**Enterprise Logic vs Product Logic: The Development of General Electric's computer product line**

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### Abstract.

The following paper focuses on corporate strategies at General Electric and how corporate-level interventions impacted the market performance of the firm’s general purpose commercial mainframe product set in the period 1960-1968. We show that in periods of both divisional independent planning and corporate-level planning strategic governance, central decisions interfered in the execution of GE’s product strategy. GE’s institutional “enterprise logic” negatively impacted the “product logic” of its computer product line leading to a weakened position in the market for these systems.

Key words: General Electric, corporate strategy, computer industry, enterprise logic, product logic.

### Introduction

The General Electric Company (that is, the United States domiciled GE) has long been an exemplar of best practice management and a source of influential reflection on business strategy. This paper uses the experience of GE to examine the relationship between product and enterprise level approaches to business strategy. We consider the origins and consequences of the tension between operating and planning realities where the strategic architecture of GE increasingly placed emphasis on the autonomy of line management to run operations but which, at the same time, maintained governance channels which ensured the corporate-level conceptualisation of the overall business model was reflected within and across operating units.

Our key research question is, how did enterprise-level decision making impact the market logic of the computer product developed, manufactured and sold by GE’s Computer Department. We primarily concentrate on the period 1962 to 1967/8, a period in which GE's computer operations were looking to establish themselves as the number one competitor to IBM's dominance of third generation computing with its 360 range and where the failure of the GE product “sets” becomes apparent. It is in this period that the product offering in the computer sector is established and which is, in no small measure, impacted by corporate-level decisions. This suggests that the development of new markets and technologies needs to be explored from a product analysis in addition to organisational and economic perspectives (Brian Arthur (2010) Geroski (2003)).

A historical approach enables us to explore how the decisions made by GE ‘played out’. The importance of time, where “actions and strategies constantly evolve” alongside organisation structures and technologies, emphasises the importance of historical contingency (Brian Arthur 2013). Our research presents evidence that suggests scholars need to think more about how product markets and organisational structures relate to each other. We find that the vision adopted by senior management neglected the operational detail required to deliver an effective product.

The level of product detail is quite high in this paper – it is our contention that this is necessary to show how the strategic management of the firm, even when it was essentially seeing itself as allowing a degree of local autonomy, still imposed changes to the operations of the product department which ultimately would undermine the products produced by that department. We introduce the notion of an internal strategic “enterprise logic” that failed to reflect the individual “product logic” developed by the decentralised Computer Department. The former played a central role in key decisions such as developing new ventures and acquiring new businesses, but with ramifications to the product line. This enables us to focus on the impact this duality had, on commercial mainframe computers.

The paper begins with a brief contextualisation of GE and its organisational structure. We then explore its strategy in computing focusing on the product strategy presented by GE’s Computer Department. This was the WXYZ product concept, a product strategy which showed local management’s clear understanding of the sector in which they were operating. Then we explore the impact of GE’s corporate planning on this product concept and how horizontal and vertical integration damaged the product concept.

The paper also contributes to the understanding of GE; one of the most influential corporate contributors to the history of strategic management. By considering the impact of corporate-level venturing decisions on the individual product sets within operating units we begin to question the oft-quoted GE adage 'A good manager, no matter what his background, can manage anything’[[1]](#endnote-1), a view which GE’s rival IBM believed by the late 1960s was “wearing thin”[[2]](#endnote-2).

The evidence used in this paper is found in the archives of the Charles Babbage Institute (CBI) located at the University of Minnesota. It draws heavily from evidence and transcripts of the 1970s anti-trust case *US vs. IBM* held in CBI Collection 13 ‘*Computer and Communications Industry Association Collection of Antitrust Records, ca. 1940-1980’*. This resource is also available in other locations, such as the Hagley Museum. The referencing system used here is uses the case numbering system, evidence is with px\*\*\*\* (plaintiff) or dx\*\*\*\* (defence) and transcripts of evidence numbered tr\*\*\*\*\*, which effectively identifies the page number of an individual’s oral evidence during the case.

### Business models and the strategic architecture at GE

The notion of an enterprise logic and a product logic complements the conceptualisation of a firm through its business model. It enables the strategic and operational issues to be clarified. Teece sees the business model during the industrial era as one where a firm primarily packaged 'its technology and intellectual property into a product which it sold, either as a discreet item or as a bundled package' (2010, 174). This view can be found in an enterprise’s strategic decision making architecture, although there are clear differences between this and strategy *per se*. Mintzberg differentiates strategic planning, a data-led function, from strategic thinking, which requires a freer form of cognition and which can be shackled by over reliance on current knowledge based on established operations (1994, 107). Strategic decision making is thus a combination of the two but should not be hamstrung by focusing only on data generated with the processes, operations and products currently in place.

As GE passed through a number of strategic decision making structures we see stages at which business units were entrusted with both planning and operations but constrained by the need to adhere to corporate requirements. The experience of the Computer Department within GE suggests that attention needed to be paid to the operational consequences of strategic decision making. The problem for GE was the management of a number of products – from locomotives to nuclear power – that employed different technologies, but were all rapidly developing at the same time. This approach to general management fell short if there was insufficient knowledge of operating and engineering activity. The difficulty for GE was to manage a set of different technologies each with varying business models. Concentrically diverse businesses were hoping to capture economies of scale and scope but face the difficulty of ensuring that each component activity is appropriate for the product and processes within the organisation and can be supported by that organisation – a major challenge where rapid technological change is taking place.

Ocasio and Joseph (2006, 2008) and Joseph and Ocasio (2012) have provided an analysis of GE's governance channels and strategic planning from 1940 to 2006. They 'define strategy as a framework, either implicit or explicit, that guides an organisation's choices of action'. Grant's (2003) view, based on researching multi business oil businesses, is that planning at business unit level creates a formative business strategy but that this is often decoupled from formal strategy making structures. This is supported in part by our research into GE’s entry into the computer sector. However, during other periods, more tightly structured processes took place which, while based on seemingly *ad hoc* working groups, actually represented a return to central oversight and decision making, in a similar manner to the processes studied by Hodgkinson et al (2006). Joseph and Ocasio (2012 p642 - 643) identified four periods of organisational architecture at GE:

(1) decentralisation (1951–63);

(2) corporate planning (1963–71);

(3) strategic planning (1971–86); and

(4) operating system (1986–2001).

Our study begins at the tail of the decentralisation period 1951-63 but primarily takes place in the corporate planning period of 1963-1971. This latter period is punctuated in 1967 where GE restructures and we begin to see the migration to the strategic planning period which would really be formalised from 1971. Decentralisation under GE President Ralph J. Cordiner made ‘Departments’ the basic building blocks of GE (see Fig 1). While reporting to Divisions, the Departments controlled design, manufacture and sales. Control of these elements was decentralised because of the largescale of GE, but primarily because of its burgeoning 'diversity' of high technology developments (Harris, 1955). Cordiner maintained an Office of the President and an Executive Advisory Committee (Ocasio and Joseph 2006, p254) which would play a key role in long range planning. Critically, in Cordiner’s era, both line and staff management was represented in these planning units, having a direct effect on the product line and production choices made by, in our case, the Computer Department working in a coordinated structure. Cordiner’s view on what decentralisation meant was articulated in a volume published in the McKinsey Foundation Lectures published in 1956, as ‘New Frontiers for Professional Managers’. Decentralisation was an attempt to introduce a “community of purpose” (1956, p49), leading to “authority proximity to decision making” and to bring applicable knowledge “and the most timely understanding actually into play on the greatest number of decisions” (Cordiner 1956, p50). What is relevant for this paper is Cordiner’s view that management “have the capacity to make sound decisions”. The argument of this paper is that what constitutes a sound decision depends on the location of the decision within the organisation – and the associated logics.

*Figure 1: GE Pre-1968 organisational chart
Source: CBI:13, US vs IBM, dx485 General Electric: General Plan of Organization, 1963
Note: the number of departments is indistinct in the copy investigated.*  *The computer operation line of command in bold and underlined*



The Computer Department had a vision of what the market would be and had a clear idea of how to realise this. The internal product logic represented the view from the business unit, whereas the enterprise logic was the corporate level understanding of what constituted GE’s approached to business. This is different from the business model: the value chain and network, revenue model and value proposition are more general and reflect the enterprise strategy. The product logic is clearly a constituent of the business model but is a more micro understanding of the design and manufacturing processes associated with delivering the product to the market.

During the Corporate Planning period under CEO Fred Borch, GE increased the number of groups and divisions to control the departments to enable the business units to focus on defined markets. GE established a Chief Executive’s Office, a Corporate Policy Board, a Corporate Executive Staff and a Growth Council. Operating unit management played no role in these governance structures, and this split between operating knowledge and strategy was to shape events later, as we will see. Under this regime, divisions would present their plans in the form of annual presentations, and one such plan, the 1965 presentation of the Computer Department to the Executive Office, forms part of the archival material used in this paper.

Strategic Planning began under Borch and was further developed under Reginald H. Jones 1971 – 1981. Even before this period, GE, having taken advice from the Boston Consulting Group and from the McKinsey consultancy, introduced Strategic Business Units (SBU - Ocasio and Joseph, 2008 p257). These controlled 10 new operating groups which became the driving force of decision making, with product focused division below this level. It was into this structure that the operating departments were consolidated[[3]](#endnote-3). While the aim of this structure was to further focus decision making to units which best reflected the level at which product competition took place (Ocasio and Joseph, 2006 p11), it is notable that the computer operation, which would become the Information Systems Group, reported to the same senior manager as the unrelated Aircraft Engines Group (GE Annual Report 1967 – see Figure 2). Clearly the two had little technological commonality, but were both considered strategic opportunities. However, the knowledge base from which they both worked was very different and indicative of the difficulties faced when separating strategy and operations.

*Figure 2: GE organisational chart 1968 onward
Source: Derived from CBI:13, US vs IBM, px3222. IBM. 1968. 'A company study of GE
Note: The computer operation line of command in bold and underlined*



This organisational chart (figure 2) showed the enormous ambitions and capabilities of GE. In addition to developing products to compete with IBM, two of GE’s other major new ventures was a major drive into the civil and military jet engines business, and developing a large business in nuclear power stations, both projects a considerable drain on capital resources (Gandy, 2013 p108 and 114-117). By 1970, they had 54 nuclear power stations on the order book[[4]](#endnote-4), and critical to GE were 11 “turnkey” projects started in the mid-1960s where payment was fully on completion and the customer could turn the start key. For these projects GE carried the whole cost of not just the electrical and nuclear engineering, but the civil engineering as well. These 11 projects (as well as the many other non-turnkey projects) were late and consuming a lot of capital[[5]](#endnote-5). In a 1968 analysis of their competitor, IBM noted the significant drain on GE’s resource that this success in nuclear power was causing and that GE had invested an extra $250m into this business to support it through this hump in capital demand[[6]](#endnote-6). Gerald L. Phillippe, chairman of GE who died in October 1968, said of the turnkey projects and the civil engineering required “What we didn’t know about the construction business could fill a book”[[7]](#endnote-7).

Likewise, all had not been smooth with the jet engine development, with GE losing major contracts to established rivals Pratt and Witney and Rolls Royce[[8]](#endnote-8). However, IBM noted the huge potential for jet business given the prospect of growth through new aircraft such as the Macdonald Douglas DC10 and the Lockheed L1101 aircraft and GE’s winning of the contract to make the engines for the giant Lockheed C-5 Galaxy military transport. Together its aerospace engines and defence electronics operations together made GE the third largest defence contractor in the USA in 1968, trailing only General Dynamics and Lockheed[[9]](#endnote-9).

The turnover and profit figures presented in Table 1 are aggregated, as was often the case in reporting at the time, into very high level groups, reflecting the pre 1967/8 structure. What these figures fail to show is the sheer scale and complexity of GE supporting as it did 250,000 products from simple components to highly complex nuclear power stations.

*Table 1: General Electric revenues and profit 1965-1967*

*Source: GE annual reports and CBI:13, US vs IBM, px3222. IBM. 1968. 'A company study of GE'*

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1967 | 1966 | 1965 |
| $m | % of revenue | $m | % of revenue | $m | % of revenue |
| Group Revenue |  |  |  |  |  |  |
| Consumer Products | 1935 | 25 | 1938 | 27 | 1740 | 28 |
| Industrial Components | 2400 | 31 | 2368 | 33 | 1989 | 32 |
| Heavy Capital Equipment | 1858 | 24 | 1579 | 22 | 1429 | 23 |
| Aerospace and Defense | 1548 | 20 | 1292 | 18 | 1056 | 17 |
| **Total Revenue** | **7741** | **100** | **7177** | **100** | **6214** | **100** |
|  |
| Direct Costs | -5779 | -75 | -5311 | -74 | -4449 | -72 |
| Gross Profit | 1962 | 25 | 1866 | 26 | 1765 | 28 |
|  |  |  |  |  |  |  |
| Selling and Admin costs | -1321 | -17 | -1234 | -17 | -1119 | -18 |
| Other exp. and inc. | 28 |  | 33 |  | 45 |  |
| **Net Profit Before Tax** | **669** | **9\*** | **665** | **9** | **691** | **11** |
| \*rounded up |  |  |  |  |  |  |

### Exploring the Enterprise Structure and its link to the performance of the computer product line

Joseph and Ocasio (2012 p642 - 643) clearly outlined in generational terms GE structural reorganisations. Chandler (1962) had noted the increasing levels of autonomy within GE, and speculated that such a disaggregation of the business would lead to “problems of coordination and control, as well as increasing administrative costs” (1962). However, when analysing the history of a single product line it becomes clear that there was no total abdication of headquarters involvement in the operating units. Despite these structural changes to GE, designed to provide high levels of autonomy to product units, there was still a desire to provide support to product units through coordination of vertical and horizontal activity. These enterprise-level efforts to deliver a successful structure were not, however, simply about planning and high level strategy – we find they directly impacted the product being manufactured and sold. These enterprise-level efforts to maintain coordination and efficiency directly undermined the competitiveness of a major new product line through creating an ineffective product strategy. We explore the conflicts between GE’s enterprise logic and the product logic of the computer industry through analysing the development of the mainframe computer products of GE during the mid-1960s. We define these two logics as:

* Enterprise Logic: the structure and strategy of the enterprise aimed at developing corporate-wide competitive advantage. In GE’s case this was high levels of individual business autonomy, but coupled to a desire to maintain some vertical integration advantages, the avoidance of horizontal duplication and an acquisition strategy aimed at increasing the scale and the scope of business units
* Product Logic: the development, production, distribution and support of products. Whether this matched or exceeded the requirements of the market in comparison to other suppliers depends on the ability of an entity to marshal capabilities and resources in an effective way. In the case of the early and mid-1960s mainframe computer industry, this meant the development of efficient, reliable, maintainable and software rich integrated computer families, which enabled easy upgrades and software and data transportability.

To examine how corporate structures and decisions impacted the product offering, we focus on the period in which the GE computer department moves from its early venturing stage, which was primarily based on building a specific family of machines built to specific contractual requirements outlined in a contract, to offering a standardised product set which was being built to sell into the general commercial market. Our period of study is focused on 1962 to 1967/8. First we focus on efforts by the GE computer department to move from its early experimentation in the sector to offering a formalised structured product line. Secondly , we consider how the computer unit tried to reform its product offering to meet changing product expectations. This study therefore straddles the decentralisation (1951–63) and corporate planning (1963–71) periods as identified by Joseph and Ocasio (2012 p642 - 643). It is notable that in 1967/8 we begin to see GE beginning to move toward the strategic planning period which Joseph and Ocasio characterise as starting in 1971. It is in 1967/8 that GE introduced Strategic Business Units to govern its operating divisions and groups and in 1969/70 begin to develop strategic decision making groups such as the Venture Task Force (Gandy 2013).

Our contribution is to look below the strategic level and to focus on how the specific product strategy of an operating unit is undermined by even the light-touch imposition of an enterprise logic, where that logic is not aligned to the developing nature of the product market. There is a disjuncture between the strategic enterprise logic envisioned by GE’s senior staff and the product logic that would be tested in the market for commercial computer systems to which we now turn.

### Formation of the Product Strategy

The early GE Computer Department developed organically within the Industrial Electronics Division and was a bottom-up initiative from the development team involved. Firstly, they were developing designs for process control computers and secondly, they had won a substantial contract from the Bank of America for a large number of Electronic Recording Machine Accounting (ERMA) computers (see for example Oldfield 1996).

Edwards and Gandy (2014) found that although decentralisation was a key part of Cordiner’s strategy for GE during his period as President, there were still aspirations to maintain operating advantages from the firm’s wide spread across electronic and electrical markets, and this required some sense of organisational coordination. Therefore, there were already tensions regarding the trade-off between enterprise and product level logic. During 1957, a major meeting, the Product Scope Review (PSR), was held which gave the nascent Computer Department an opportunity to present its case for investment in the computer sector. The new business unit was authorised to develop and sell computer systems, industrial control computers and computing sub-assemblies. Yet economies of scale and scope were still hoped for between departments. Where practical GE required the Computer Department to source components internally and to coordinate with other units in developing computer systems for their own markets. The PSR relied on a collegiate shared responsibility for developing new venture opportunities, not only between line-management in the Computer Department and corporate staff (Greenwood 1981 and Oldfield 1996), but which also drew on line management from overlapping business units, primarily (but not exclusively) senior management from the Heavy Military, Light Military and Industrial Control Departments[[10]](#endnote-10). While this process encouraged cooperation and led to synergies being identified between developments and product lines, it also allowed the Computer Department to drive the new venture process from the bottom up. This used the expertise of those closest to the design and production processes required to deliver a product to market.

This process shows a success for the decentralisation agenda as it demonstrated the ability of an “Operating” Department to build from below. Indeed, notably, it was possible for these lower ranks of GE to overturn an earlier edict from Cordiner himself that GE should avoid competition with IBM in the commercial computer business (Edwards and Gandy 2014). Despite some senior management concern, the Computer Department was free to follow up earlier success in commercial-orientated computing (including ERMA ) and was not restricted, as it had feared, to process control computing, thus overturning the intentions of senior management.

Nevertheless, while GE wished to decentralise operating department decision making, it also wished to retain benefits from the scale and scope of GE’s product markets at an enterprise level. Therefore, it was not surprising that a key part of the PSR process was to manage this and avoid duplication of effort while exploiting synergies (Edwards and Gandy (2014). The expectation, if not the requirement, to source components internally was a *quid pro quo* and, in return, the Computer Department was able to manage the development of most computing developments within GE. Thus, the Cordiner regime had, albeit reluctantly (Snively (1988), Oldfield (1996)), enabled a ‘bottom-up’ form of operating strategy that might have embraced a product logic. However, even this loose coordination to exploit synergies would have a negative impact on the computer product line, and resulted in a multitude of product architectures a situation which would became worse. Further, the enterprise logic effectively forced GE’s new Computer Department to be vertically linked to weak internal component supply chains.

The product logic of the Computer Department in 1957 was devoted to the two main contracts, ERMA and the NCR 304. Competing in the accounting machines market NCR was under pressure to use digital technology to compete with IBM and Burroughs. To do this it had bought the start-up Computer Research Corporation, (CRC)[[11]](#endnote-11). However, the CRC development was based on first generation computing technologies, primarily used vacuum tubes, and this was being superseded by the more efficient and lower cost transistors. NCR turned to GE to build a new computer, the NCR 304 which was to be “solid state” and which GE could market internally as the GE 304[[12]](#endnote-12).

At GE’s disposal for these computer contracts were 220 engineers and, ironically, an IBM 704 for design work[[13]](#endnote-13). With work provided by ERMA and the NCR 304, coupled to knowledge relating to industrial computing, the Computer Department had the resources to launch the first of its mainstream general purpose computers, the GE 225. This was an early entrant into the second generation (fully transistorised; a technology more reliable, smaller, faster and requiring less power than the previous vacuum tube building blocks of computers) computer market. The GE Computer Department estimated that this successful early second generation computer gave them a 2% market share[[14]](#endnote-14). The trade journal Datamation (1960:11-12) saw this system, as a significant milestone in the development of GE’s computer ambitions. Initially, the GE225 was sold for scientific functions, which was valuable to GE internally, and an example of the Computer Department providing inputs to other Departments, another side to the enterprise logic at the corporate level[[15]](#endnote-15). It was estimated by Datamation (1960) that GE was paying $12m per annum in rental bills to IBM for its leased computers most of which were dedicated to engineering calculations in areas such as flow dynamics and nuclear engineering. So there were internal cost savings which at least partially underpinned expansion into computing.

##### Clear vision: the WXYZ Product Logic

To embed GE further in the market, they needed a plan to offer a range of small, medium and large systems to address the needs of different customers. Such a range would not only allow GE to offer appropriate systems for different user requirements, but it would also help to support very large customers who internally had various forms of computing needs, but who required those systems to be compatible. In 1962, GE Computer Department examined a series of specifications for a proposed range of machines dubbed the WXYZ range that embedded a number of attributes that were identified at product level as desirable for consumers[[16]](#endnote-16). Firstly, compatibility between small and large systems gave customers flexibility to run programmes and carry out tasks across functions and departments/divisions while retaining the ability to relatively easily share data and run the same software at all levels. Secondly, compatibility gave customers the ability to upgrade to larger systems as the demand for processing power increased. Thirdly, they also recognised that the previous industry norm of dividing computer platforms between business systems, with an emphasis on input and output of data with relatively simple processes performed on that data, and scientific computers, where the emphasis was traditionally more on the computing power and less on the data input-output capability, was disappearing, except in what became the more esoteric supercomputing arena.

GE announced a range of systems which partially reflected the WXYZ concept. The range was initially announced as the 425, 435, 455 and 465[[17]](#endnote-17), and in advertising the range was nicknamed the 'compatibles'[[18]](#endnote-18). The 425 and 435 used the same central processor unit with two different memory schemes giving the 435 greater memory access and other capabilities[[19]](#endnote-19). These were the X elements of the WXYZ programme. The 455 and 465 used a more powerful but compatible central processor and were effectively the Y element of the scheme.

IBM’s initial analysis of this announcement indicates that they thought this was a legitimate attempt at competing in the computer hardware market. They believed that GE was on the brink of establishing a position of strength and becoming a major threat because of their apparent financial resources and the potential for this 400 Series to compete with IBM's forthcoming 360 family[[20]](#endnote-20). Significantly IBM itself had undertaken its own WXYZ-like planning under the code name SPREAD (Pugh 1984), thereby confirming GE’s vision. However, the GE Computer Department would fail to deliver on the vision and the weaknesses of their enterprise logic soon became clear: The WXYZ plan would not be fulfilled

##### Impact of horizontal integration

However, the 400 range, rather than being expanded to cover small-scale and large-scale computing as outlined in the WXYZ plan, would instead be limited to a mid-tier family of commercial data processors covering only the “X” element of the product strategy and would have little relationship to smaller and larger systems developed by GE. Thus the advertised product attribute and the branding of the range as the “compatibles” had already been ignored. A tactical reality was that the 200 series, especially the middle of the range GE225, was successful, and there was understandable reluctance to jeopardise profits that were ‘in the hand’. The 200 range of computers were based upon transistorised second generation technology, as planned for the WXYZ family, and could be seen as relatively modern on this count, although its architecture was different from the 400 range. It was decided that this sunk cost should see the system survive and it effectively replaced the “W” part of the compatible WXYZ range at an early stage[[21]](#endnote-21).

However, it was not only departmental-level realities which ended the WXYZ vision. GE’s enterprise-level logic required that there was coordination across departments, and it was this which would have terminal consequences for the WXYZ product logic. While the 425 and 435 mid-range systems came to market (and would later be joined by the smaller 415), the larger members of the family, the Y element of the scheme, would be dropped. Development of the larger machines in GE’s 400 series had reached prototype stage when their development was pulled to devote resources to a development acquired from outside of the Computer Department, but then incorporated into it[[22]](#endnote-22).

Elsewhere in GE, the Heavy Military Electronics Department had been developing the advanced M-236 computer for two overlapping purposes[[23]](#endnote-23). Firstly, it was to be used for the control of large strategic radar systems and had built-in facilities for the real-time control of such a system. Secondly, it could be used by the Heavy Military Department and other departments of GE for its own scientific processing needs.

Following the Product Scope Review process, it had been determined that the Computer Department would act as midwife in the completion of this large and highly capable system and would bring it to market. The whole project was transferred from the Syracuse-based Heavy Military Electronics Department to the Computer Department in Phoenix and became the foundation of the GE 600 series. The program was headed by J.W. Weil who gave extensive evidence in the US vs IBM case about the problems GE faced, especially as they related to the 600 series.

The 600 series was developed to closely mimic the large scale computers made by IBM for the scientific and engineering markets – the IBM 7090 and its update the 7094[[24]](#endnote-24). The plan was to replace IBM systems within GE with the 600 and of course the system could be offered to external 7090 users. Critically, it was hoped the 600 series would offer users a better price: performance ratio than current IBM machines. The mainstream member of the 600 series, the GE635, was expected to offer 4-5 times the performance of the IBM 7090, at only 80% of the cost[[25]](#endnote-25). Given this profile, the investment already made by the Heavy Electronics Department, and the decision to make the Computer Department the hub of computer development, the 600 replaced the “Y” element of the WXYZ plan and became the focus of GE’s computer operations. The 600 was an example of backward compatibility with superseded IBM architectures, a strategy which Honeywell would also adopt by producing the H200 family which gave upgrade paths for users of IBM’s 1401 business machines when they were superseded by the more modern 360 family (Gandy 2014).

By 1965, the WXYZ plan had changed out of all recognition with the 200 series filling the “W” slot, the 400 series reduced to just being an “X” level machines and the 600 becoming the “Y” and above. This was in contrast to IBM which announced its System/360 family of computers in April 1964[[26]](#endnote-26). Unlike the GE product, the IBM System/360 was a nearly totally compatible (the very smallest member was only partially compatible) range of small, medium and large scale computers (see Pugh 1984, Pugh et al 1991, Malik 1975, Fisher *et al* 1983). They were able to share peripherals, run the same programmes and process the same data. They also had access to large libraries of programmes and sub routines ready for users to run on small, large or big systems.

*Table 2: Post WXYX product range:*

*Source: Authors*

|  |  |  |  |
| --- | --- | --- | --- |
| **Initial Plan:** | **WXYZ Compatible Machines Announced** | **Machines eventually delivered or retained instead** | **Architecture – word size** |
| W | none | 200 Series retained115 Series launched mid 1960s | 20-bit8-bit |
| X | 425435 | 415425435 and others | 24-bit |
| Y | 445455 | 600 series | 36-bit  |
| Z | none | None  |  |

Despite the breakdown in the WXYZ plan, ‘initial acceptance’ of the 600 series was good[[27]](#endnote-27). Indeed, in the April 1965 Computer Department annual presentation to the GE executive office, future projections for sales by 1969 were now an estimated $378 m because of the speed with which the 400 and 600 had come to market. This was an increase over the previous 1964 ‘base plan’ which, only a few months earlier, projected or 1969 annual sales a figure of $285m[[28]](#endnote-28).

However, two issues undermined the programme. Firstly the IBM System 360 had been designed to allow rapid change in the underlying hardware code through the use of “Microcode” thereby ensuring flexibility. IBM quickly announced emulators of older systems, removing much of the 600’s advantage of offering backward compatibility[[29]](#endnote-29). In contrast, the instruction set (the basic instructions of the machine) of the 600 series was hardwired and could not be updated, greatly reducing flexibility.

Secondly, and even more critically, the 600 had real engineering problems. The 600 had been initially designed outside of the commercial computing environment and had not been engineered to allow low maintenance in the field. Further, the real world performance of the 600 in the field was a long way short of expectations. These were issues which the market knew about as it was reported in the trade journals[[30]](#endnote-30). Some of the problems can also be laid at GE’s lack of investment in its field force of sales people, engineers and customer application developers. In 1965, the Computer Department noted that from March 1964 to March 1965 it had increased its field force from 294 to 634 people, roughly a 116% increase[[31]](#endnote-31). However, the GE team also noted that IBM had more than 14 times this number, at least 9000 people, in the field force.

In 1966, the reliability and performance shortcomings led to the 600 being temporarily suspended from the market[[32]](#endnote-32), leading to a number of redundancies at the Phoenix factories. This undermined morale in the organisation as the 600 series had become the flagship of GE's range and its failure was a blow to the reputation of the GE computer business[[33]](#endnote-33).

That is not to say GE did not have areas of success in the computer business. The allure of the 600 was in part based on its potential to change the way users interacted with computers. In the 1960s, batch processing was the most common form of performing large-scale computing tasks; it was a form of processing which relied on sequential running of programmes and inputting of data. GE was at the forefront of in developing timesharing computing which allowed multiple programmes to be run at the same time and which could support multiple users interacting with the system, greatly aiding those who needed to communicate with computer devices in a more interactive way. While initially advantages for engineers, this form of computing would be vital to an ever growing list of commercial applications.

GE’s success in timesharing was based on its hardware being used from 1962 in the development of Dartmouth College Time-Sharing System (DTSS) and its associated BASIC programming language (Campbell-Kelly *et al* 2014 p205). GE would develop a very successful bureau service, allowing customers to access computer power as and when they needed it (Oldfield 1996). GE hoped further to expand its lead in timesharing based on the large scale 600 using the revolutionary MULTICS operating system. MULTICS (Multiplexed Information and Computing Service) was part of Project MAC, a research programme run by the Massachusetts Institute of Technology, Bell Labs and the project identified the GE 635 as a system very close to what they envisaged and chose GE as its partner over IBM, much to the latter’s annoyance especially as IBM viewed these developments as a significant threat at one point[[34]](#endnote-34) (Norberg and O’Neill, 1996 p101). GE developed a special version of the GE 600 (the GE 645) as a very large scale timesharing system running MULTICS (Campbell-Kelly et al p 209).

However, MULTICS was incredibly complex allowing hundreds of simultaneous users and applications to be run. This complexity, coupled to the engineering problems of the 600 series led to delays, to such a degree that Bell engineers went their own way and developed the UNIX operating systems (Ceruzzi, p129). Indeed, the very public problems of MULTICS simply added to the 600 series reputation. The 645 would never be marketed by GE[[35]](#endnote-35) and Multics-based computers running MULTICS would only go on general sale after the GE computer operation had been absorbed by Honeywell in 1970.

In 1968 GE commissioned engineering consultants Auerbach Corporation to review the 600 program. It found that, while the 600 program was running again, the system had developed a very poor reputation in the market for unreliability and faced real marketing difficulties[[36]](#endnote-36).

Thus, while GE’s Computer Department did have a vision for its computer product line, horizontal rationalisation and departmental expediency had cannibalised the WXYZ plan; enterprise logic had damaged the product logic.

##### Impact of vertical integration

However, it was not just in terms of the structure of the product offering where GE’s initial desire to see loose coupled decentralisation between business units and a desire to exploit synergies would create problems. GE had its own electronics components divisions which struggled to satisfy the needs of the Computer Department. In Oklahoma City, GE had a Memory Equipment Department that was able to supply magnetic core memory (a form of random access memory) for the lower performance GE200 and GE400 series. However, it was unable to supply the faster memory required by the GE600 range. These memory subunits had to be sourced from component rivals Fabritek, Lockheed, and Ampex[[37]](#endnote-37).

The same problems existed in mass storage systems. IBM had enormous success with electro-mechanical disc drive memory, and this was exemplified by the IBM 2311 drive launched with the IBM 360 and the 1965 IBM 2314 which further enhanced IBM’s leadership. GE was not able to build equivalents of the 2311 until 1968[[38]](#endnote-38). In the meantime, GE sourced drives from Burroughs and, to a lesser degree, CDC[[39]](#endnote-39). Disastrously for GE, when it eventual began producing 2311 equivalents, IBM would again move disc technology forward and in 1970 it announced a huge step forward with the IBM 3330 “Merlin” drives. GE was always behind on this key technology.

GE also lagged behind in fundamental electronic components. IBM itself noted that GE’s electronic component operations had lost market share in the semiconductor industry, and therefore believed GE’s computer business was forced to use components which were behind other suppliers[[40]](#endnote-40).

GE was a leading supplier of electrical and electronic components both for commercial markets and internal use. Malerba (1985 p4-5), noted that GE was a leading developer of semiconductor diode technologies in the 1930s and even as late as the period 1965-68, GE had won 13% of all US semiconductor patents. However, sales performance lagged its patent submissions. In 1966 GE’s market share was 8%, lagging Bell-Western Electric at 9%, Motorola at 12%, Fairchild at 13% and Texas Instruments at 17% (Malerba, 1984, p132).

Lojek (2007, p177) argues that in fact GE had been slow to adopt the transistor, the vital logic component of second generation computing, and that its major contribution had been in the epoxy packaging of the new components. Nevertheless, GE had developed the junction transistor, however, this was not capable of the speeds useful in computers and reflected the needs of other divisions of GE, such as consumer electronics and power controls. GE then failed to establish an integrated circuit business which would be one of the defining characteristics of third generation computing – the generation of computing which the WXYZ plan would have competed. Malerba (1985) notes GE exited the “mass production of digital integrated circuits and continued to produce discrete and power semiconductors, partly for internal consumption” (p131).

Malerba’s analysis draws comparison between GE’s failure in the integrated circuit business and its computer operations. He argues that the vertically integrated firms created demand for established component lines and little incentive for some new technologies. Simultaneously GE was also spread horizontally across markets meaning that resources were spread thinly across many different products. These were circumstances facing those in GE developing computers and developing advanced digital components.

### International expansion and further product confusion

Under Borch, there was a move toward further operational decentralisation, with a more formal split between line-management and strategy. Operational management was removed from the strategy making process associated with new strategic ventures and transferred to the corporate level. Coordination still took place through an annual business review process and through reporting to the Chief Executive Office. However, the line management were not part of the forward-looking strategy groups such as the “Growth Council”, or in the other forums tasked with creating and assessing new growth opportunities (Joseph and Ocasio 2012 p643). In this period, we see the Computer Department attempting to refine its product line and failing. The new structure meant that autonomous decisions to change the business model from a product perspective were difficult to achieve. This problem was reinforced with the acquisition of the computer operations from Olivetti in Italy and the purchase of a controlling stake (66%[[41]](#endnote-41)) in Machines Bull in France. The decision to undertake these acquisition was made by the Growth Council, not by the business unit (Joseph and Ocasio 2012 p648 and 653).

When Borch became CEO in 1963, he appointed John McKitterick, previously a market research manager working with Borch, as Manager of Corporate Planning (Ocasio and Joseph 2008 p256). McKitterick then established the Growth Council to drive growth at a strategic level in nine target markets, one of which was computing. Joseph and Ocasio note that this was an example of decoupling of line management and the decision to follow strategic growth opportunities. This concept of a council of senior management looking to develop a growth strategy above the product groups was something GE would return to in 2003 when a Commercial Council was formed by then CEO Immelt and consisting of the “best sales and marketing people in the company” (Stewart 2006).

GE and Bull already had an established link in computing. In the early days of computing there was a strong reliance on established business machines technologies for input and output, punched cards for input and electro-mechanical printers for output. GE had no history in these technologies and had established a link with Bull to acquire business machine peripherals (Mounier-Kuhn, 2014, p47). As early as 1962 the head of GE’s Industrial Electronics Group, Harold Strickland, had visited Bull both to discuss peripherals and even suggested GE potentially taking a 20% stake in GE (ibid).

However, GE held overseas operations in an International Office/Group. It initially turned to GE’s established French licensee and partner, Thomson-Houston, to sell its computers. It took a similar approach in Japan where GE’s Toshiba, licenced GE technology and in 1964 announced the TOSBAC 5400 based on the GE 400 technology and then the TOSBAC 5600, based on the GE 600 (National Research Council, 1982). However, Thomson-Houston was not strong in this area and neither had the skills or the relationships to sell and service computers in the business market (Mounier-Kuhn, 2014). Meanwhile, Bull had started to experience financial problems as it tried to carry the large expense of developing its own mainframe computers. In December 1963 GE took an interest in Bull’s problems and the GE Treasurer visited France to begin negotiations to take control of the French computer company (Mounier-Kuhn, 2014). It is notable that it was not until the 1967/68 restructuring of GE that the International Division was closed and international relationships, partnerships, manufacturing and sales would pass to the operating units of GE[[42]](#endnote-42).

Nevertheless, On the face of it, this internationalisation of the computer business seemed to make sense. By 1968, IBM had identified GE as its second most important competitor in non-US domestic markets. IBM estimated GE’s Bull and Olivetti had 45.3% of the French market and 62.8% of the Italian market, though these were small markets in comparison to the US, however, IBM estimated GE had only 6.2% of the US market, but which still made it the largest part of the GE computer business[[43]](#endnote-43). However, IBM might well have under estimated the problems GE had in the US. GE itself believed its market share peak in the US was 1965 at just 4.2% and declined to just 2.5% in 1966 and 2.9% in 1967 as problems with the GE 600 series restricted deliveries[[44]](#endnote-44).

Whatever merit there was in purchasing these businesses, a key problem was that they reinforced prior product strategy failures in that they further complicated product level logic (where interoperability was becoming vital) and rendered problematic the departmental planning processes required to deliver a coherent product line.

The strategic decision by the Growth Council to take control of Bull in France and acquire Olivetti’s computer operations in Italy led to a widening of the product range and a move further away from the simplicity of the integrated WXYZ plan. At the same time, enterprise level capital-rationing meant that the computer business was starved of resources at a time when the computer operation was trying to create a product offering able to compete in the third generation of computing technology. The overall impact on the product line was simply to reinforce the problems. IBM’s summary of the GE product set by 1968 opined that it was a quite remarkable range of systems made by a business now many times smaller than IBM and yet having to support development of multiple architectures. IBM noted the following system families in the GE range: 50, 115, 130, 200, 400, and 600 series computers plus from France the legacy Bull Gamma 10 and 55[[45]](#endnote-45); indeed, the list could have been much longer if the smaller Datanet systems were included.

In addition, there were real operating problems with the overseas organisations, especially at Bull. It produced a large range of computer and punched card equipment but the costs of maintaining these had escalated, drawing on already limited resources. Bull’s mainstream product was therefore underfunded and the replacements seen as outmoded. Bull employed 11,500 compared to GE's own Computer Department which employed 9,500 and yet the US unit produced more than twice the total output of Bull, while labour laws in France made reducing staffing difficult[[46]](#endnote-46). By 1968, IBM estimated that GE had invested $100m in its overseas affiliates[[47]](#endnote-47), but due to its problematic management and rigidity in its local affiliates it had failed to realise profits from these activities. The result of GE’s European acquisition strategy further stretched GE’s resources across yet more products, crippling further the ability of GE to live up to its mid-1960s marketing strap line for its computers “The Compatibles”. Each part of GE was engaged in its own development and production work, a result of decentralisation, with little coordination and a failure to achieve the economies of scale that were hoped for in the late 50’s Product Scope Review. Notably, by 1970, GE itself characterised its own product set as “major product lines, obsolete, complete but incompatible, not vertically integrated, weak in peripherals, mass storage and terminals”[[48]](#endnote-48).

#### Abandoned attempts at product-level integration

With the purchase of the European firms and following the announcement of the IBM 360 family, GE once again turned its attention to producing an integrated range of computers. During 1964-66 Lou Raeder, then general manager of the computer operation, supported a programme to develop a single, worldwide, range of systems[[49]](#endnote-49). It was christened the 100 Line and aimed to build on the perceived strengths of GE's disparate computer teams across the globe. A division of labour emerged, with Italy focusing on the smaller members of the 100 Line, France concentrating on medium scale systems and the US focusing on larger scale systems and manufacturing, as well as owning design and architecture.[[50]](#endnote-50) The aim of the 100 project, as laid out in the 1965 annual presentation by the Computer Department to the GE Executive Office, was to create an integrated product range which could move GE’s market share from 3% to 10%[[51]](#endnote-51). Once more, this strategy did not last very long. When, in 1966, Hershner Cross became the general manager of the computer operation[[52]](#endnote-52), his first act was to suspend production of the problematic 600 series and to put a hold on the 100 strategy. This was despite strong support for the 100 programme from the business units who wanted an integrated architecture*[[53]](#endnote-53)*. Weil, head of the 600 range, believed it was simply a matter of resources[[54]](#endnote-54). While the 600 had been temporarily suspended it and the 400 series were still relatively new products. GE had committed a lot of resources to these products and it was difficult to justify changing to a completely new computing architecture without seeing a return from the 600 and 400 investment programmes.

The only end product from the 100 concept came from the Italian business which produced the very successful GE115. Weil noted the Italian management was strong and willing to take personal responsibility. However, on a wider level, instead of the full development of the 100 range, and with the 600 suspended from the market, it was decided that the push in Europe would be with the 400[[55]](#endnote-55).

The objective of a unified product range was becoming a chimera. The 100 and the earlier WXYZ concept were largely stillborn. Following the demise of the 100, other plans included the E.R.W study and Project Charley. However, these were little more than paper plans with little development work undertaken (Gandy 2013). As other firms launched third generation families of computer systems based upon integrated circuit componentry and with increasingly high performance input-output capability, GE’s limited success in timeshare computing based on second generation architectures was not enough to sustain their drive in the sector. Once more, we have to turn toward evidence from IBM, who estimated that in 1967-8 GE sales in the USA were actually declining, while the overall market was booming, international sales were still growing at 11%, albeit well below the sector average which was 25%[[56]](#endnote-56). IBM characterised GE’s line as being a “hodge podge of three different fixed word orientated architectures”[[57]](#endnote-57). They described morale in the GE information Systems Group as low and their domestic performance in the USA as “comparatively a horror”.

In addition, ongoing operations at Bull had led to losses of $50m in just 18 months. Other estimates suggested that, by 1967, GE’s computer operations had generated a total loss of $400m, including losses at Bull[[58]](#endnote-58) plus an estimated $100m in the acquisition of Bull and Olivetti computer operations in Europe[[59]](#endnote-59). Further, there was little in the way of saleable product bar the GE 115, the smaller Datanet systems and the timesharing systems, but even these were not likely to be sustained as they were based mainly were on the aging 200 series technology while development of the Multics version of the 600 languished.

In the period following, the failure of this product line to deliver competitiveness would eventually lead to a strategic plan from the operational unit to develop the Advanced Product Line, (APL) and to a group-level veto following an internal strategic review under the guise of the Venture Task Force[[60]](#endnote-60). This was caused in part by the failure of GE to develop a successful integrated computer family to compete with its key rivals, primarily the IBM 360 family. By 1968, GE had a complex range of computing systems but it had real strengths which few other firms could boast. It had a global network of manufacturing, sales and distribution, capabilities which only IBM surpassed and had leadership in timesharing systems. However, these areas of success could not be translated into wider product success: the main bulk of its product line was either old (200 series), of limited commercial success (the 400 series) or proving problematic to bring to market (the 600).

### Conclusion

Our findings that enterprise logic conflicted with product logic is almost wholly in contrast to Chandler (2001) who argued the failure of GE’s computer initiative was managerial capability within the computer unit (102-103). Chandler refers to GE’s own Venture Task Force findings as evidence. However, these Venture Task Force reports make little mention of management capability per se bar their characterisation of the management team as “yeoman service”[[61]](#endnote-61). This was not a failure of the decentralised management, but a failure of the enterprise logic to adapt to the circumstances in a rapidly developing and growing high technology market.

The Venture Task Force papers reveal a process which led ultimately to GE exiting the sector. In contrast to Chandler’s view they almost exclusively deal with whether GE could create computers which fitted the then current product logic without generating major financial risks to the entire corporation. The then Information Systems Group at GE developed an integrated product concept called the Advanced Product Line (APL), based upon the product logic necessary to compete in the market and following the leads of the previous WXYZ, 100 Series, and the other concepts for such an integrated family of computers. The APL plan was rejected by the Venture Task Force because it was estimated to need $0.5 billion. They concluded it was unlikely that this would succeed never mind a suitable return on investment. The conclusion was that it could not and it was recommended the company exited the business with a sale of the computer operation to Honeywell*[[62]](#endnote-62)*.

GE’s decentralised and then corporate planning eras had a direct effect on the product because the decisions made embodied a clear strategic vision of the enterprise that was at odds with the operational product logic, and after all, it is the product which is being bought by customers, not the structure and the organisation of the enterprise. Without a strong effective product line, no entity can hope to survive and prosper.

Initial efforts to retain the benefits of integration, economies of scale and scope within GE, ultimately damaged the product strategy. Firstly, the elegant plan of the Computer Department to develop an integrated product line (WXYZ) were damaged by the local decision to exploit prior investment and maintain the incompatible 200 series as the W element of the plan and then, at the strategic level, to gift the Computer Department the developments made in another unit of the organisation which gave it the 600 series to occupy the Y spot of the range. The internal WXYZ plan led to only a standalone mid-scale range called the 400. Secondly, the Computer Department was expected to purchase internally which meant that core components, memory subsystems and some other peripheral devices were being purchased from non-market-leading sources. Ultimately, GE had poor access to advanced memory and peripheral systems and failed to introduce a third generation (based on integrated circuits) range of systems as the rest of the market moved to these technologies. Finally, the purchase of Bull and Olivetti led to further product-line confusion and lack of resources meant that the 100-series, E.R.W and Project Charley programmes came to little. Further problems, such as getting the 600 to market simply compounded the product line problems.

GE had a value chain for the development and manufacture of computers but had effectively blocked off sources of supply outside their internal network thus tying the supply of components to internal suppliers, with no guarantee that these were appropriate for the end product market. Worse still, the acquisition of Bull and Olivetti represented an extension of the value chain with parallel activities that were not a match for GE’s existing business and indeed reinforced the earlier problems created by horizontal integration of the 600 range of computers into the Computer Department, thus undermining the product logic that the Computer Department had developed. The experience of GE suggests that general management skills are not always enough to understand the business reality faced by those engaged in the delivery of products. The enterprise logic needs to have product logic embedded within it and a senior management team that has the skills to conceptualise designing, making and selling of goods and services.

There was clearly enterprise logic at the corporate level in trying to retain the benefits of integration and trying to add international manufacturing and marketing capability. However, this was at the expense of product logic which, in the market of the 1960s, meant a rapid move to integrated families of mainframe computers using third generation componentry.

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61. CBI:13 US vs IBM, px371A. GE, 2/2/70. Ventures Task Force, Preliminary Report:10 [↑](#endnote-ref-61)
62. CBI:13 US vs IBM, px331A. GE 24/4/170. Venture Task Force Presentation to the Board of Directors. [↑](#endnote-ref-62)