ELEC6049: REPORT 1, How Does Technology Make Money? - Established Companies

By Henry S. Lovett, Ashley J. Robinson, Thomas J. Smith
Assigned group number: 14

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ABSTRACT

This report takes the idea that diversification is a vital means for an established company to profit and continue to profit from technology. Particularly, the importance of understanding what makes a business successful and identifying other markets where these strategies are equally advantageous is highlighted. A company that successfully diversifies into areas related to their core competence gain a strategic advantage over their competitors, allowing them access to a new revenue stream. A body of evidence is gathered to support this claim through case studies of established companies. Other diversification strategies are also examined, such as not diversifying at all, or diversifying into areas that are unrelated to the core competence of the business. Through analysis of the performance of several technology firms, this report concludes that related diversification is generally an advantageous strategy for a company to pursue, ensuring that the business remains successful for the years to come.

INTRODUCTION

In the context of this report, the definition of an established company is inspired by [1]. Established companies are those that have been successful for a number of years, with a defined product range for a specific consumer market. As a company develops and expands, a clear corporate strategy is required to enable continued profitability and further growth. In this report, it is proposed that related diversification is the optimal corporate strategy for an established business, ensuring the company continues to profit from technology.

Diversification is a corporate strategy set on the simultaneous departure from the present product line and market structure [2]. Businesses have differing approaches to diversity broadly put into three categories; specialism, related diversification and unrelated diversification. Many companies start with a breakthrough product or technological innovation, and a specialised strategy chooses to keep this product as the sole focus of the business [3]. At the other end of the spectrum is unrelated diversification. This strategy involves a company choosing to depart completely from the sector it initially operated in [3], and is often referred to as the conglomerate strategy. In between these two extremes is related diversification, where a company enters a new but related market using the skills base and knowledge they have gained in their current field [3]. Although argued to be contextual and subjective, it is generally the agreement of literature that related diversification produces better company performance [3, 4, 5]. This report aims to investigate if related diversification is advantageous to the profits of established technology companies through various case studies from invited talks and independent research.

This report comprises 2 sections. The first discusses the invited talks from Domino Printing, ARM and Imagination technologies with thought to the hypothesis. Section two gives further case studies both supporting and opposing the hypothesis in order to gain further insight into the impacts of diversification strategies.

SECTION 1 - INVITED TALKS

Domino Printing Sciences PLC - Carl Reynaud - Director of Hardware Development

Domino Printing Sciences PLC designs, manufactures and markets a range of printing equipment for a wide range of applications [6]. In 2013 Domino achieved a global turnover of £335.7m from operations in over 120 countries [7]. Domino was founded in 1978 [7] as a spin out following a project at technology consultancy Cambridge Consultants. Graeme Minto led the project developing continuous inkjet (CIJ) technology, and consequently founded Domino Printing Sciences following the departure of the project's client [8]. This is an example of a company starting with a core technological innovation as the focus, as asserted by Johnson in [3].

By the mid-90s CIJ was reaching technological limits of exploitation. Despite the many advantages of the technology, customers wanted higher resolution images in bigger sizes than were possible with CIJ. Hence Domino began an extensive review of alternative technologies including laser printing, 'binary' inkjet and 'drop-on-demand' technology. During the 90s, Domino built on the expertise built from CIJ technology to expand and diversify to become a multi-technology company. This diversification into other related technologies have enabled Domino to retain their existing customer base while entering new and emerging markets [8]. Instead of just printing date codes, Domino has diversified into technologies to print patterns for laminates, ceramic floor tiles, complex food labels, cable labelling and more. This is an example of a company adopting related diversification as a corporate strategy, enabling continued and extensive profit from technology.

ARM - John Biggs - Consultant Engineer and Co-Founder

ARM was founded in 1997as a joint venture between Apple and Acorn. The primary function of ARM is to design processor architectures. Robin Saxby, ARM's first CEO, developed the innovative business model that is partially responsible for ARM's success. ARM licenses their architecture IP to chip manufacturers, as opposed to the manufacturing and selling a physical product themselves. As well as a license, the partnership model includes a royalty system. This gives ARM a constant revenue stream, allowing the funding of further research. They are now the world's leading semiconductor IP company and have shipped 50 billion devices to date.

ARM were able to grasp the low power market ahead of larger CPU firms such as Intel. 1988 saw handheld PDAs starting to emerge, prompting several low power CPU designs from different manufacturers. The ARM610 chip featured in the Apple Newton Message Pad, prompting the joing venture spin out. ARM has significant expertise in low-power design and this core competency has given ARM a competitive advantage as the transition to the mobile age and the Internet of Things continues.

Building on this core expertise in low power architecture design, ARM have developed a focused but varied range of products. In 1997, the company expanded into memory, video and I/O controllers to support the processors they designed. The latest processors can be found in a range of devices, from mm^3 sized devices, to km^3 sized. ARM is also currently expanding into the microserver market. By applying the low-power design considerations in a server environment, a significant reduction in server running costs can be achieved. Although a relatively young company, some degree of related diversification has already occured at ARM. When coupled with technical excellence, related diversification will allow ARM to continue to exploit tehcnology for profit.

Imagination Technologies - Dr David Knox - Senior Director Software Engineering

Imagination technologies began in 1985, then known as Video Logic. In 1999 the company moved toward IP licensing instead of manufacture and have since become a leading company in silicon, software and cloud technology [9]. Imagination has shipped 5 billion devices containing their IP, 1.2 billion of which were in 2013 [10].

Imagination is acquiring an increasingly diverse IP portfolio. In February 2013, it aquired the MIPS CPU architecture IP. The company already had expertise in integrating Imagination and MIPS complementary technology. MIPS provides the company an opportunity to enter the mobile processor market, as MIPS is one of the few CPU architectures supported by the Android OS [10]. It remains to be seen if this related diversification will be successful for Imagination, especially when considering the success of the incumbant ARM.

Imagination also has a commercial electronics devision named Pure. The brand is synonymous with DAB radio, and allows Imagination a direct route to the consumer market. Adopting the licensee business model adds the challenge of removal from the end user and customer. By using Pure as a showcase for Imagination IP, an important line of feedback is developed. The business model, shown in figure 1, is a multi-year cycle in which the Imagination use direct customer feedback to drive chip development for licensees. This also gives Imagination an advisory role to OEMs regarding consumer preferences. Imagination is a leading IP company with a diverse yet related portfolio of business opportunities which allow it be succesful.

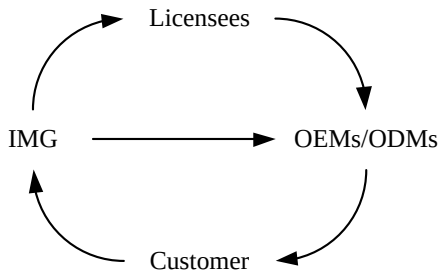

Figure 1: Imagination Technologies business model.

Reflection on Common Themes

The full content of the invited talks is given in Appendix 5. The shorter summaries given in this section have highlighted some elements of common strategy. Each of these companies started with a technological core focus. This technical excellence or key innovation often has an integral role in the early company stages. However, these companies are now well established and have since expanded and diversified into new areas. These new markets and products are often related to the core technical competence of the initial business. This allows the company to exploit their core competencies in other markets, increasing the profit potential of the company. With these thoughts in mind, Section 2 examines further case studies of established companies to build a body of evidence for the claim that related diversification is the key to profitability.

SECTION 2 - DIVERSIFICATION FOR PROFITABILITY

Atmel Technologies Ltd.

Atmel Technologies Ltd are a leading company in the design and manufacture of a variety of hardware products. The company was founded in 1984 by George Perlegos in the USA, a former Intel employee. It started with only $30,000 in capital [11] and has since made $150.93 million profit in Q4 of 2013 alone [12], and is traded in the NASDAQ [13]. Atmel satisfies the criteria for being an established company - it has been successful for many years, and has a defined product range. This case study will give a brief overview of the company, including an investigation into the diversity of Atmel, and whether this diversity has helped the success of the company.

Atmel's original expertise was non-volatile memory devices, primarily EEPROM memory. Atmel sold it's memory devices to companies such as Nokia and Motorola. However, in 1987, Intel started legal proceedings against Atmel. Intel claimed the Atmel had infringed their patent, and Atmel did not fight the case [14]. Instead of spending time and money on the law suit, Atmel redesigned their memory devices which subsequently outperformed and consumed less power than the Intel equivalents. By being forced to innovate a new and better technology, Atmel gained a competitive advantage over the incumbent Intel, which was critical to the success of Atmel as an emerging company.

As Atmel became increasingly dominant in the memory market, new potential markets were explored. Atmel licensed an architecture from ARM to enter microcontroller industry. The company then combined their memory devices, both flash and EEPROM, with their AVR devices and the first microcontroller was released in 1996. This is a logical extension of Atmel's core capabilities in memory, allowing Atmel access to a new and profitable marketplace.

Following the diversification into the microcontroller market, the company acquired a number of fabrication plants to support development in these areas. The first acquisition was the Honeywell fabrication plant, increasing Atmel's R&D capability [15]. Atmel then continued to diversify by aquiring further fabrication plants in a variety of locations. These acquisitions were costly investments in large assets. Although related to Atmel's product line, manufacturing was unrelated to Atmel's core competence of memory and microcontroller design. These activities require vastly different expertise, skills and approach. Atmel's experience and excellence in microcontroller and memory design had no bearing on the ability of the company to manage a fabrication plant. As a result, this venture into manufacture ended as Atmel proceeded to sell the majority of it's fabrication plants [16, 17, 18, 19]. This shows that not all diversification strategies are successful when unrelated to the core competence of the business. It highlights the importance of understanding what makes a business successful in their current market, and the ability to identify related markets where these capabilities can be equally advantageous.

Atmel now design a number of hardware devices, testing them using their remaining R&D foundry, and getting them manufactured for the market by external companies. These devices range from microcontrollers for various applications, touch screens, Wi-Fi and security. Keeping to their core competence of designing hardware has since enabled Atmel to become a global leader in multiple markets, and successfully diversify into these market areas. Atmel support the hypothesis of this report.

Google Inc.

Google Inc. was founded in 1998 [20] by Larry Page and Sergey Brin based on their work carried out at Stanford University [21]. From humble beginnings as a search engine provider, Google has grown to dominate

70% of the online search and advertisement industry [22] and has interests in a wide field of software applications [23]. Google is one of the world's most valuable companies, with a market capital value of $212.4bn [24]. Google has successfully moved into areas as diverse as email, office software, geographical software, operating systems, mobile hardware and intelligent systems [22, 23]. The success of these ventures can be attributed to consistently outperforming competitors with their core internet search services [23], which allows diversification to be based upon a renewal and reapplication of well-proven concepts.

Google's entry to the mobile operating system (OS) market in 2007 has been a worldwide phenomenon, with over 1 billion activated Android devices and 975,000 apps in the Android ecosystem [20]. 79% of all smartphones run the Android OS [25]. While the relationship between internet search and mobile OSs is not immediately apparent, the success of Android over it's competitors is through the re-application of the experience gained from the internet search industry. This includes all aspects of the Google approach, from the working environment to the corporate strategy.

The way Google makes money is through advertising. The use of advertising as a money making method has been long perfected by google through it's core internet search service. Although there are other Android revenue streams such as royalties and charges for content from the "play store" the bulk of Google's profit from Android comes from advertisements [25]. The OS itself can be offered for free to the end user in much the same way the internet search service is free to use by the end user. This is a marked removal from the approaches of competitors such as Apple and Microsoft [22], and allows Android to be installed on a range of phones from budget to flagship models. In 2013, there were over 3,900 differnet android device models [25] compared to just a few iPhone models. This drives Google's profits, not from the value of the individual devices sold but due to the greater reach of advertisements afforded by the larger user base.

While not all companies that use related diversification necessarily succeed [3], it has worked for Google. Google has been able to critically assess the areas of core competence gained from the internet search market, and identify other markets that could be exploited through these competencies. The amount of data Google is willingly given and the everyday use of Google services in everyday life makes Google very powerful, and we can certainly expect the Google model to be used in more and more market scenarios.

Intel Corporation

Intel is a pioneering company in the field of microprocessor design and fabrication. The company was founded in 1968 by Bob Noyce and Gordon Moore [26]; the man behind the self fulfilling prophecy known as Moore's law - "The number of transistors incorporated in a chip will approximately double every 24 months." [27]. The first products intel produced were memory chips, including the 1101 and 1103 DRAM chips [28]. Following the success in the memory market, Intel released the 4004, a four-bit microprocessor. This was the first commercially available microprocessor and was released in November 1971 [28]. Although the technology was emerging, the founders were already well established in the electronics industry. Members of the "The Traitorous Eight" created the west coast silicon industry from which direct links can be made to many well established companies [29]; including Atmel. The two experienced engineers had already made a mark in Fairchild semiconductor [30] and were backed by a $2.5 million investment from Aurthur Rock [28].

A case study taken from [3] considers Intel as moving through three eras. The first was involvement in the memory market followed by the second with huge successes in microprocessors. The third era, possibly still their current drive, is moving focus away from the desktop market towards low power devices for the mobile technology market and the Internet of Things. The end of the second era coincides with their highest every share price at the beginning of the 21^{st} century then dropping rapidly shortly after and remaining below 50% of the peak value up until this day [31].

While Intel remains a profitable entity, the company failed to continue to profit as extensively as it did at the end of the second era. What is the reason for this relative failure? Lack of diversification is a possible factor as the company may have failed to do this early enough. Intel had particular expertise in microprocessor design and manufacture, and dominated the expanding PC CPU industry during the second era. The nineties saw ten years of 30% per annum growth in the market, which only started to slow around 1998 [3]. The company remained relatively specialist and failed to identify and capitalise on changes in the market. Competitors in the processor market, namely ARM, came out of nowhere with innovative new business models and technology. Their low power designs were suitable for the emerging portable digital electronics revolution on the horizon. Intel needed to make some considerable corporate changes in technology and ethos to enter this new market. Additionally, the mobile market poses a threat to the profitability of the desktop market Intel was already dominant in, and therefore marks a significant conflict of interest. Although Intel are now adapting to these changing market conditions with their new Intel Atom product line and other low-power devices, the company remains on the backfoot in the market due to their lack of related diversification.

CONCLUSIONS

All the companies studied in this report meets the requirements of an established company - they have been operating for a number of years with a defined product range [1]. There are clearly some common ideas throughout these case studies that have made a significant contribution to the success of each company. All six of the considered companies emerge with a technical innovation, breakthrough or specific expertise. Atmel developed a better memory device, ARM were experts in low-power CPU design, Domino formed on the back of a breakthrough in printing technology, Google formed following the page rank algorithm breakthrough, Imagination were experts in video hardware design and Intel designed the world's first commercial microprocessor. Clearly, the initial competencies of the business are crucial to the company becoming established in the first place. A successful company cannot be built on inferior technology, a flawed product or poor strategy no matter how diverse that company becomes.

When a company becomes established, it is sensible to asses why that success has happened. Identifying the core competence of a business is of key strategic importance. Google successfully identified their core competence in advertising, Domino in printing technology and ARM in CPU architecture design. Atmel misdiagnosed it's core competence in it's foray into the fabrication industry, later correctly identifying hardware design as their core competence. By understanding what it is about a company that makes it successful, the company can capitalise on these strengths to make further profit.

Related diversification into areas where the core competence of a business is advantageously applied allows an established company access to a new market and a new source of revenue. This is a strategy employed by many of the companies that have been studied in this report. Related diversification builds on the strengths of the company to gain a strategic advantage over their new competitors through the reapplication of core competencies. The cases studies also highlight the dangers of not diversifying at all - as in the case of Intel missing an opportunity to profit in the mobile revolution, and also diversifying into unrelated areas, as shown by Atmel entering manufacturing. Overall, there is a strong body of evidence to suggest that related diversification is an important strategy that established companies use to profit and continue to maximise their profit from technology.

REFERENCES

[1] Tauno Kekäle and Sari Kola-Nyström. Successful innovations from an established company. *Business Strategy Series*, 8(2):109–115, 2007.

[2] H Igor Ansoff. Strategies for diversification. *Harvard business review*, 35(5):113–124, 1957.

[3] Gerry Johnson, Kevan Scholes, and Richard Whittington. *Exploring corporate strategy: Text and cases*. Pearson Education, 2008.

[4] Michael Mayer and Richard Whittington. Diversification in context: a cross-national and cross-temporal extension. *Strategic Management Journal*, 24(8).

[5] Leslie E. Palich, Laura B. Cardinal, and C. Chet Miller. Curvilinearity in the diversificationperformance linkage: an examination of over three decades of research. *Strategic Management Journal*, 21(2).

[6] Domino Printing Sciences PLC. Annual Report and Financial Statements 2013. Technical report, Domino Printing Sciences PLC, 2013.

[7] Domino Printing Sciences PLC. Company information - factsheet. `http://www.domino-printing.com/Global/en/AboutDomino/Factsheet/Factsheet.aspx`, Feb 2014.

[8] K. Goffin and R. Mitchell. *Innovation Management: Strategy and Implementation using the Pentathlon Framework, Second Edition*.

[9] Leavitt Communications. Imagination technologies analyst report. `http://www.leavcom.com/imgtec_070908.htm`. (Visited on 22/02//2014).

[10] Imagination Technologies Group PLC. Annual 2013. Technical report, Imagination Technologies Group PLC, 2013.

[11] FundingUniverse. History of Atmel Corporation. `http://www.fundinguniverse.com/company-histories/atmel-corporation-history/`. (Visited on 16/02/2014).

[12] Wikinvest. Gross profit for Atmel (ATML) 2013 Q4. 2013.

[13] NASDAQ.com. ATML stock quote - Atmel Corporation stock price. `http://www.nasdaq.com/symbol/atml`. (Visited on 16/02/2014).

[14] 946 f.2d 821 - Intel Corporation, appellant, v. U.S. International Trade Commission, appellee.

[15] about.com. Atmel history. `http://components.about.com/od/Companies/p/Atmel-Corporation.htm`. (Visited on 16/02/2014).

[16] Atmel announces sale of Nantes fab. `http://ir.atmel.com/releasedetail.cfm?releaseid=274575`. (Visited on 16/02/2014).

[17] Atmel completes sale of Grenoble, France subsidiary. `http://ir.atmel.com/releasedetail.cfm?releaseid=274564`. (Visited on 16/02/2014).

[18] Atmel announces sale of manufacturing facility in North Tyneside, U.K. `http://ir.atmel.com/releasedetail.cfm?releaseid=274539`. (Visited on 16/02/2014).

[19] Atmel completes sale of manufacturing operation in Heilbronn, Germany. `http://ir.atmel.com/releasedetail.cfm?releaseid=357217`. (Visited on 16/02/2014).

[20] Google Inc. Company timeline. `http://www.google.com/intl/en/about/company/timeline/`. (Visited on 17/02/2014).

[21] Sergey Brin and Lawrence Page. The anatomy of a large-scale hypertextual web search engine. *Computer networks and ISDN systems*, 30(1):107–117, 1998.

[22] F.T. Rothärmel. *Strategic Management: Concepts and Cases*.

[23] T.L. Wheelen and J.D. Hunger. *Strategic Management and Business Policy: Towards Global Sustainability*.

[24] The Financial Times LTD. Ft 500. http://www.ft.com/indepth/ft500. (Visited on 17/02/2014).

[25] I. Krajci and D. Cummings. *Android on X86: An Introduction to Optimizing for Intel® Architecture*. Apress, 2013.

[26] Intel. Intel timeline: A history of innovation. http://www.intel.co.uk/content/www/uk/en/history/historic-timeline.html. (Visited on 19/02/2014).

[27] Intel. Moore's law and Intel innovation. http://www.intel.com/content/www/us/en/history/museum-gordon-moore-law.html. (Visited on 19/02/2014).

[28] Encyclopaedia Britannica. Intel corporation (American company). http://www.britannica.com/EBchecked/topic/289747/Intel-Corporation. (Visited on 19/02/2014).

[29] Business Week. Fairchild's offspring. http://www.businessweek.com/pdfs/fairkid.pdf, August 1997. (Visited on 19/02/2014).

[30] Fairchild Semiconductor. About fairchild: Fairchild Semiconductor history - producing silicon transistors. http://www.fairchildsemi.com/about-fairchild/history/#. (Visited on 19/02/2014).

[31] Intel Corporation: NASDAQ:INTC quotes and news - Google Finance. https://www.google.co.uk/finance?q=NASDAQ:INTC. (Visited on 24/02/2014).

APPENDIX

1. TEAM CONTRIBUTIONS

Note that for each report there will be a different chair person. The chair person is expected to lead the report writing process, including ultimate decision on topic, the allocation of research and the collation of content provided by others. Hence it is expected that one team member contribute more per report, thus averaging out over all three reports for the module. The contribution to the module as a whole will be approximately even from each team member.

Team Member	Contribution
Thomas J. Smith 23914254	Chairperson for this report. Authored the abstract, introduction, Domino printing, Google and conclusion sections. Also authored minutes.
Henry S. Lovett 23900091	Authored the Atmel and ARM sections.
Ashley J. Robinson 24008346	Authored the Imagination and Intel sections.

2. MEETING MINUTES - KICK-OFF MEETING

Purpose	ELEC6049 Team Kick-Off Meeting
Date and Time	Tuesday 4th February 2014 at 12:00
Venue	3rd floor Zepler Building, Highfield Campus
Participants	TJS (Tom Smith), HSL (Henry Lovett), AJR (Ashley Robinson)
Apologies	None
Agenda	Assign Chair for this report. Generate initial ideas for research. Agree expectations of work and schedule. Agree date and agenda of next meeting.

Minutes of the Meeting

ID	Subject	Notes and Discussion	Action
1.0	Chair	The group decided that TJS should be the chair for this report. Both HSL and AJR are currently pursuing job applications, hence the logical choice that TJS be chair for this report.	-
2.0	Case Study Ideas	TJS presented some ideas previously undertaken in a management module regarding Bowman's Strategy Clock, and the different strategies employed in the tablet market. The group discussed this as a case study and agreed it was interesting but obvious, but struggled to make a hypothesis. Discussions of reputation (Apple) and quality.	-
3.0	Hypothesis 1	HSL discussed Reputation - Companies such as Intel, Apple, Microsoft rely on their reputation as an established brand to sell their products. AJR proposed quality along the same lines.	-
3.1	Hypothesis 2	The group discussed collaboration in the context of ARM being fabless which enabled it to be more agile than Intel in the microprocessor market. AJR highlighted that ARM and Xilinix collaborate in the microprocessor and FPGA markets. Hypothesis is that by collaborating, established companies make money by reducing and spreading risks across multiple entities. Apple is an example contradicting the hypothesis.	-

ID	Subject	Notes and Discussion	Action
3.2	Hypothesis 3	TJS proposed that smart diversification was how an established company makes money. The group discussed Apple as an example with the iPhone, iPad and Mac ranges. Also Google with the search engine at the core, and Chrome and Android as diversification. Amazon with the online store at the core, and the Kindle e-reader and tablet as smart diversification along the same theme. A quick look in a textbook shows that this is called "Related Diversification". Microsoft with OSs and XBox. The group agreed that this was a possible hypothesis.	-
3.3	Hypothesis selection	The group narrowed it down to collaboration or diversification as a topic. TJS chose to head toward the diversification hypothesis due to the strength and number of case studies.	**ALL A1.0 All A3.0**
4.0	Milestones	The group agreed to meet again on the **11th Feb** and that by then, most research should be complete, report stubs should be started and a clear hypothesis should be sought. The next meeting will be to put what we have together into a plan and to allocate work to complete the report by the tutorial on **18th Feb**.	**TJS A2.0**

Action List

ID	Action	Comments	Status
A1.0	Research	All to start research. Use Git Issue to highlight useful research to the group. Make notes of all sources.	Open 4th Feb
A2.0	Introduction	Define an established company. Introduce hypothesis.	Open 4th Feb
A3.0	Case Study	Each to identify a case study for proposal to the group by next week.	Open 4th Feb

Next Meeting: 11th Feb 2014, 12:00, Level 3 Zepler, Highfield Campus.

3. MEETING MINUTES - PROGRESS MEETING

Purpose	ELEC6049 Report Meeting
Date and Time	Wednesday 12th February at 11:00
Venue	3rd floor Zepler Building, Highfield Campus
Participants	TJS (Tom Smith), HSL (Henry Lovett), AJR (Ashley Robinson)
Apologies	None

Agenda	Update on research status. Discuss case study examples. Read any report stubs as a group. Identify and allocate work to finish report. Agree next meeting.

Minutes of the Meeting

ID	Subject	Notes and Discussion	Action
1.0	House Keeping	HSL identified and addendum to the minutes of the last meeting and has corrected the typo. Subsequent to this the minutes of the last meeting were adopted by the group	-
2.0	Tutorial Session	TJS attended the non-official tutorial session with Chris Freeman (CF). TJS fed back to the group that CF had been very positive regarding the hypothesis proposed. CF said it looked like a good report with good examples to back it up, the ideas were received with considerable enthusiasm. CF highlighted the importance of good and appropriate referencing which should be heeded.	-
3.0	Research Progress	HSL provided some initial reading on Google, Amazon and Apple with particular emphasis on ZDnet article. AJR questioned if this is a credible source. The group agreed it is important to follow reference trails through literature to establish the original source.	-
4.0	Report Progress	TJS has drafted an introduction to the report and written the Domino Printing section. The group read the report so far.	
4.1		HSL noted that IEEE allows you to refer to numbered references as nouns, which the group agreed should be followed despite the report not being explicitly IEEE style.	**TJS A4.0**
4.2		HSL suggested moving the introductions from the start of each section to the introduction of the report - Actioned.	
4.3		TJS proposed that the Domino Printing case study should be used as a template - Agreed by the group.	

ID	Subject	Notes and Discussion	Action
4.4		The group decided on three or potentially four case studies for section 2. Google was chosen as an example of related diversification. It was mentioned in the previous meeting as an example. Atmel was also suggested, and HSL has some insider experience in this area hence justifying the choice. Intel were discussed by the group. Their failure to diversify into mobile must have caused some damage. This will make a good study of a company that has remained relatively specialised. Finally another company on the other end of the spectrum will be chosen. Virgin Group was discussed with operations in finance, travel, space exploration and just about everything. Mitsibushi were also discussed, with unrelated diversification spanning power equipment, cars and nuclear power stations. One of these conglomerate organisations will also form a comparison for section 2. The group agreed that the case studies should be written by the next tutorial, so that then the report could be collated into a coherent document.	**TJS A5.0 & A8.0, AJR A6.0, HSL A7.0**
4.5		HSL mentioned that the group should break up the TEXfiles.	**HSL A9.0**
5.0	Remaining Talks	The team agreed that HSL and AJR will take responsibility for one of the remaining invited talks each. This includes keeping lecture notes in the appendix of the report and writing the relevant subsection in section 1.	**AJR A10.0, HSL A11.0**
6.0	Minutes	The group agreed that TJS would collate these minutes.	**TJS A12.0**
7.0	AOB	The next meeting will take place at the tutorial. The meeting was closed.	-

Action List

ID	Action	Comments	Status
A1.0	Research	All to start research. Use Git Issue to highlight useful research to the group. Make notes of all sources.	Open 4th Feb - Closed 11th Feb
A2.0	Introduction	Define an established company. Introduce hypothesis.	Open 4th Feb - Closed 11th Feb
A3.0	Case Study	Each to identify a case study for proposal to the group by next week.	Open 4th Feb - Closed 11th Feb
A4.0	IEEE Styling	Change reference from author and citation to citation as a noun	Open 11th Feb
A5.0	Google Case Study	Research Google as a successful implementation of related diversification.	Open 11th Feb
A6.0	Intel Case Study	Research Google as a specialised company and the effects of not diversifying.	Open 11th Feb

ID	Action	Comments	Status
A7.0	Atmel Case Study	Research Atmel as a successful implementation of related diversification.	Open 11th Feb
A8.0	Conglomerate Case Study	Research a conglomerate (Virgin, Mitsibushi etc) for an example of unrelated diversification.	Open 11th Feb
A9.0	TEXfiles	Break up the TEXfiles into sections so the LATEXword count will work properly.	Open 11th Feb
A10.0	ARM Talk	Write up the invited talk notes and corresponding Section 1 part.	Open 11th Feb
A11.0	Imagination Talk	Write up the invited talk notes and corresponding Section 1 part.	Open 11th Feb
A12.0	Minutes	Write up the minutes and circulate.	Open 11th Feb

Next Meeting: 18th Feb 14, in the scheduled tutorial session 12:00 05/2015.

4. MEETING MINUTES - FINAL PROGRESS MEETING

Purpose	ELEC6049 Report Meeting
Date and Time	Tuesday 18th February at 12:00
Venue	Building 2, Highfield Campus
Participants	TJS (Tom Smith), HSL (Henry Lovett), AJR (Ashley Robinson)
Apologies	None
Agenda	Update on research status. Discuss case study examples. Read through report as it stands. Identify and allocate work to finish report. Agree next meeting.

Minutes of the Meeting

ID	Subject	Notes and Discussion	Action
1.0	House Keeping	The group adopted the last meeting minutes.	-
2.0	Introduction	Identified a small change in the introduction that was changed during the meeting.	-
3.0	Action List Review	A1.0, A2.0 and A3.0 closed at last meeting	
3.1		A4.0 Outstanding but is a very minor change. Actioned by TJS and closed.	
3.2		A5.0 and A7.0 first draft achieved. To be reviewed in this meeting.	
3.3		A6.0 not complete due to AJR interview and report commitments. To be completed shortly.	**AJR A6.0**

ID	Subject	Notes and Discussion	Action
3.4		A8.0 not sure if required due to word count and relevance.	
3.5		A9.0 Done - actioned by HSL	
3.6		A10.0 assigned to HSL and A11.0 assigned to AJR - swapped due to HSL interview commitments.	**HSL A10.0 and AJR A11.0**
3.7		A12.0 TJS will write these minutes.	**TJS A12.0**
4.0	Atmel Discussion	The group discussed the Atmel case study by HSL. Generally agree the case study is good needs condensing slightly. Focus on the points not necessarily the history although the history is necessary for understanding. Drew parrallels perhaps between Intel with high stocks at one point then a change. All to read it a bit and review, HSL to condense.	**ALL A7.0**
5.0	Google Discussion	The group discussed the Google case study by TJS. Main point that Google had a core capability and reapplied that in a related sector. Group agreed this was good and looked at Intel as a company that was specialised and didn't reuse those skills. All to read it a bit and review.	**ALL A5.0**
6.0	Reference Format	Asked the tutorial leader what the reference format should be. Not entirely important but need to ensure it is traceable. Need to make clearer.	**HSL A13.0**
7.0	Outstanding Work	AJR to do Intel and Imagination and start conclusions. HSL to do ARM and References. TJS to do minutes, conclusion and comparisons. Abstract will be done last (TJS take ultimate responsibility as chair).	**AJR/TJS A14.0**
8.0	AOB	The next meeting will take place at the tutorial. The meeting was closed.	-

Action List

ID	Action	Comments	Status
A1.0	Research	All to start research. Use Git Issue to highlight useful research to the group. Make notes of all sources.	Open 4th Feb - Closed 11th Feb
A2.0	Introduction	Define an established company. Introduce hypothesis.	Open 4th Feb - Closed 11th Feb
A3.0	Case Study	Each to identify a case study for proposal to the group by next week.	Open 4th Feb - Closed 11th Feb
A4.0	IEEE Styling	Change reference from author and citation to citation as a noun	Open 11th Feb - Closed 11th Feb
A5.0	Google Case Study	Review Google as a successful implementation of related diversification.	Open 11th Feb, Mod 18th Feb
A6.0	Intel Case Study	Research Intel as a specialised company and the effects of not diversifying.	Open 11th Feb, Mod 18th Feb

ID	Action	Comments	Status
A7.0	Atmel Case Study	Review Atmel as a successful implementation of related diversification.	Open 11th Feb
A8.0	Conglomerate Case Study	Research a conglomerate (Virgin, Mitsibushi etc) for an example of unrelated diversification.	Open 11th Feb
A9.0	TEXfiles	Break up the TEXfiles into sections so the LATEXword count will work properly.	Open 11th Feb
A10.0	ARM Talk	Write up the invited talk notes and corresponding Section 1 part.	Open 11th Feb
A11.0	Imagination Talk	Write up the invited talk notes and corresponding Section 1 part.	Open 11th Feb
A12.0	Minutes	Write up the minutes and circulate.	Open 11th Feb
A13.0	References	Format references better.	Open 18th Feb
A14.0	Conclusions and Abstract	Weave report together into one choerent document and finish.	Open 18th Feb

Next Meeting: None - Coordinate through GitHub Issues.

5. NOTES FROM INVITED PRESENTATIONS

These notes are raw and not altered in any way from when they were taken from the invited presentation. These notes have been distilled and focussed through the lens of our report title and hypothesis to the content shown in section 1.

Domino Printing Sciences PLC - Carl Reynaud - Director of Hardware Development

Success - "bringing new products into market and making a profit." The key question for any business is how to make profit in a sustainable manner. You need to be able to make profit, then keep on making a profit.

Background to Domino Printing - mission statement - we will achieve market recognition as the first choice global provider of coding, marketing and variable printing solutions delivering convenience, security and peace of mind. Key markets for Domino include;

- Date coding packaging - Slippery surfaces requires special technology.
- Industrial printing and coding - this is on fast moving, small and hot plastics and requires a similar technology to date coding.
- Printing and Mailing - Completely different technology required to the other two market areas.

Domino started with a key breakthrough technology in inkjet printing. This has led to diversification into laser and multijet technologies. The head office is in Cambridge. Domino manufacture around 1000-10,000 products per year, making it a low-medium volume business. This presents a number of challenges and opportunities. The technology portfolio ranges from ideas to mature technologies.

"Most ideas take 20 years to become an overnight success" - Paul Saffo.

Four key points:

- You want what?
- Celebrating Diversity
- No absolutes
- Keep updating the toolbox

You want what highlights that people are often the forgotten ingredient. It is key to know your customer. The customer often lacks the ability to articulate the problem properly and also lacks the vision to see the solutions. Identify what the customer really values (not necessarily the same as what they say they value) and why that is the case, as that is what customers will pay for. As an engineer, just because it is possible doesn't mean we should do it. Does the world need a better mouse trap? There is a significant skill in being able to capture and distill customer values and then apply that to a practical concept. A practical example was given of a customer specification asking for a printer weighing less than 25kg. Asking why this was the case broke the specification down to a real world requirement, that the printer should be able to be installed by one person to minimise installation costs. This requirement requires far more consideration than just weight and concerns shape, handling, regulation (lone working) and other factors. This is called a 5Y process. Another useful model to follow is the V-model.

Celebrating Diversity - don't try to put in what nature left out. changes in culture, education adn psychology. We need to identify how to work best with each other as a team. This involves knowing how you personally work, and identifying how others you work with behave so that you make best use of the diverse skillset in your team. Meyers Briggs type indicators are often used here. Diversity is particularly important when considering foreign markets.

No absolutes - there will always be variations, but what is the failure zone. Process capability - understand variance. Need to identify suitable margins of error. Test products to make them fail - don't let the customer have a failed product as that can be disasterous.

Keep updating the toolbox - Pareto and the 80:20 rule was mentioned, identify the 20% of the work that delivers 80% of the value etc. Failure mode effect and analysis provides a framework for risk analysis.

Question and answer session:

"What's the biggest barrier you have encountered as an engineer?" - Not understanding how to apply technology as such to make it valuable for the customer.

"How do the features of an engineering product relate to its success?" - Good products tend to have less features. It may be the case that less time can be spent fixing a parameter by researching customer preferences than implementing parameter adjusting functionality. For example take the iPad versus a laptop. Older generations will choose an iPad because there are less features therefore making it simpler to operate.

"Does Domino have any plans for expansion?" - We are currently invested in date code printing but are making a move to variable surface printing and also the printing of different materials.

"You mentioned how knowing your customer was important. How could a business suceed with emrging technologies when no record of the customer is already known?" - There may exist parallel markets which can give some confidence of an expected customer base. Focus groups and trade shows are a good way to test new technologies without fully deploying any products. Constantly requesting customer input is also a good way to update the possible requirements which would lead to the design of a sucessful product.

”How do you measure success?” - I look at technical forums where customers seek solutions to problems.

”Does domino have any plans to takeover smaller businesses?” - Not at the present. We tend to look for businesses that are making a profit rather the businesses which are producing future possible technologies.

”Have you thought of diversifying by making components you would otherwise outsource?” - Some of our print heads are brought in because the piezo electronics is too complicated for us to invest resources. The mounting mechanisms however are designed internally but built externally. This allows to retain the intellectual property but not get involved with the machining required for implementation. We look internally for skills that already exist onto which we could diversify rather than jumping to a completely new business.

ARM - John Biggs - Senior Engineer

John has been at ARM since 1986 and helped form ARM in 1990. ARM - The architecture of a digital world. ARM is the worlds leading semiconductor IP company with 30 million processors entering the market every day. Over 50 billion ARM chips have been shipped to date, 10 billion of which in 2013. A major driver is the mobile revolution, with smartphones and tablets vastly outselling desktop machines.

Acorn was founded on 5th December 1978 by Hermann Hauser and Chris Curry. Their first contract was to develop fruit machine hardware, to replace the conventional electromechanical solutions. The Acorn system 1 was sold for 70 pounds in 1979 based on the 8 bit 6502 processor. Acorn’s next big hit was the BBC Micro in 1982. Chris Curry told the BBC that they would have a working prototype within a week, and the Acorn team just about managed to build it in time. Having won the BBC Micro contract, Acorn went on to make a number of other 6502 based machines, including the Electron and Master.

Acorn needed a more powerful computer, and looked to Intel to license the 80286 processor, which was refused. As a result Acorn’s advanced R&D labs was set up to build Acorn’s own 32-bit processor. In 1983, Acorn engineers were inspired by a trip to the Western Design Centre. The small scale of this operation gave Acorn confidence to design their own chip. Hermann gave the design team two key advantages. There was no money, and no people for the project meaning the design had to be simple and elegant.

The first ARM silicon was built in 1985 with 3 micron technology, 25k transistors, 6MHz and less than 0.1W power. This was the worlds first commercial available RISC processor.

To reduce the cost of a home computer, Acorn continued to design further chips, memory controller, video controller and IO controller which were assembled onto a single board. These were eventually launched as the Archimedes in 1997.

PDAs started to emerge around 1988 based around portability and handwriting recognition. Low power chips were required, and Hermann asked ARM to develop an especially low power chip. Around the same time, Apple were developing the Newton Message Pad based around the AT&T Hobbit processor. In the end they swapped it for the ARM chip, using the ARM610. In a bizarre twist of fate the machine designed by Hermann and the Apple device swapped processor. The ARM610 was made from 1.2 micron technology and some 358 thousand transistors.

In 1997 ARM was founded as a joint venture with Acorn and Apple, since Apple required to have control over their IP. Apple put in 1.5 million pound capital, and Acorn supplied the people and the IP (valued similarly). Acorn was financially troubled during the 1980s, and were trying to sell the research group any way. So the ARM spin out was mutually agreeable. Robin Saxby was decided to be the CEO of the ARM spin out, after meeting him in a pub.

ARM took some of the benefits of RISC architectures and attempt to reduce costs. Robin Saxby was initially advised not to work for ARM as ”joint ventures never work”. He performed a simple SWOT analysis and identified some of the key areas of value in ARM. Robin took some of the engineers and promoted them to commercial roles. The early years were not easy, 92 featured a company wide pay freeze.

Robin Saxby - *”If you aren’t making mistakes you aren’t trying hard enough”*.

Robin developed the partnership model. Did he grow ARM until it was acquired by a larger company, grow to become a semiconductor company in its own right or become more embedded with Apple? Robin did none of these, and developed the licensee/royalty partnership model.

The first licensee was with GEC and Sharp. GEC were in Portsmouth, and Sharp in Japan which meant they were geographically separate. Next the automotive part of TI and Samsung also became a licensee. By 1995 ARM started to gain international recognition due to this model, despite there was only 40 people actually working for ARM. It was the leverage provided by the partners that made the difference.

The early licenses were perpetual licenses. As time progressed, further license terms were developed. Term licenses allowed a time limited version of the perpetual license, and there were also several other types.

1993 - ARM was 3 years old when Nokia approached TI to build a new chipset based on the ARM 7. But the footprint was too large due to large 32-bit instruction set. The ARM7TDMI was built with a high code density for the mobile phone market. This had 170 licensees and shipped over 10 billion of these. It took until 1996 for the product to enter the market, the Nokia 8110. Innovative layout techniques were developed which helped this processor be so successful.

In 1998 ARM was a 27 million pound business with a net income of 3 million pounds. It was time to float the company in April 1998. The stocks soared, and ARM became a billion dollar company overnight. The acronym was also dropped at this point.

IP deployment has 3 players, the creator, implementor and integrator. A key change in the process was handing over soft IP, so that the implementor developed the processor from RTL to a final design. This was driven by the consumer. Developments in logic synthesis meant that soft IP was becoming favorable in terms of flexibility and time to market. ARM developed a reference methodology to minimise the effort to integrate this soft IP into their product, depending on the required features. ARM needed to completely change their technology in order to take advantage of synthesisable cores. This became the foundation for the ARM9 and others.

In 2000 the ARM926E was developed which is one of ARMs most successful processors selling over 5bn units. The ARM instruction set has had to develop considerably to allow some of the more advanced and extended features. Eventually the ARM processors were divided into three families, focusing on different aspects.

2008 saw the ARM Cortex-A9 which was a step forward in multicore processing. This was driven by consumers wanting ever more advanced user experiences in mobile devices but also with longer battery life. 2011 saw the Cortex-A15 which developed the idea of big-little connected by a coherent cache. This allowed energy savings of approximately 70%.

Looking to the future, a new generation of computing is set to take hold. Currently we are in the Mobile Internet phase, but soon entering The Internet of Things phase. The Cortex-M0 was built in 2012 which is the most energy efficient 32-bit processor ever built. It is aimed at low power IoT applications, such as wireless sensor nodes etc. Much more compact design. Freescale produced a processor based on this technology that measures just 2mm square, for ideas such as ingestible electronics.

ARM and ECS at Southampton started a joint research project in 2008. Mostly the work is based in the area of energy efficiency. The first PhD student has just graduated.

John then made some reflections on how things have changed at ARM. Synthesis tools have improved implementation time from 6 months for the ARM1 to just 30 minutes with the Cortex-M0. This is in-keeping with Moore's Law. Area scaling follows similarly. Performance and Voltage do not follow Moore's Law due to the laws of physics. However, Power Efficiency has also managed to be increased with Moore's Law. ARM is also now a much more global company and is much more connected. A couple of extreme examples is a $1mm^2$ implementation of the Cortex-M0. At the other end is a $1km^3$ computer for neutrino monitoring in the Arctic. There is a huge diversity in application.

ARM servers are now increasingly important, and represent a huge opportunity for ARM. ARM's partnership model is paying off in this area as companies seek to produce micro servers that save huge amounts of space, cooling and energy. This saves around half the cost of a conventional data sensor.

A world where all electronic products and services are based upon energy efficient technology from ARM, making life better for everyone.

Key lessons:

- Top-right isn't everything
- Design once, use many times
- The partnership is everything
- Listen to your customer, and their customer
- Timescales are long
- People are the biggest asset we have
- It pays to be different
- Strive for simplicity beyond complexity.

Alan Perlis - *"Fools ignore complexity; pragmatists suffer it; experts avoid it; geniuses remove it!"*

Questions: Why so many offices - culturally it is better to go and meet the customer face to face. Is it beneficial to invest in companies attributed to ARM - No, focusing on licensing and royalty model. Is the ARM-ECS relationship important - increasingly so. ARM investing in lots of areas, science museums and Raspberry Pi as corporate social responsibility. What point did ARM feel established and secure in the market - 1996 a guy from Samsung asked if he could come and speak to ARM partners, and he gave the motivational speech. How important is the mobile sector - It was integral to the business, but now ARM is in so many different market areas. What makes ARM unique - The partnership model is critical. Defends against aggressive take over from big players like Intel. Are ARM considering buying any other companies - yes ARM bought Mali graphics just a few years ago that compete heavily with imagination technologies. How do ARM deal with competing with Imagination and Mali - Issues are more to do with Synopsis as you need synopsis to build these soft cores, but they also have their own IP which can make working together difficult at times.

Imagination Technologies - David Knox - Senior Director Software Engineer at Ensigma Communications IP

Talk is entitled Software Defined Radio for Consumer Products. High volume consumer products influence our aspirations for technology. Who are Imagination Technology? Imagination are a leading silicon, software and cloud IP provider. They mainly focus on high volume products. They also own PURE digital radios which

do manufacture a product. The city say that PURE should be sold off, but the reason for having it is not necessarily to make money, but give a direct showcase for imaginations IP directly in the market. This makes their marketing and licensing of IP much easier. They operate in graphics, video, general purpose processors, communications and cloud products.

Big global company. UK is the global HQ with four R&D facilities. Imagination aim to provide SoC IP for every market. Imagination can provide all of the comms, graphics, MIPS CPU and VPU as licensed technology. Imagination have licensees but also sell directly to the OEMs, which is a slightly different model to ARM. Perhaps this is a sign that the licensees (silicon manufacturers) are some what out of touch with the end consumer of products. Licensees vary hugely in size, location and industry. Imagination also engage with the end users as mentioned. Technology is used in a huge amount of products, 5 billion products, 3 million products shipped per day. Imagination is also trying to drive new technology.

Looking wider in the electronics industry, devices are becoming smarter. Everything is intelligent and customisable and connected. The Internet of Things is starting with around 10bn plus which is an order bigger than the mobile market. Wearable electronics is starting to take off. LTE further liberating smart phones. 4k screen resolutions are starting to appear. Variety of processors, MIPS, ARM and Intel.

The market in communications is too fragmented. There are too many standards worldwide. Different trade offs need to be made for each standard. The standards are likely to not be consolidated due to this, as they all do different jobs. There seems to be no one size fits all strategy. Additionally, there is the power of world politics at play. If you want a worldwide product you have to support many many different communications protocols, consider mobile phones as an example. Additionally, more products are becoming connectable.

The Internet of things will permeate everywhere, central heating, thermostats, lighting, computers, phones, TV, car, radio, healthcare, security, toys, industrial. A healthcare partner of imagination are building smart plasters that alert the doctor of condition changes before you return for a check up. So, to connect all this stuff, we need a flexible radio processor.

The traditional solution for this was CPUs and or DSP using common hardware. Product development essentially comes down to software development. In radio there are a number of challenges. Ideally you would simply connect an antennae to the right pin and that would be it. In reality, analogue RF tuners are still required to reduce signal bandwidth and control gain for realisable ADCs. However, the data rates are still too high for low power processors. Price and battery life are key factors for products. A hybrid design is used with a combination of hardware and software. The aim is to reduce power consumption while providing plenty of comms standards.

There was some considerable technical discussion of the RPU technology. This was largely beyond the scope of this report. It has 96-bit instruction words.

High volume consumer graphics are based on SoC designs. Microprocessors replaced hard logic, but we need additional hardware to complement the design to keep power down. This is well established in GPU hardware. Imagination has the Ensigma RPU to continue this trend into radio.

Questions - How do you approach the new emerging markets and is it different to your competitiors? Imagination are quite visionary and on the crest of the wave. Imagination are also delivering some low complexity communications products for cheap near-field devices.