project and later the VP of the Alpha and VAX Group at DEC and retired in 1995.

Hans Dirkmann – Born 1941. Has degrees in electrical engineering and business economics and was a long term employee having joined DEC in 1972. DEC European President from 1996, previously he had been the managing director of DEC Germany.

Georges F. Doriot – 'General' Doriot was born in Paris in 1899. Received an MBA from Harvard and was a professor there from 1926. He was often referred to as the father of venture capital. He died of lung cancer in 1987.

Pier Carlo Falotti – Born in 1942 Mr. Falotti holds a degree in Electrical Engineering from the Institute Avogadro, Torino, Italy. He served as President and CEO of Digital EMEA from 1983 to 1992. During his tenure revenues grew from US$1 to US$7 billion and it was the most profitable region of the corporation. He announced his resignation days before Olsen was removed.

Jay Forrester - Resigned in 1966 over a conflict of interest with his core memory patent and DEC's use of it.

Don Gaubatz – VP of Workstations at DEC, developed Ethernet and disk controllers for the MicroVAX and ran the workstation team developing products based on MIPS, VAX and Alpha and also the first 3D graphics board for Digital. He is a founding member of the Computer History Museum and on the editorial board of the Microprocessor Report. He also holds a PhD in Computer Science from Cambridge University in England.

Rose Ann Giordano – First female VP and corporate officer at DEC. VP of Internet business group in late 1990s

Bob Glorioso - (M.S. 1964 and Ph.D. 1967; Electrical Engineering) served as Vice President at Digital Equipment Corporation, where he managed worldwide engineering, marketing, and manufacturing for the company's Information Systems Business.

Phil Grove – BS in Physics, MBA Babsons College. Director of Internet marketing at DEC. Employed by DEC 1984 to 1998

Ben Gurley – Born 1926 in Pipestone. Joined Digital Equipment in 1959 where he helped design the PDP-1. Gurley left in 1962 after finding DEC too stressful and tired of Olsen treating him like a child. He was murdered in 1962 by another DEC engineer who was annoyed that he had not taken him with him when he left the company[514].

Win Hindle – MS in Industrial Management from Sloan School of management. Joined Digital in 1962 as assistant to the president and was responsible for a number of business groups within the corporation. He retired from DEC 1994 as vice president of Quality, Ethics and Business Practices,

Grace Hopper – Born 1906 in New York City she received a PhD from Yale University in 1934. She became one of Americas first computer programmers. When she retired from the navy in 1986 she became a senior consultant to Digital Equipment Corporation. She died in 1992.

Dick Hustvedt - Software architect for VMS with Dave Cutler. It was a big loss to company when he was involved in a car accident in 1984.

Ted Johnson – MS in business Administration from Harvard. He was the first sales engineer at DEC and held badge number 10. He was named VP of sales and Service in 1967.

Andy Knowles - Joined DEC in 1969 and was the PDP-11/20 product manager. He was the components group product manager being named a VP in 1972. He was a senior vice president for 14 years, leaving during the mass exodus of senior executives who clashed with Olsen in 1984. Died 2009.

Peter de Lisi – Has a B.S. degree in Chemistry from the University of Detroit and has completed post-graduate work in Meteorology, Philosophy and Psychology. In addition, for the past 25 years, Pete has worked closely with Edgar Schein from the MIT Sloan School He spent sixteen years at Digital

---

[514] Interview with Bob Wyman transcribed by the Computer History Museum www.computer-history.info/Page1.dir/pages/Wyman.html last accessed 23/Sep/2011 *also documented in* Edmund C. Berkeley Papers (CBI 50), Charles Babbage Institute, University of Minnesota, Minneapolis, Benjamin Gurley's murder, 1963. (#202) **Box 44, Folder 1**

Equipment Corporation in senior sales and marketing positions, eight of those years as a consultant to Digital's large, Fortune 500-size customers.

Julius Marcus – MS in Instrumentation Engineering from Case Western Reserve University. Joined DEC in 1969 as Marketing Manager for the PDP-11. He was named a VP for information systems.

Bryan Marler –Cornell University, Global Account Manager all through 1990s

Leo Merta – Graphics applications product manager for 1988 to 1992.

Avram Miller – Digital's first PC programme manager. Responsible for the DEC Professional product range.

Kenneth Olsen – Born February 20th 1926 in Bridgeport Connecticut – received a Master of Science from MIT then worked at Lincoln Labs on the TX-0 and TX-2. He left there with Anderson to found Digital Equipment with funding of $70,000 from ARD in 1957. In 1960 he was elected "Young Engineer of the Year" by the electrical engineering honorary fraternity. In 1992, at the age of 66, was ousted by senior management and the board at Digital after the firm suffered substantial losses. Olsen was badge number 1.

Cormac O'Reilly – Joined DEC as VP, CIO Global Services and member of the executive management team reporting to John Rando, when Digital was in the middle of a major shift from high margin computers, to the fast emerging commoditized world of PCs and cheap computer power. He built a service alliance with Microsoft around its Exchange product, and led the charge away from Digital traditional products to Microsoft.

Robert Palmer – Born 1940, one of the founders of Mostek, joined Digital Equipment in 1985. He replaced Ken Olsen in 1992 and left in 1998 after selling the company to Compaq.

Edgar Schein – Born 1928 in Zurich, Edgar Schein attended Stanford University where he received a Masters Degree in 1949, and at Harvard University where he studied for his Ph.D. in social psychology in 1952, he is a Sloan Fellows Professor of Management Emeritus at MIT. He was an organisational consultant for DEC from 1966 to 1992 whilst still working for the Sloan School of Management at MIT.

Jack Shields – Graduate of the School of Industrial Management a Worcester Polytechnic. Joined DEC in 1961 as a Field Service Engineer and grew to be VP of Customer Services in 1974.

Jack Smith – Received a BSEE from Northeastern University in 1963 and joined DEC in 1958. He was VP of Systems Manufacturing.

Sue Skonetski –VMS programme manager at DEC from 1984 to 1998. Founder of DEC's VMS partner group and a VMS evangelist. Left HP in 2009.

Bill Strecker – Has a PhD from Carnegie Mellon University. He was with Digital Equipment Corp. for 28 years in various executive and senior technical positions, most recently as SVP Corporate Strategy & Technology and CTO. Was Bell's doctoral student at Carnegie Mellon and was responsible for the VAX architecture. Later he took Bell's place in DEC and was responsible for the Strategic Task Force.

Robert Supnik –VP, Senior Corporate Consulting Engineer Digital Equipment Corporation June 1977 — June 1999. Multiple positions including: VP of Corporate Research; Engineering Program Manager for Alpha (chips, systems, software); Group Manager of Microprocessor Development. Deliverables include VAX microprocessors starting with MicroVAX II; Alpha, all aspects; and new business/technology opportunities, such as the Palo Alto Internet Exchange and the Personal JukeBox (pre-iPod MP3 player).

Maurice Wilkes – Born in Dudley, England in 1913 and was a graduate student at the Cavendish Laboratory. He was instrumental in the design and construction of EDSAC. He joined Digital Equipment Corporation on his retirement from Cambridge in 1980. He died in 2010.

Rich Witek – Graduated from Aurora College in 1976 with a bachelor's degree in computer science. Joined DEC in 1976 and worked there until 1997 when Digital Semiconductor was sold to Intel. Worked on MicroVAX II, PRISM, Alpha and StrongARM. Left to start Alchemy Semiconductor and is now a Distinguished Engineer with Microsoft.

The board – taken from the SEC filings for 1997

Vernon R. Alden

Mr. Alden, age 74 in 1997, was Chairman of the Board and Executive Committee of The Boston Company, Inc., a financial services company, from 1969 to 1978. He was President of Ohio University from 1962 to 1969. Mr. Alden is a director of Intermet Corporation and Sonesta International Hotels Corporation. He is also a trustee of several cultural and educational organizations. He has been a director of the Corporation since 1959 and is a member of the Audit Committee and Nominating Committee.

Thomas L. Phillips

Mr. Phillips, age 73 in 1997, retired as Chairman of the Board and Chief Executive Officer of Raytheon Company ("Raytheon") in March 1991, having served as Chief Executive Officer since 1968, and as Chairman of the Board since 1975. He has been a director of Raytheon since 1962. Mr. Phillips is also a director of SRA International, Inc., State Street Research and Management Co. and Knight-Ridder, Inc. Mr. Phillips has been a director of the Corporation since 1991. He is Chairman of the Compensation and Management Development Committee and is a member of the Nominating Committee.

Delbert C. Staley

Mr. Staley, age 73 in 1997, was Chairman, Chief Executive Officer and a director of NYNEX Corporation ("NYNEX") from 1983 until his retirement in September 1989. He continued serving as a director of NYNEX and served as Chairman of NYNEX International Management Committee until October 1991. Mr. Staley is a director of Polaroid Corporation and SRA International, Inc., and is Chairman of Alcatel Network Systems Inc. Mr. Staley has been a director of the Corporation since 1993 and is a member of the Compensation and Management Development Committee and Strategic Direction Committee.

Colby H. Chandler

Mr. Chandler, age 72 in 1997, retired as Chairman of the Board and Chief Executive Officer of Eastman Kodak Company ("Kodak") in May 1990. Prior to that time he had been Chief Executive Officer, Chairman of the Board and Chairman of the Executive Committee of Kodak since July 1983. He assumed the presidency of Kodak in January 1977. Mr. Chandler was a director of Kodak from 1974 to 1993. Mr. Chandler has been a director of the Corporation since

1989. He is Chairman of the Audit Committee and a member of the Nominating Committee.

Arnaud De Vitry

Mr. de Vitry, age 71 in 1997, is an engineering consultant. From 1980 to 1990, Mr. de Vitry was Chairman of the Board and Chief Executive Officer of Eureka SICAV, France, an investment company. He is a director of Ionics, Incorporated. Mr. de Vitry has been a director of the Corporation since 1957 and is Chairman of the Nominating Committee.

Thomas P. Gerrity

Dr. Gerrity, age 56 in 1997, has served as Dean of the Wharton School of the University of Pennsylvania since July 1990. From 1969 to 1989, Dr. Gerrity was chief executive officer of Index Group, Inc. ("Index"), an information technology consulting company he founded. In 1988, Index became part of Computer Sciences Corporation ("CSC") and Dr. Gerrity was subsequently appointed president of CSC's commercial professional services group, CSC Consulting. Dr. Gerrity is a director of Fannie Mae, CVS Corporation, Reliance Group Holdings, Inc., Sun Company, Inc. and Union Carbide Corporation. He has been a director of the Corporation since 1992, and is a member of the Compensation and Management Development Committee and Strategic Direction Committee.

Frank P. Doyle

Mr. Doyle, age 66 in 1997, retired in December 1995 as an Executive Vice President of General Electric Company ("GE"). Mr. Doyle had been an Executive Vice President of GE and a member of its corporate executive office since July 1992 and was a Senior Vice President from 1981 to July 1992. He is a director of the Paine Webber Group Inc., Roadway Express, Inc., and Educational Testing Service. Mr. Doyle has been a director of the Corporation since 1995 and is a member of the Audit Committee and Strategic Direction Committee.

Kathleen F. Feldstein

Dr. Feldstein, age 56 in 1997, has been President of Economics Studies, Inc., an economics consulting firm, since 1987. Dr. Feldstein is a director of Bank America Corporation, Conrail Corporation and The John Hancock Mutual Life

Insurance Company. Dr. Feldstein has been a director of the Corporation since 1993 and is a member of the Audit Committee.

Robert B. Palmer

Mr. Palmer, age 57 in 1997, has been President and Chief Executive Officer of the Corporation since October 1992, and Chairman of the Board since May 1995. Mr. Palmer joined the Corporation in 1985 and served as Vice President, Semiconductor and Interconnect Technology until 1990, and as Vice President, Manufacturing, Logistics and Component Engineering from 1990 to 1992. From 1983 to 1985, he was Executive Vice President of Semiconductor Operations at Mostek Corporation ("Mostek"), a subsidiary of United Technologies Corporation. Mr. Palmer was a co-founder of Mostek, where he held a series of senior management positions prior to its acquisition in 1980 by United Technologies Corporation. Mr. Palmer is a director of Allied Signal Inc. Mr. Palmer has been a director of the Corporation since 1992 and is Chairman of the Strategic Direction Committee.

Appendix.A.2 Interviews

Strout interviewed the following people for his documentary:

Board members Vernon Alden, Tom Phillips.
Senior management Andy Knowles, Jack Shields, Jack Smith, Jay Forrester, Sam Fuller, Stan Olsen, Ted Johnson, Win Hindle.
Others Ann Jenkins, Abbott Weisse, Bob Metcalfe, Bob Moore, Bob Puffer, Dan Aliage, Dan Dobberpuhl, David Carlson, David Lee, David Sutterbrown, Deborah Pace, Debra Amidon, Doug Harms, Edgar Schein, Fred Bowers, Gordon Bell, Jack Richardson, Jim Sims, Jim Wenger, John Sims, Judson Carlbas, Marilyn Goodrich, Mill Broll, Mort Ruderman, Nancy Kilty, Patrick Finnegan, Paul Kampas, Peter Koch, Rod Sutherland, Roger Hannemann, Rose Ann Giordano, Sheridan Forbes, Tricia Bagilio.

Interviews were also carried out with the following:
Board members Vernon Alden, Thomas Gerrity.
Senior management Ted Johnson, Win Hindle, Rose Ann Giordano, Pat Cataldo, Julius Marcus, John Barrett, Hans Dirkmann, Don Gaubatz, Cormack O'Reilly, Bryan Marler.
Others Dave Cutler, Avram Miller, B J Johnson, Carl Pick, Debra Amidon, John Holz, Peter DeLisi, Phil Groves, Sue Sonetski, Ann Jenkins, Marcia Russell, Fred Balfour, Alan Evans, Peter Bembridge, Ian Waring, Steve Briebart.

Email conversations were exchanged with the following:
John Sculley (Apple), Bob Glorioso, Bill Armitage, Stephen Jenks, Bob Supnik, Stephen Cullen, Bryan King, Ron Smart, Dileep Bhandarkar, Karel Uyttendaele, Edgar Schein, Michael Spindler, Fred Fisher, Kathy Hornbach, Ken Smith, Gordon Bell, Larry Kennedy, Jesse Lipcon, Nick Carr, Leo Merta, Paul Kinzelman, Mark Russinovic, Peter Moyes, Adrie Sweep, Richard Seltzer, Christa Nehls, Ron Lusk, Dick Murphy, Doug Thornburg, Bashir Jivani, Ziva Orian, John Kalinowski, Jeff Gardiner, Cyril Gaydos, Jack Mileski, Gary Finerty, Brian Reid, Chip Schooler, Ian Royal, Chuck Youse, Keith Todd, Dick Grier, Tony Evans, Don McInnes, Jos Noordhuizen, Ed Kramer, Andrew Turnbull, Eric Hilman, Bob Brownson, Stefan Fiala, Bob Farquhar, Dagmar Fischer, Bobbin Teegarden, Bobby Choonavala, Grant Saviers, Steve Wells.

Also, board members emailed, but who returned no response or negative response, were:
Tom Phillips, Dr Feldstein, Colby Chandler, Robert Everett, Arnaud de Vitry.

The following attempts were made to contact the members of the board and their response is captured:

Philip Caldwell – Wrote on a number of occasions and phoned and left messages. Unfortunately none of these attempts resulted in any form of response from Mr Caldwell or his secretary.

Tom Phillips – Contacted via the Ken Olsen Archives but he declined to answer any questions on the subject. He did however give an interview to Ben Strout in which he commented:

> Well it wasn't dissatisfaction. It was that the board began to express concern that Digital was now losing a lot of money and we had to do something. We had missed the boat on the microprocessor, on the minicomputer. We needed to catch up and the board was insisting that Digital trim expenses to the bone and catch up. And Ken was unwilling to let go of any people at all. And that was the difference between the board and Ken. He believed the way to go by profitability was not by not by firing people. And the rest of us, our experience had been, when you're in a down period, you trim down the number of people and give yourself a chance to catch up again. And that was a sticking point with Ken. The downsizing was very painful for Ken. Whether it was love for his people or he didn't believe that was the way to go. But so at the board, all of them had worked at other companies, knew it had to be done, and Ken did not. There were, it was very, very generous amount of severance packages. People took a severance package and started a competing company. And you know we thought for severance packages with that rich, we couldn't make it. We had to cut back on the size of the severance packages and reduce the payroll temporarily until we caught up.

Bob Everett – was contacted by email and offered to help but when he was asked some questions he declined to answer considering them too penetrating. The questions were –

1) Did the operation of the board change after General Doriot's death?
2) I understand that Ken Olsen was forced out and have been told that it was a unanimous board decision. Is that your recollection?
3) I believe that it was because Ken Olsen would not reduce expense as much as the board wanted. Am I correct in that assumption?

4) Can you tell me how the decision to ask Robert Palmer to take over was arrived at, was there any consideration to people outside of DEC and how long did the decision take?
5) I believe the board considered replacing Robert Palmer around 1994, is that something that was actively on the table?
6) Were you still a board member when the option of merging with Compaq came up and what were the board's views on this?
7) What were the board's views on the Alpha chip and the viability of it?
8) Is there anything you can add about the operation of the company from 1988 that you did not agree with?

Thomas Gerrity – Was interviewed by telephone and commented that he was part of the discussions about Olsen's future. The reasons the board asked him to resign was that an overall assessment concluded that he wasn't fulfilling the role in a fashion that was helping the board and the shareholder. Examples were the PC decision, closed operating system and finally the decision to take IBM head on in the mainframe market. He also said that discussion took place to decide whether to look externally, there was a time factor that came in as the board thought the decision was urgent. Gerrity stated that they looked at a few external candidates against internal but decided that it should be internal and came to a solid conclusion that Palmer was correct. The board thought that Palmer understood the business and displayed the deepest understanding of how the company functioned and was very forthcoming in the presentations. He saw the forest and the trees and described them effectively. Gerrity didn't recall the timing of the Compaq discussions but it became intense a few months before. He didn't believe sell offs were in anticipation of a merger. The board meetings became more structured and more organised after Olsen left. He commented that Olsen's meetings were more casual.

Vernon Alden – Was visited at his office in Boston and interviewed. Alden said that there was no vote on whether Olsen should give up his role, it was just a general discussion. He said that Palmer was selected because of his presentation and the fact that he appeared to understand the PC market. Also that Palmer had not been approached until Olsen had resigned. Alden stated that Olsen was asked to resign because he missed the PC and Apple market and wouldn't cut headcount as much as the board wanted. He said that the merger with Compaq was not discussed until a few months before the deal went through and the reason for merging was to share research and gain market. He suggested that the board believed that DEC didn't have the software for the PC market. Alden didn't know what other companies Palmer had spoken to, they weren't aware of any. He also said that Pier Carlo Falotti wasn't discussed as a successor by the board. Alden was personally disappointed by what happened after the sale to Compaq and he didn't think the sale worked out well, suggesting that Compaq wasted a lot of good people and as a board they probably made a mistake in agreeing to the merger. He also indicated that he did not agree with Olsen's dismissal.

Alden had also been interviewed by Ben Strout for a documentary and in that interview he said:

> The Digital meetings were not formal. They were really a series of conversations. The board members and Ken and of course when the General was there would have just a general conversation of where the company was going, what problems they had encountered, what the competition was like. Actually the only competition they had at that time was IBM and I don't think IBM even recognized the Digital was a competitor. But we talked about how we're gaining on IBM. And we talked about uh different areas in which the company was doing well. And the development of new products, you have the PDP1, the PDP7, and so on. So they were general conversations. They were not formal board meetings. It was almost as though a group of 8 people sat down just to talk about things.
>
> Well you know later on in the uh '80s and early I guess it was late '80s, Apple came along and Compaq and Hewlett Packard and they were appealing primarily to the individual person and Ken. Ken never took that too seriously and I think that after a while the fact that Ken did not take that more seriously caused some problems with the board. There were some people who said, "I think Ken, we ought to pay more attention to what Apple is doing to us. Forget about IBM and so on but these young companies are coming up and they're going to be taking market away from us and going more and more to individuals. I think Ken kind of poo-pooed that. He felt that well let's not worry so much about that. So that began to develop a kind of strain between the board and Ken, at least between some members of the board. I never felt that way, myself, but I think there were some people who began to be uneasy that we were not taking more seriously the competition from these other companies.
>
> Yes, there was a point when some of the board members asked Ken if he would retire early, which he did do. And one of the people who had been working in the company for a while was then put in Ken's place. And that was the beginning of the downfall of Digital. Before that, the price of the stock it, it soared on the stock market. At one point, it was

up to close to 190 per share I think. But then the price of the stock began to erode, because I think the person who took over—and I've even forgotten his name—was not really doing the job that he should have done. So at some point, the board felt, that in order to survive, we probably have to join another company and that's when we joined Compaq. And our hope was that much of these research activities and the software that we had developed and so on would enhance what Compaq was doing, but that did not work out. I think Compaq, over the years, ignored some of the strengths that they acquired when they got Digital, so eventually, the company was acquired by Hewlett Packard. So now of course, Digital doesn't exist anymore; it's simply part of Hewlett Packard. But when Ken left the company, that was the beginning of a downward slope.

No I think that there must have been some private conversations between individual board members. I was not much involved at that time. Because I did not have the same concerns that some other people did. Now Phil Caldwell was the head of the Ford Motor Company and Ken was asked to go on his board, so I think they had the opportunity to see each other quite often not only at Digital boards but also at Ford meetings. And I think that Ken and Phil Caldwell perhaps had several conversations together, and maybe that was simply an evolving thing that finally when the board formally met, some of the board members then thought it would be wise if Ken would retire. I worried about that at the time, but of course, I couldn't do anything to turn around the rest of the board.

Dr Feldstein – did not respond to repeated emails via company secretary.

Arnaud de Vitry – unable to contact as email address no longer valid.

Bob Palmer – unable to contact.

Ken Olsen – not well enough to answer questions and has since passed away.

Appendix.A.3 Results of employee survey

Table 13: Job function.

	Answer	**Count**	**Per cent**
1.	Administration	45	5%
2.	Finance	49	5%
3.	Manufacturing	60	6%
4.	Customer Service	147	16%
5.	Software Service	108	11%
6.	Human Resources	41	4%
7.	Marketing	76	8%
8.	H/W Engineering (US)	34	4%
9.	H/W Engineering	17	2%
10.	S/W Engineering (US)	41	4%
11.	S/W Engineering	16	2%
12.	IT/MIS	49	5%
13.	Sales	141	15%
14.	Other	121	13%
	Total	**945**	**100%**
Confidence Interval @ 95%			[7.825 - 8.433] n = 953
Standard Deviation			4.784
Standard Error			0.155

Table 14: Leaving year.

	Answer	Count	Percent
1.	before 1988	21	2%
2.	1988	5	0.5%
3.	1989	7	0.5%
4.	1990	27	3%
5.	1991	36	4%
6.	1992	75	8%
7.	1993	73	7%
8.	1994	127	14%
9.	1995	55	6%
10.	1996	51	5%
11.	1997	45	5%
12.	1998	79	8%
13.	after 1998	346	37%
	Total	**947**	**100%**
Confidence Interval @ 95%		[9.575 - 9.989] n = 955	
Standard Deviation		3.267	
Standard Error		0.106	

Table 15: Downsizing method. (How was the downsizing handled?)

	Answer	Count	Per cent
1.	Percentage cut across the board?	188	20 %
2.	Badly performing units targeted?	40	4%
3.	Functions with excess staff targeted?	102	11%
4.	People working in non core areas targeted?	138	15%
5.	Voluntary?	126	14%
6.	Early Retirement?	89	10%
7.	N/A	99	11%
8.	Other	140	15%
	Total	**922**	**100%**

Confidence Interval @ 95%	[4.286 - 4.597] n = 930
Standard Deviation	2.420
Standard Error	0.079

Table 16: Attitude towards the company after Olsen left.

	Answer	Count	Per cent
1.	Better	57	6%
2.	Worse	618	67%
3.	The same	209	23%
4.	Other	38	4%
	Total	**922**	**100%**

Confidence Interval @ 95%	[2.205 - 2.286] n = 929
Standard Deviation	0.625
Standard Error	0.020

Table 17: Impact on work ethic. (Did the multiple rounds of downsizing have an impact on your work ethic?)

	Answer	Count	Per cent
1.	Yes	108	12%
2.	Yes, increasingly as the downsizing went on.	351	38%
3.	No	418	45%
4.	Other	45	5%
	Total	**922**	**100%**
Confidence Interval @ 95%		[2.387 - 2.485] n = 929	
Standard Deviation		0.759	
Standard Error		0.025	

Table 18: Impact on morale. (Did the multiple rounds of downsizing have an impact on your morale?)

	Answer	Count	Percent
1.	Yes	621	88%
2.	No	51	7%
3.	N/A	36	5 %
	Total	**708**	**100%**
Confidence Interval @ 95%		[1.136 - 1.208] n = 715	
Standard Deviation		0.493	
Standard Error		0.018	

Table 19: Compensation package over period.

	Answer	Count	Percent
1.	Better	52	6%
2.	Worse	448	49%
3.	The same	301	34%
4.	Other	101	11%
	Total	**902**	**100%**
Confidence Interval @ 95%		[2.447 - 2.547] n = 909	
Standard Deviation		0.766	
Standard Error		0.025	

Table 20: Handling of downsizing.

	Answer	Count	Per cent
1.	With compassion	106	13%
2.	Well	205	26%
3.	Average	228	29%
4.	Poorly	139	18%
5.	Insensitively	107	14%
	Total	**785**	**100%**
Confidence Interval @ 95%		[2.836 - 3.007] n = 791	
Standard Deviation		1.231	
Standard Error		0.044	

Appendix.A.4 SEC filings

Table 21 Tabular format of Fortune 500 data for DEC

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Revenues	1058	1436	1804	2368	3198	3880	4271	5584	6686	7590	9389	1145	12866	13084	14024	14027	14371	13450	13813	14563	13046
Profits	108	142	178	250	343	417	283	328	446	617	1137	1306	1072	74	-617	-2795	-251	-2156	122	-112	141
Assetts	1070	1491	1863	2666	3456	4024	4541	5593	6368	7173	8407	10112	10667	11654	11874	11284	10950	10579	9947	10075	9692
Stockholder equity	735	904	1120	1651	2679	3164	3541	3979	4554	5727	6294	7510	8035	8181	7623	4930	4885	3279	3528	3606	3545
Market value										21056	15113	14002	9337	9916	7238	6149	4257	5555	9858	4641	7100
Employees	36000	39000	44000	5500	6300	6710	73000	85600	89000										61700	59100	54900
Earnings per share $	3.4	4.1	5.45	6.7	7.53	5	5.73	7.42	4.81	8.53	9.9	8.45	0.59	-5.08	-22.4	-1.93	-15.8	0.59	-0.97	0.68	
Return to investors %	15.9	28.4	37.9	-8.9	15	-27.6	53.8	19.6	58.1	28.9	-27	-16.6	-33	0.7	-38.9	1.5	-2.9	92.9	-43.5	2.4	

Table 22 SEC filing data for the twelve year period 1986-1997

TWELVE-YEAR FINANCIAL SUMMARY

(dollars in millions except per share data and stock prices)

	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986
STATEMENTS OF OPERATIONS(1)												
Product sales	$7,197	$8,362	$7,616	$7,191	$7,588	$7,696	$8,299	$8,146	$8,190	$7,541	$6,254	$5,103
Service and other revenues	5,850	6,200	6,197	6,260	6,783	6,235	5,612	4,797	4,552	3,934	3,135	2,487
Total operating revenues	13,046	14,563	13,813	13,451	14,371	13,931	13,911	12,943	12,742	11,475	9,389	7,590
Cost of product sales, service and other revenues	8,725	9,756	9,392	8,912	8,631	8,132	7,278	6,795	6,242	5,468	4,514	4,282
Research and engineering expenses	1,014	1,062	1,040	1,301	1,530	1,754	1,649	1,614	1,525	1,306	1,010	814
Selling, general and administrative expenses(2)	3,177	3,788	3,273	5,234	4,447	6,181	5,572	4,521	3,639	3,066	2,253	1,665
Operating income/(loss)	130	-44	108	-1,996	-237	-2,136	-588	13	1,336	1,635	1,612	829
Net interest income/(expense)	-48	-24	-33	-24	13	57	68	111	85	106	77	28
Income/(loss) before income taxes and cumulative effect of changes in accounting principles	178	-68	76	-2,020	-224	-2,078	-520	124	1,421	1,741	1,689	857
Provision for income taxes	37	44	18	85	27	232	97	50	348	435	552	240
Net income/(loss)(3)	$141	$(112)	$122	$(2,156)	$(251)	$(2,796)	$(617)	$74	$1,073	$1,306	$1,137	$617
Net income/(loss) applicable per common share(3)	$.68	$(.97)	$.59	$(15.80)	$(1.93)	$(22.39)	$(5.08)	$.59	$8.45	$9.90	$8.53	$4.81
Weighted average shares outstanding (in millions)	155	152	146	137	130	125	122	125	127	132	133	131
FINANCIAL POSITION												
Inventories	$1503	$1,821	$2,054	$2,064	$1,755	$1,614	$1,595	$1,538	$1,638	$1,575	$1,453	$1,200
Accounts receivable, net of allowances	2,930	3,223	3,219	3,319	3,020	3,594	3,317	3,207	2,965	2,592	2,312	1,903
Working capital	3,035	3,188	3,026	1,832	2,964	2,015	3,777	4,332	4,501	4,516	4,377	4,223
Net property, plant and equipment	2,104	2,223	2,269	3,129	3,178	3,570	3,778	3,868	3,646	3,095	2,127	1,867
Total assets	9,693	10,075	9,947	10,580	10,950	11,284	11,875	11,655	10,668	10,112	8,407	7,173
Long-term debt	743	999	1,013	1,011	1,018	42	150	150	136	124	269	333
Stockholders' equity	3,545	3,606	3,528	3,280	4,885	4,931	7,624	8,182	8,036	7,510	6,294	5,728
Stockholders' equity per common share	21	20.62	20.89	20.24	36.19	38.58	61.18	66.76	66.12	59.47	49.87	44.54
RATIOS AND OTHER INFORMATION												
Current ratio	1.7:1	1.8:1	1.7:1	1.4:1	1.8:1	1.4:1	2.0:1	2.3:1	2.9:1	2.9:1	3.4:1	4.9:1
Quick ratio	1.3:1	1.2:1	1.1:1	.9:1	1.2:1	1.0:1	1.4:1	1.6:1	1.9:1	2.0:1	2.4:1	3.5:1
Debt/debt plus equity	22.10%	22.00%	22.50%	24.10%	17.50%	1.80%	2.20%	2.00%	2.00%	3.60%	4.20%	5.90%
Operating income/(loss) as a percentage of revenues	1.00%	-0.30%	0.80%	-14.80%	-1.70%	-15.30%	-4.20%	0.10%	10.50%	14.20%	17.20%	10.90%
Net income/(loss) as a percentage of revenues	1.10%	-0.80%	0.90%	-16.00%	-1.70%	-20.10%	-4.40%	0.60%	8.40%	11.40%	12.10%	8.10%
Return on equity	3.90%	-3.10%	3.60%	-52.80%	-5.10%	-44.50%	-7.80%	0.90%	13.80%	18.90%	18.90%	12.00%
Return on assets	1.40%	-1.10%	1.20%	-20.00%	-2.30%	-24.10%	-5.20%	0.70%	10.30%	14.10%	14.60%	9.10%
Non-U.S. revenues as a percentage of total revenues	67%	66%	65%	62%	64%	63%	60%	56%	55%	50%	47%	42%
Days sales outstanding	76	78	77	76	69	83	76	86	76	75	78	79
Number of employees at year-end	54,900	59,100	61,700	77,800	89,900	107,900	115,100	116,900	118,400	113,900	103,000	88,300
Number of shares outstanding at year-end (in millions)	151	156	150	142	135	130	130	130	130	130	130	129
Common stock yearly high and low sales prices	$ 47-25	$76-35	$49-18	$43-18	$49-30	$72-33	$87-45	$103-70	$122-86	$199-99	$174-82	$94-46

(1) Amounts may not be additive due to rounding.

(2) Includes restructuring charges of $492M in 1996, $1,206M in 1994, $1,5000M in 1992, $1,100M in 1991 and $550M in 1990. Includes reduction in carrying value of intangible assets of $310M in 1994.

(3) The cumulative effect of changes in accounting principles were: a one-time benefit of $65M, or $.44 per share, on net income and net income per share for fiscal 1995; a one-time charge of $71M, or $.51 per share, and a one-time benefit of $20M, or $.14 per share, on net loss and net loss per share for fiscal 1994; and $485M or $3.89 per share on net loss and net loss per share in fiscal 1992.

26

Source: SEC Info - www.secinfo.com - Fran Finnegan & Company - 950135-96-4030

Table 23 Summary of SEC filings for DEC

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Product sales	5103	6254	7541	8190	8146	8299	7696	7588	7191	7616	8326
Service revenue	2487	3135	3934	4552	4797	5612	6235	6783	6260	6197	6200
Total Op Revenue	7590	9389	11475	12742	12943	13911	13931	14371	13451	13813	14563
Cost of sales	4282	4514	5468	6242	6795	7278	8132	8631	8912	9392	9756
R&D	814	1010	1306	1525	1614	1649	1754	1530	1301	1040	1062
Selling and gen admin	1665	2253	3066	3639	4521	5572	6181	4447	5234	3273	3788
Operating income	829	1612	1635	1336	13	-588	-2136	-237	-1996	108	-44
Restructuring costs					550	1100	1500		1206		492
Inventory	1200	1453	1575	1638	1538	1595	1614	1755	2064	2054	1821
Accounts receivable	1903	2312	2592	2965	3207	3317	3594	3020	3319	3219	3223
Working capital	4223	4377	4516	4501	4332	3777	2015	2964	1832	3026	3188
Property	1867	2127	3095	3646	3868	3778	3570	3178	3129	2269	2223
Total Assets	7173	8407	10112	10668	11655	11875	11284	10950	10580	9947	10075
	1986	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Long term debt	333	269	124	136	150	150	42	1018	1011	1013	999
Employees	88300	103000	113900	118400	116900	115100	107900	89900	77800	61700	59100
Revenue per employee	86	91	101	108	111	121	129	160	173	224	246
Salary bill (estimated)	3127	3648	4034	4280	4226	4246	4062	3524	3112	2369	2955

All financial figures are $million apart from income and revenue per employee which is $thousand

Table 24 DEC's final SEC filing for FY98 from Edgar online

	Three-month Period ended March 28 1998	Nine-month Period ended March 28 1998
	------------	-------------
Product sales	$1,681,618	$5,080,232
Service revenues	1,509,392	4,395,566
Total operating revenues	3,191,010	9,475,798
Cost of product sales	1,073,646	3,226,158
Service expense	1,022,201	3,002,895
Research and engineering expenses	261,274	798,760
Selling, general and administrative expenses	738,400	2,262,562
Operating income/(loss)	95,489	185,423
Other (income)/expense, net (1)	-244,791	-271,691
Income/(loss) before income taxes	340,280	457,114
Provision for income taxes	33,457	50,400
Net income/(loss)	306,823	406,714
Dividends on preferred stock	8,875	26,625
Net income/(loss) applicable to common share	$297,948	$380,089
Basic earnings/(loss) per share (2)	$2.03	$2.58
Diluted earnings/(loss) per share (2)	$1.99	$2.54
Weighted average common shares outstanding (2):		
Basic	146,929	147,574
Diluted	149,398	149,617

Note (1): In the third quarter of fiscal 1998, Other (income)/expense, net includes $25 million of interest income, $17 million of interest expense and $237 million of net gains on divestments. In the third quarter of fiscal 1998, approximately $223 million related to the sale of network assets were included in net gains on divestments. In the third quarter of fiscal 1997, Other (income)/expense, net includes $30 million of interest income, $21 million of interest expense and $2 million of net gains on divestments. In the first nine months of fiscal 1998, Other (income)/expense, net includes $85 million of interest income, $59 million of interest expense and $246 million of net gains on divestments. In the first nine months of fiscal 1997, Other (income)/expense, net includes $82 million of interest income, $64 million of interest expense and $9 million of net gains on divestments.

Appendix.A.5 *Conferences Attended and Papers delivered*

Association of Business Historians Conference, Birmingham 2008

"Digital Equipment Corporation – Downsizing, Cause or Cure?"

Association of Business Historians Conference, Liverpool 2009,
Attended conference.

Society for the History Of Technology, Pittsburgh 2009

"DEC: The mistakes that led to its downfall"

World Computer Congress, History of Computing, Brisbane 2010

"Recession, S-curves and Digital Equipment Corporation"

Society for the History Of Technology, Tacoma 2010

"Presentation of Thesis dissertation"

Appendix.A.6 *Digital Equipment Corporation Timeline*

Table 25 Company timeline

Date	Hardware	People	Sales	Net Income	Employ ees
1957	Digital Equipment Corporation founded by Ken Olsen, Stan Olsen and Harland Anderson on August 23rd with funding from American Research and Development who took a 70% holding in the firm for $70,000.				
1959	The first PDP-1 was delivered in December and the last one was delivered in 1969				
1961	DECUS was founded – Digital Equipment Computers Users Society				
1962	The first PDP-4 was delivered – 18-bit		6.5M	1.6M	
1963	The first PDP-5 was delivered – 12-bit	Ben Gurley designed PDP-1 left	9.9M	2.4M	
1964	First 'product line' formed		11M	1.8M	
	The first PDP-6 was released – 36-bit				
	The PDP-7 was released – 18-bit				
1965	The PDP-8 was released – 12-bit		15M	1.4M	
	The PDP-9 was introduced – 18-bit				
1966		Co-founder Harlow Anderson left.	23M	3.5M	
		Jay Forrester Whirlwind engineer and board member left			
1967	The PDP-10 was released – 36-bit		39M	8.3M	
1968	The PDP-X project stalled	Ed de Castro and Henry Burkhardt left to start Data General	57M	13M	2600
1969	The PDP-12 released – 12-bit – succeeded the LINC-8		91M	17M	4360
	The PDP-15 released – 18-bit – successor to the PDP-9				
	The PDP-14 released				
1970	Two manufacturing plants built		135M	35M	5800
	The PDP-11/20 released				
1971	The 15,000th installation makes Digital the second largest computer manufacturer in the US. Plant at Galway opened		147M	18M	6200
	The DECsystem-10 introduced				
	The PDP-11/15 released				
	The PDP-11/05 released				
	The PDP-11/45 released				
1972	Digital purchase memory division in Taiwan	Nick Mazzarese, member of the operations committee and vp in charge of small systems, left	187M	26M	7800
	The PDP-16 released				
	Digital introduces the PDP-11/40				
1973	The PDP-11/10 is released along with the GT40		265M	39M	13000
	RK-15 released low cost cartridge disk system released				
1974	Marlborough facility opened		422M	69M	17600
	RJS03/04 fixed head disk system announced for PDP-11 family				
	The KL 10 processor is introduce in the DECsystem-10/80 and 10/90				
	First LSI manufacturing plant opened				
1975	DEC installed its 50,000th computer system – leading mini-computer manufacturer		532M	74M	19000
	RP04 high performance disk drive introduced				
	PDP-11/04, PDP-11/03 introduced				
	LSI-11 Large Scale Integration family introduced				
	PDP-11/70 introduced				
	DV-11 introduced allowing PDP-11 to link up to 16 other computers				

	VAX architecture announced				
	Microsoft founded				
1976	DMC11 Network Link announced	Dennis Burke director of personnel left	736M	119M	25000
	RP05 and RP06 disk drives announced				
	Power management systems introduced to decrease costs				
	PDP-11/34 system announced				
	DECsystem-20 released				
	Apple founded				
1977	RK06 medium capacity disk announced	Peter Kaufmann, vice president of manufacturing, left	1058M	176M	36000
	PDP-11/60 announced				
	Digital is the first computer company to connect to the ARPANET				
	Digital introduces the VAX-11/780				
	Hudson semiconductor manufacturing plant construction begins				
1978	Digital introduces the DECsystem-2020				
1979	Digital introduces the PDP-11/23	John Leng, vice president and ran DEC10/20 development, left			
	The first computer spam was sent by a Digital employee with over 400 people receiving it				
	Digital introduces the PDP-11/44				
1980	Digital introduces the VAX-11/750				
	Digital, Intel and Xerox cooperate in the Ethernet local area network project				
	Notes-11, VAXnotes two examples of online collaboration. One of the original Notes developers joined Lotus and helped develop Lotus Notes				
	Hudson LSI manufacturing starts delivering first wafers for 11/750				
1981	Digital introduces the PDP-11/24	Stan Olsen, Ken's brother and first employee, member of operations committee and vp in charge of commercial markets, left			
	IBM PC released				
1982	Digital introduces the third member of the VAX family the VAX-11/730	Ted Johnson, member of operations committee and head of worldwide sales until 1980, left			
	Digital introduces a range of personal computers 'Rainbow' and 'pro350' 'pro380'				
	Second chip manufacturing facility built at Hudson				
1983	Digital announces VAXclusters	Gordon Bell leaves DEC after getting tired and confrontational with Ken Olsen.	4272M		73000
	Digital ships the HSC50 intelligent disk subsystem	Andy Knowles, vice president and member of operations committee and head of low end, left			
	Digital establishes Internet connectivity. Email, FTP and USENET hubs established	Avram Miller, created Pro350,380 left			
	Construction begins on third Fab facility at Hudson				
1984	Digital introduces the VAXstation I – first 32-bit single user workstation	Eric Hustvedt had car accident – severe head injuries. (worked with Cutler on OpenVMS)	5584M		86000
	Digital introduces the VAX-11/785	Julius Marcus, helped build commercial markets and created DEC's office strategy, left			
	Digital announces the VAX 8600				
	Digital delivers it 25,000 VAX system				
	Apple Mac released				
1985	Digital introduces the MicroVAX II	Barry James Folsom, head of Rainbow and PC project left for SUN	6686M		89000
	Digital introduces the MicroPDP-11/83	First ever layoffs			

	VAX 8650 introduced				
	Digital is the first computer company to register an Internet domain				
1986	Digital introduces the VAXmate networked personal computer combining VAX-VMS and MS-DOS	Ken Olsen named "Americas most successful entrepreneur"	7590M	617M	95000
	VAX 8800 and 8500 released				
	Digital introduces Local Area VAXclusters				
	Digital creates the first Internet firewall and establishes http://gatekeeper.digital.com as a major ftp site on the Internet				
1987	Introduction of the VAX 8978 and 8974 systems – most powerful yet	Dick Berube public relations chief left	9389M	1140M	11100 0
	Digital introduces the MicroVAX 3500 and 3600	General Georges Doriot president of ARD who financed DEC, advisor to Ken Olsen and member of board died			
	VAXstation 2000 released				
	Digital ships the 100,000 th VAX system	Jeff Kalb, low end development, left			
1988	Digital introduces the VAX 6000 system based on the CVAX chipset	Dave Cutler leaves DEC after PRISM was cancelled.	11475M	1306M	12200 0
1989	Digital introduces the VAX 6300 system		12742M	1073M	12600 0
	The Rigel chipset is introduced	Kevin Melia VP of materials left for SUN, frustrated that he couldn't make changes to supply chain management that he thought essential to DEC's survival.			
	Digital introduces the VAX 9000 mainframe – late and during recession.				
1990	**The World Wide Web is born when Tim Berners-Lee develops HTML in CERN**		**12943M**	**74M**	**12400 0**
	Digital marks 20th anniversary of the PDP-11 with the introduction of the MicroPDP-11/93 and the MicroPDP-11/94	Jack Shields, member of executive committee, senior vp of sales and marketing, left after 28 years			
	VAX4000 released				
	Digital introduces the VAXft 3000 family of fault tolerant computers				
	Digital introduces the Mariah chip set in the VAX 6500				
1991	Digital introduces DECnet Phase V supporting OSI standards	James M. Osterfhof leaves DEC. CFO 1985 – 91. Reportedly clashed with John Smith, snr V.P. over financial restructuring	13911M	-617M	12100 0
	Digital buys Kienzle				
	Digital buys Philips information systems division				
	Digital introduces Application Control Architecture – the industry's first object request broker				
	Digital first in the industry to offer an Internet tunnel offering				
	Digital and Microsoft announce an alliance with Microsoft Windows systems to retrieve and exchange data with local area network servers running Digital Pathworks software	Dorothy Terrell left for SUN. Responsible for bringing VAX 9000 to market against all odds.			
1992	Digital introduces the DECpc – first internally designed compatible PC	Ken Olsen ousted by board	13930M	-2796M	11400 0
	Digital introduces the VAX 7000	Robert Palmer appointed president			
	Digital announces the Alpha	Pierre Carlo Fallotti left			
	Digital buys Olivetti stock in return for agreement to purchase a number of AXP products	David Stone leaves DEC Head of Software Strategy			
	Digital installs industry's first commercial Internet firewall				
1993	Digital becomes the first Fortune 500 company with a corporate website on the Internet	.	14371M	-251M	94000
	Digital delivers first video on demand for broadband	Edward Lucente VP worldwide sales left			
	Digital announces StorageWorks next				

	generation storage solution				
	Digital introduces the GIGAswitch/FDDI				
	New VLSI facility built at Hudson for Alpha chip				
1994	Digital introduces the HiNote Ultra laptop	DIGITAL EQUIPMENT lost $2.1 billion in the fiscal year that ended last July. Over 9,000 jobs were cut last spring as part of a massive "downsizing" effort, which, will mean some 70,000 DEC jobs will have disappeared since 1989. The pay for the top 5 execs went up 70% last year. CEO Robert Palmer received stock options that exceeded, on paper at least, his $900,000 salary. VP Enrico Pesatori got an 18% raise. Sales head Edward Luciente got a $630,000 settlement; consulting chief Gresham Brebach Jr. $500,000	13450M	-2156M	77800
	NSL and Digital deliver first live election returns over the Internet	Fred Traversi left. Was responsible for decentralised decision making			
	Digital sells Consilium (semiconductor manufacturing)	Tracy Gibbons left. Member of Corporate Organisational Consulting Group and worked with Cupertino staff on VAX 9000 facility startup.			
	Digital sells Stratacom (networking company)	William M. Steul CFO resigned after a year. Blamed on Palmer being taken by surpirise by Q3 losses. Vincent J. Mullarkey named as successor.			
	Digital worldwide training spun off to form independent company GKN	Win Hindle VP quality, ethics and business practices and Edward McDonough VP manufacturing retired			
	Digital sells database product Rdb to Oracle including engineering	Digital announce another 20,000 job cuts as a result of worse than expected Q3 figures. Expect a $1b restructuring charge			
	Digital sells TK series tape and disk technology to Quantum Corporation				
	Digital Semiconductor becomes a business unit				
1995	Digital develops FX!32 to run x86 Win32 code on VAX	Dirk Meyer, co-architect of Alpha 21064 and 21264 left to join AMD	13813M	122M	61700
	Digital and Microsoft announce strategic alliance				
	Digital announce plans for virtual networking and integration of LANs, WANs and ATM				
	Digital sells text terminal business to Boundless Technologies				
	Digital sells disk and tape business to Quantum				
	Digital sells Augusta manufacturing business to SCI (Augusta) inc 700 employees				
	Digital sells Scottish semiconductor manufacturing plant to Motorolla inc 530 employees	Bruce Claflin (ex IBM) appointed VP and General Manager of the PC business unit			
	Digital introduces the AlphaServer 8400				
1996	Cisco buys Stratcom	Jack Smith, who reduced $2 billion of operating costs in FY 1993, member of executive committee, left	14563M	-112M	59100
	Digital sells learning services including 600 employees				
	Digital introduces the Prioris series of Pentium based application servers	July 5th Pesatori leaves DEC after running midrange and PC business group received approx $600,000			

	Digital releases 64-bit Unix – Digital Unix version 4				
	Digital becomes first computer company to operate an Internet Network Access Point – Palo Alto				
1997	Digital is worlds number one provider of mail and messaging to global accounts	Irene Lang left DEC blaming AltaVista ipo cancellation.	13047M	141M	54900
	Digital provides the worlds first live streaming webcast to over 1,000,000 viewers	Charles Christ retired. Credited with the introduction of Storageworks. VP and general manager of components division.			
	Digital announces Millicent for cybercommerce				
	Digital sues Intel for patent infringements – settled by selling semiconductor business including StrongARM – ARM processors are still in use in Blackberrys etc				
	Digital sells printer business to Genicom				
	DECtalk and DECvoice spun off – Fonix – Still on sale				
	Digital cancels Shark project (network server in conjunction with Oracle) under pressure from Microsoft				
	Digital enhances the AltaVista Search service				
	Digital announces 9GB disk drive for StorageWorks providing the industries highest storage density				
	Digital starts work on the first hard disk mp3 player				
1997?	Digital develops iPaq formerly known as itsy				
1998	Digital sells semiconductor operations to Intel				
	Digital sells network business to Cabletron for $430				
1998	Compaq buys Digital for $9.6 billion				
1999	Sales of new systems ends				
2000		Schrock leaves AltaVista Bill Strecker leaves Compaq.			
2001/2	HP buys Compaq for $25 billion				
2003					
2004					

This thesis therefore argues that DEC failed primarily for these two substantive reasons:

- DEC made a number of technology decisions that cost the company billions of dollars. In particular, DEC missed the S-curve in the late 1980s and early 1990s due to lack of technical leadership and failed to recognise the rising importance of disruptive technologies that were emerging. (covered in chapter 6)
- Rounds of redundancies were implemented with little thought for the consequences in terms of the business or employee morale, and a period of stagnation ensued, which continued throughout the 1990s. (covered in chapter 7)

Each of the above put a strain on the company finances and restricted the funds available for other research projects. Furthermore, the board was weak and not sufficiently knowledgeable in the business of the company.[515] They removed the CEO in 1992 and replaced him with an internal candidate, without applying sufficient diligence to their selection. The company failed to recover primarily because the management failed to recognise the lead the company had in Internet technologies and did not invest sufficiently.

This thesis also argues that the implementation of the downsizing process and its extended timescale had a direct bearing on the lack of recovery of the company. This resulted in the breakdown of the employer/employee relationship. Coupled with this was a focus on maintaining cash reserves by selling off divisions rather than investing for the future.

. Also in the early 1980s, Gordon Bell had a heart attack, attributed to the stress of work in charge of engineering at DEC.[516] He had a strained relationship with Olsen and, after his heart attack, he left to return to academia.[517] This was a blow to DEC, as its chief technologist and directional guru had left and there was a

[515] The board were considered weak by the financial press at the time, although without access to the board minutes this comment is just conjecture. Many people also commented on the weakness of the board in private conversations with Goodwin.
[516] Gordon Bell was the chief technologist and main technical strategist at DEC.
[517] E.H. Schein, *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation*, 1st ed. (San Francisco, CA: Berrett-Koehler, 2003), 204. http://research.microsoft.com/en-us/um/people/gbell/CGB%20Files/DEC_Is_Dead_Bell_Appendix_Schein_Book.pdf (accessed July 6, 2015).

vacuum in its ranks. Bell stayed in contact with Olsen and offered advice on technology, which was not always appreciated.[518] Bill Strecker eventually took over Bell's role and his input has been invaluable in the technology matters considered in this thesis.

[518] Memo in Ken Olsen archives. From: Olsen; To: distribution; Subject: Gordon's comments and suggestions, November 12, 1986.

11 Summary in English

The minicomputer began a revolution in the computer industry and was influential in the industry for over twenty years until superseded by client server computing and the personal computer. The subject of the thesis is a case study of how DEC, which was number two in the world in 1988, became a takeover candidate for a PC manufacturer in just ten years. It is a business history that considers the decline from the viewpoint of the decision makers and their strategic choices. We examine whether management indecision or technological leadership played a part in DECs problems. This thesis considers the part that Schumpeter's Creative Destruction and Christensen's theories on Innovation played in the downfall of Digital Equipment Corporation (DEC) in particular his assertion that it was the rise of the PC that was instrumental in the failure. It also considers Schein's theory of the money gene as the cause of the failure and Saxenien's view that the east coast versus west coast was at the heart of DEC's demise. The study uses a variety of sources including interviews with senior technical and managerial employees, archival material and reports to examine the company history, the ways in which it achieved its success, and the reasons for its downfall. It compares similar computer companies of the time, looking at how they either avoided the mistakes that DEC made or how they fell into similar traps.

This thesis argues that DEC made a number of strategic errors in the 1980s. In particular it considers the failure of its high end machine, the VAX 9000, and subsequent downsizing, DEC missing the rise of the RISC workstation and being late to join the PC revolution as major contributors to its downfall. It examines the technologies that emerged during the period and investigates the hesitation in adopting these newer technologies. We look at whether the problems were caused by indecision, a lack of technological leadership or both. The board removed the CEO in 1992 after which the company went through a number of years of downsizing and stagnation, trying to regain control and direction. The downsizing process undertaken by the company is examined to identify its effect on the company's performance.

In Chapter 2 we investigate the relevant literature on Creative Destruction and innovation in relation to the high tech industry, the rise of Silicon Valley and also the downsizing process at DEC. We also formulate the theoretical framework on which the thesis is grounded. Chapter 3 details the methodologies used in the research of the topic. As this is a case study, multiple methodologies are used. This chapter describes the major tools employed to analyse the

company financially and those used to analyse its products and technologies. It also identifies the data sources referenced. Chapter 4 analyses comparable companies that experienced the same issues at the time and investigates why and how some managed to survive when DEC did not. During the 1990s, five main companies dominated DEC's computer marketplace. IBM, HP, SUN, Data General and DEC all faced issues involving the change in the marketplace, reinventing themselves and defining new strategies for growth. Of these, only DEC and Data General failed, although SUN followed some ten years later. Chapter 5 looks at the rise of the company and its innovational products that defined the industry. It briefly details the history of the company from the initial investment by American Research and Development (ARD), examining how DEC introduced its own disruptive technology and then successfully rode the technology waves through the 1960s, 1970s and into the 1980s.

The next two chapters propose the two primary reasons for the failure of the company. Chapter 6 examines the main technical reasons behind the failure, including those products that were costly to the company both financially, and in terms of reputation and personnel. The main innovative technologies that were relevant to the company's success and the impact of Creative Destruction are considered. In this chapter it is argued that DEC missed the technology wave at the same time as the industry was changing and recession was biting. It invested in a product intended to cause serious damage to IBM, when the market was disappearing and DEC was late with its development. It will be argued that DEC missed the Reduced Instruction Set Computing (RISC) market, the PC market and the UNIX market, and focussed on its proprietary VAX system for too long without developing a follow-on architecture.[519] Chapter 7 is devoted to the downsizing in DEC in the 1990s and the subsequent effect on employee morale and capabilities as well as the impact on the finances of the company. It verifies a number of theories with a survey of ex-DEC staff. We believe that this had a major impact on the company at a time when it should have been rebuilding. It is argued that the manner in which the downsizing was implemented went against all of the popular theories of how to reduce staff without negatively affecting the company, and the result was of major significance to DEC. Chapter 8 is a brief analysis of the financial aspects of the company which, even though it posted a

[519] RISC technology will be explained in detail later in this thesis but the following is a short explanation of the significance of Reduced Instruction Set Computers (RISC) in the 1990s. Prior to RISC most computers were driven by a complex instruction set (CISC) where many instructions were carried out in microcode. RISC computers introduced the concept of a reduced instruction set in microcode leaving complex instructions to be constructed by the compilers. This made the computer much simpler to design and test, any changes or additional instructions could then be implemented in the compiler, meaning there would be no need for changes to the hardware in the case of errors or enhancements.

number of negative annual statements, still had a healthy balance when it merged with Compaq. Much of the later financial data is complicated by wholesale sell-offs and plant closures, which make analysis difficult. It is not usual for a business history to cover the financial performance of a company but it is important for this thesis so it can consider Schein's theory of the 'money gene'. In this chapter, the argument is that DEC was always financially prudent, but that Palmer focussed solely on maintaining cash reserves instead of investing for the future. It will be shown that the financial problems the company faced were due to imprudent hiring in the late 1980s and to falling margins. Chapter 9 is the concluding chapter and summarises the findings of the research, suggesting some lessons that could be learned by any company that finds itself in a similar position to DEC.

Appendix A1 has a biographical summary of the main people involved in the rise and fall of the company.
Appendix A2 has a list of people interviewed by Strout and myself as well as transcripts of interviews with the board members.
Appendix A3 contains data from the survey carried out to gain feedback from ex-DEC personnel.
Appendix A4 contains data from the SEC filings.
Appendix A5 summarises the papers that were authored and were delivered at the Society for the History of Technology conference in Pittsburgh in 2009 and the World Computer Congress in Brisbane 2010, together with the ABH paper which was published in the journal of business history *Zeitschrift fur Unternehmensgeschichte* in 2010.[520]
Appendix A6 contains the timeline of the important events that occurred in the company history and the people who were influential in its growth and decline, as well as a short biography of the key people identified.

[520] D. T. Goodwin and R. G. Johnson, "DEC, the Mistakes That Led to Its Downfall," http://www.sigcis.org/files/Goodwin_paper.pdf; D. T. Goodwin and R. G. Johnson, "Recession, S-Curves and Digital Equipment Corporation," *World Computer Congress conference, History of Computing* (2010); D. T. Goodwin and R. G. Johnson, "The Demise of Digital Equipment Corporation: Downsizing - Cause or Cure," *Zeitschrift fur Unternehmensgeschichte* 1(2010).

12 Samenvatting in het Nederlands

De minicomputer bracht een revolutie in de computerindustrie teweeg en was invloedrijk in het bedrijfsleven voor meer dan twintig jaar tot client server computing en de personal computer hem vervingen. Het onderwerp van het proefschrift is een case study van hoe DEC, de tweede ter wereld wereld in 1988, in slechts tien jaar een overnamekandidaat werd voor een PC fabrikant. Het is een bedrijfsgeschiedenis die de aftakeling beschouwt vanuit het gezichtspunt van de beslissers en hun strategische keuzes. We onderzoeken of besluiteloosheid van het management of technologisch leiderschap een rol heeft gespeeld in de problemen van DEC. Dit proefschrift beschouwt de rol die Schumpeters “Creative Destruction” en de theorieën van Christensen over Innovatie speelden in de ondergang van Digital Equipment Corporation (DEC), in het bijzonder zijn bewering dat het de opkomst van de PC was die een cruciale tol speelde in de achteruitgang. Het beschouwt eveneens de theorie van Schein over het “geldgen” als de oorzaak van de mislukking en de zienswijze van Saxenien dat Oostkust versus Westkust de kern van de ondergang van DEC vormde. De studie gebruikt een verscheidenheid aan bronnen, waaronder vraaggesprekken met senior technische en managementfunctionarissen, archiefmateriaal en management employees, archief materiaal en rapportages om de bedrijfshistorie te onderzoeken, de manieren waarop het bedrijf zijn succes behaalde en de oorzaken van de ondergang. Het vergelijkt soortgelijke computerbedrijven uit die tijd, kijkende naar hoe zij ofwel de vergissingen van DEC vermeden of hoe zij in soortgelijke valkuilen vielen.

Dit proefschrift betoogt dat DEC in de jaren 1980 een aantal strategische fouten maakte. In het bijzonder kenschetst het de mislukking van de *high end* machine - de VAX 9000 - en de daaruit volgende inkrimping, DEC dat de opkomst van RISC werkstations mist en te laat meedoet in de PC revolutie als de voornaamste contribuanten aan de ondergang. Het onderzoekt de technologieën die in de periode opkwamen, alsmede de aarzeling om deze nieuwere technologieën over te nemen. We bezien of de problemen werden veroorzaakt door besluiteloosheid, een gemis aan technologisch leiderschap of beide. De raad van bestuur ontsloeg de CEO in 1992 waarna het bedrijf door een aantal jaren van inkrimping en stagnatie ging, trachtend om controle en richting terug te krijgen. Het door het bedrijf ondernomen inkrimpingsproces is onderzocht om het effect ervan vast te stellen op de prestatie van het bedrijf.

In Hoofdstuk 2 onderzoeken we de relevante literatuur over “Creative Destruction” en innovatie in relatie tot de *high tech* industrie, de opkomst van

Silicon Valley en ook het inkrimpingsproces bij DEC. We formuleren eveneens het theoretische raamwerk waarop het proefschrift is gegrondvest. Hoofdstuk 3 geeft de methodologieën aan die zijn gebruikt bij het onderzoek naar het onderwerp. Aangezien dit een case study is, zijn er meerdere methodologieën gebruikt. Dit hoofdstuk beschrijft de voornaamste gereedschappen die zijn aangewend om het bedrijf financieel te analyseren en die zijn gebruikt om de producten en technologieën te analyseren. Het identificeert eveneens de gegevensbronnen waaraan wordt gerefereerd. In Hoofdstuk 4 worden vergelijkbare bedrijven die destijds dezelfde problemen ervoeren geanalyseerd en wordt onderzocht waarom en hoe sommige wel konden overleven terwijl DEC dat niet deed. In de jaren 1990 domineerden vijf toonaangevende bedrijven de computer markt van DEC. IBM, HP, SUN, Data General en DEC hadden alle te maken met problemen die de verandering van de markt met zich meebracht, zichzelf opnieuw uitvinden en het definiëren van nieuwe strategieën voor groei. Van deze lukte het alleen DEC en Data General niet, alhoewel SUN zo'n tien jaar later volgde. Hoofdstuk 5 kijkt naar de opkomst van DEC en zijn innoverende producten die maatgevend waren voor de industrietak. Het beschrijft beknopt bijzonderheden van de geschiedenis van het bedrijf vanaf de initiële investering door American Research and Development (ARD), onderzoekend hoe DEC zijn eigen "disruptive technology" introduceerde en dan succesvol over de technologiegolven ging gedurende de jaren 1960, 1970 en tot in de jaren 1980.

The twee volgende hoofdstukken doen een voorstel omtrent de twee hoofdredenen voor het falen van het bedrijf. Hoofdstuk 6 onderzoekt de voornaamste technische redenen achter de mislukking, inclusief die producten die zowel financieel als in termen van reputatie en personeel kostbaar waren voor het bedrijf. Het bevat een beschouwing van de voornaamste innovatieve technologieën die relevant waren voor het succes van het bedrijf en de sterke invloed van "Creative Destruction". In dit hoofdstuk wordt betoogd dat DEC de technologiegolf miste op het zelfde moment dat de industrietak aan het veranderen was en recessie toesloeg. Het bedrijf investeerde in een product dat was bedoeld om ernstige schade voor IBM te veroorzaken op het moment dat de markt aan het verdwijnen was en DEC te laat was met zijn ontwikkeling. Er zal worden betoogd dat DEC de Reduced Intruction Set Computing (RISC) markt, de PC markt en de UNIX markt miste en zich te lang concentreerde op het eigen VAX systeem zonder een opvolgende architectuur te ontwikkelen.[521] Hoofdstuk

[521]RISC technologie zal later in dit proefschrift in detail worden uitgelegd, gevolgd door een globale omschrijving van het belang van een korte uitleg van het belang van Reduced Instruction Set Computers (RISC) in de jaren 1990. Voorafgaand aan RISC werkten de meeste computers met een complex instruction set (CISC) waarbij veel instructies werden uitgevoerd in microcode. RISC

7 is gewijd aan zowel de inkrimping binnen DEC in de jaren 1990 en het daaruit volgende effect op de houding en de inzet van de medewerkers als aan de sterke invloed op de financiën van het bedrijf. Het verifieert een aantal theorieën met behulp van een enquête onder ex-DEC personeel. We geloven dat dit een zeer grote invloed op het bedrijf had op een moment dat het zich opnieuw had moeten opbouwen. Er wordt betoogd dat de manier waarop de inkrimping ten uitvoer werd gebracht inging tegen alle gangbare theorieën over hoe personeelsvermindering tot stand te brengen zonder het bedrijf negatief aan te tasten, en het resultaat was van zeer grote betekenis voor DEC. Hoofdstuk 8 is een korte analyse van de financiële aspecten van het bedrijf dat, ofschoon het een aantal negatieve jaarverslagen uitbracht, nog steeds een gezonde balans had toen het fuseerde met Compaq. Veel van de latere financiële gegevens zijn ingewikkeld door grootscheepse uitverkopen en fabriekssluitingen, hetgeen analyse moeilijk maakt. Het is niet ongebruikelijk in een bedrijfshistorie om de financiële prestaties van een bedrijf te belichten, maar het is belangrijk voor dit proefschrift om Scheins theorie van het "geldgen" in ogenschouw te nemen. In dit hoofdstuk is het argument dat DEC financieel altijd weldoordacht is geweest, maar dat Palmer zich uitsluitend concentreerde op het behouden van kasreserves in plaats van investeren in de toekomst. Er zal worden aangetoond dat de financiële problemen waarmee het bedrijf te maken had te wijten waren aan onverstandige inhuur van personeel in de late jaren 1980 en aan teruglopende marges. Hoofdstuk 9 is het afsluitende hoofdstuk en vat de bevindingen van het onderzoek samen en oppert een aantal lessen die geleerd kunnen worden door ieder bedrijf dat zich in een soortgelijke positie als DEC bevindt.

Appendix A1 bevat een bibliografische samenvatting van de voornaamste mensen die betrokken zijn in de opkomst en ondergang van het bedrijf.
Appendix A2 bevat een lijst van mensen die zijn geïnterviewd door Strout en mijzelf, alsmede transcripties van interviews met leden van de raad van bestuur.
Appendix A3 bevat data van de enquête die is uitgevoerd om terugkoppeling van ex-DEC personeel te verkrijgen.
Appendix A4 bevat data van de SEC dossiers.
Appendix A5 vat de verhandelingen samen die werden opgesteld en aangeleverd bij de Society for the History of Technology conferentie in Pittsburg in 2009 en het World Computer Congress in Brisbane 2010, tezamen met het ABH paper

---

computers introduceerden het concept van een gereduceerde instructie set in microcode waarbij ingewikkelde instructies aan compilers werden overgelaten. Dit maakte de computer veel eenvoudiger om te ontwerpen en te testen, iedere verandering of aanvullende instructies konden dan worden geïmplementeerd in de compiler, hetgeen betekent dat het niet nodig was om de apparatuur te veranderen in het geval van fouten of optimalisaties.

dat werd gepubliceerd in het bedrijfshistorisch tijdschrift *Zeitschrift fur Unternehmensgeschichte* in 2010.[522]

Appendix A6 bevat de tijdslijn van de belangrijke gebeurtenissen die in de bedrijfsgeschiedenis voorkwamen en de mensen die invloedrijk waren bij de groei en aftakeling, alsmede een korte biografie van de geïdentificeerde sleutelpersonen.

---

[522] D. T. Goodwin en R. G. Johnson, "DEC, the Mistakes That Led to Its Downfall," http://www.sigcis.org/files/Goodwin_paper.pdf; D. T. Goodwin en R. G. Johnson, "Recession, S-Curves and Digital Equipment Corporation," *World Computer Congress conference, History of Computing* (2010); D. T. Goodwin en R. G. Johnson, "The Demise of Digital Equipment Corporation: Downsizing - Cause or Cure," *Zeitschrift fur Unternehmensgeschichte* 1(2010).