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Strategizing under Uncertainty and Ignorance: The influence of knowledge and technological path-dependence on corporate strategies.

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1. Introduction

What are the limits to strategy? How does the knowledge in the firm influence strategy? Recent years have seen turbulence and unanticipated change, as new technologies, new leading firms and new patterns of demand have rapidly emerged. Companies have been compelled to re-evaluate their strategic positions and enter new markets and exploit these new technologies. Probably as a result of these imperatives, one of the *sacred cows* of innovation studies and the economics of technical change has been challenged by theorists and researchers; the notion of technological path-dependency.

This paper has two purposes, first; to show that there is considerable scope for managerial choice in terms of product market strategies, therefore many strategic paths, but that these are strongly constrained by the underlying technological competences. The paper reaffirms the importance of path-dependency by presenting illustrative case studies of real firm strategies in turbulent and uncertain environments. Secondly, a framework is developed that shows the relationships between the conditions of strategic decision-making, and the knowledge resources available to the firm. The framework distinguishes between ignorance and uncertainty and shows how the firm moves between the two conditions. The paper is a contribution to the current debates over the validity of the Resource-Based and Knowledge-Based Views of the Firm.

The next section outlines the treatment of knowledge and path-dependency in the Resource-Based View of the Firm. Section Three then discusses the tradition of technological path-dependence in the innovation studies and economics of technical change fields. The recent challenges to the concept are covered in Section Four, which considers path *in*dependence and the notion of *vision*. Sections Five, Six and Seven contain empirical case studies of firms entering the uncertain market of interactive television, the cases show quite different outcomes from the intended visions and strategies, but while product market strategies may change, the technological competences applied are quite stable over time. A summary of the conclusions to the cases is included in Section Eight. Finally, Section Nine develops the discussion, and presents a framework to show the relationships between the conditions of strategic decision-making and the knowledge resources of the firm. It distinguishes between ignorance and uncertainty, and suggests ways in which the firm may move between the two.

2. Knowledge, Path-Dependency and the Resource-Based View of the Firm

What does the Resource-Based View (RBV) of the Firm say about knowledge and path-dependency? The RBV asserts that firstly the ownership of rare and valuable resources is the source of competitive advantage (Penrose, 1995; Collis & Montgomery, 1995; Barney, 1991). Secondly, for a resource to be of competitive advantage it needs to be protected against imitation or substitution. Thirdly, knowledge is one of, perhaps *the* most important resource for competitive advantage in the current era (Grant, 1991, 1996a, 1996b; Teece, 1998). Fourthly, one way in which knowledge resources may be protected is through path-dependency (Dierickx & Cool, 1989; Kogut & Zander, 1992); if there is a necessary requirement to

accumulate the resource over time e.g. through learning, then this acts as an entry barrier to competitors who cannot easily acquire the resource.

The importance of knowledge and its accumulation has become a central theme of theories of strategy. Ownership of knowledge assets is said to be the source of competitive advantage, but also requires deployment through integration (Grant, 1991; 1996b) or dynamic capabilities (Teece & Pisano, 1994; Teece, Pisano & Schuen, 1997) to attract rents and maximise value. However, knowledge assets are only the source of competitive advantage when appropriability regimes are tough, when they are non-tradable and difficult to imitate (Teece,1998). Appropriability is also highlighted by Kogut & Zander (1992) who state that the central competitive dimension of firms' know-how, is to create and transfer knowledge efficiently. But paradoxically while making knowledge more transferable, it is also more imitable by competitors. Complementary assets (Teece, 1986) are also required, as knowledge assets are intermediate goods. Finally, strategies based on knowledge assets need sensemaking with regard to environmental information and the seizing of opportunities; so strategic decisions are critically important (Teece, 1998).

So for knowledge resources to be the source of competitive advantage they require protection, reconfiguration, competences, complementary assets and also the kind of strategy that supports dynamic capabilities, nevertheless *the essence* of firms is in doing things with intangible, knowledge assets; maximising their value, more than minimising transaction costs (Teece, 1998). This is where the association of knowledge resources and competitive advantage in the strategy literature extends into the Theory of the Firm, suggesting the emergence of a Knowledge-Based View (KBV). Liebeskind (1996) argues that the firm exists because it is more efficient at protecting explicit knowledge, employment contracts hinder knowledge transfer for the purposes of expropriation. Grant (1996a; 1996b) argues that the continuity of association in the firm enables the integration of the tacit knowledge of individuals into common knowledge. Corporate rules and routines facilitate co-ordination.

For all these reasons, these authors generally argue that the firm is a superior mechanism for knowledge development, integration and application than the market, and some go on to juxtapose this position against Transactions Costs Economics (TCE). Kogut & Zander for example, "Organisations know more than what their contracts can say."(1992: 383). The firm is seen as a repository of capabilities determined by knowledge embedded in enduring relationships, which are structured by organising principles. This is very much like Lazonick's (1991) 'organisational successes, not market failures' depiction of firms, a celebrated criticism of TCE.

More pragmatically, Foss (1996) and Phelan & Lewin (2000) suggest that both knowledge-based and contractual perspectives are important theoretically, while Eisenhardt & Santos (2000) argue that empirically there is no evidence that firms are any better at knowledge transfer than markets, and therefore that the KBV is not a theory of organisation. They take issue with Grant's (1996a) contention that the firm is necessarily more efficient than market transactions for the integration of knowledge. The KBV, for Eisenhardt & Santos is a special case of Resource-Based thinking, rather than a coherent, discrete theory in itself.

However, it is not only path-dependency and the KBV that has been challenged, the RBV itself has recently been under attack. For example, the incisive debate between Priem & Butler (2001a; 2001b) and Barney (2001) in a recent issue of Academy of Management Review. Priem & Butler argue that the RBV does not qualify as a theory on strict Popperian terms: it does not make empirically testable statements, cannot infer generalisable rules about the competitive advantage of particular resources, and therefore can offer no prescription to strategy. Barney responds with attempts at parameterising the key concepts of the RBV so as to render them testable, and argues that while the identification of resources that yield competitive advantage is unfeasible, the RBV does identify the attributes that such resources should have.

Path-dependency emerges as a key issue for the reaffirmation or rehabilitation of the RBV. What both sides agree on is that work on the *temporal* aspects of firm resources is a fruitful research direction. Priem & Butler propose that the analysis of firm histories could generate a deeper understanding in the strategy field of the relations between the resources of the firm and its environment. Through the RBV lens the development of firm capabilities can be tracked, and their contribution to competitiveness at various points in time assessed. This suggests developing propositional "if/then" type generalisations as in contingency theory. Barney concurs that a dynamic view of the RBV is the way forward, aligning the school more strongly with the dynamic capabilities (Teece & Pisano, 1994; Teece, Pisano & Schuen, 1997) and evolutionary approaches (Nelson & Winter, 1982).

The concept of path-dependency is a central pillar of the dynamic capabilities triad of processes, positions and paths. Similarly, Barney (1989) and Dierickx and Cool (1989) have stressed the sustainability of competitive advantage over time. Kogut & Zander (1992) argue that organisational learning is dependent on current capabilities. Competitive advantage accrues to the firm that possesses *combinative capabilities*, the synthesis and application of current and acquired knowledge.

All of which is to say that an entry barrier applies where a metaphorical path must be followed and passed in order to "arrive" at ownership of the knowledge resource. Path-dependency is a critical advantage where the required learning cannot be effected easily and quickly. Investment and activity trying to "cram" or catch up is less efficient than stable commitments over longer periods, what Dierickx & Cool (1989) have called 'time compression diseconomies'. Path-Dependency then, is a core concept in the Resource Based View, with regard to knowledge assets. The next section shows that this is a familiar concept in the field of innovation studies, before considering the challenges to path-dependency.

3. Path-Dependency of Technological Knowledge

The resource-based view, then, suggests that knowledge assets advance in a cumulative way; one innovation follows another in logical and proximate steps. One step is not too far from the previous, largely because of the resource-intensive learning entailed. This is the notion of path-dependence that is received wisdom among scholars of technical change and innovation studies. Rosenberg (1994) for instance, stresses that firstly, product development activities are expensive, second, much development activity is not devoted to new products, but refining and

modifying existing products, and third, where major innovations do occur, they also generate path-dependence by enabling and introducing new frames and directions for research and development: "…certain trajectories of improvement that are made possible by the existing stock of technological knowledge." (16).

Dosi (1982) borrows the paradigm metaphor from Kuhn's (1962) notion of scientific paradigms. Technological trajectories are the pattern of "normal" problem solving activity within a technological paradigm. This means there are "…strong prescriptions on the directions of technical change to pursue and those to neglect." (1982: 152). Engineering effort and imagination is focused in precise directions, and is `blind' to other possibilities.

Once a path is initiated it builds a momentum, continuing to direct problem solving activity in particular directions. This is the sense in which technical change follows "natural trajectories" a term used by Nelson & Winter (1977). Innovation proceeds with an inner logic, and "advances seem to follow advances in a way that appears somewhat `inevitable' and certainly not fine tuned to the changing demand and cost conditions." (Nelson & Winter, 1977: 56-57) As for non-technological influences on choice of paths, Dosi identifies economic, institutional and social criteria as important selective devices. Criteria such as feasibility, marketability and profitability may be influential. Yet because of the inherent uncertainty over outcomes in innovation the *a priori* assessment of the superiority of one path over another is impossible.

The implications of all this for the firm is that the range of technological trajectories available is restricted. Innovations must be compatible with the firm's existing skills, technology and product range, and this has considerable significance for strategic management (Pavitt, 1986). Firms are more likely to be successful when innovating in product classes that are technologically related to existing activities. As technological trajectories are specific and differentiated in nature so firms' technological capabilities are specific and specialised. "Firms do not `search' for innovations in a general `pool' or `stock' of knowledge, all of which is equally accessible and assimilable by them. Instead, they search in zones that are closely related to their existing skills and technologies." (Pavitt, 1986: 174)

Patel & Pavitt (1994) show this in a large-scale empirical study based upon patenting data in all sectors. Technological competences were operationalised as the technological sub-fields firms are active in. The authors found that competences are highly stable and differentiated in composition, technology mix and that the directions of localised technological search are strongly influenced by the firms principal products. The stability in firms' technology mix shows that accumulation of new competences is a slow process. The study serves to confirm path dependency, putting severe limits on the range of exploitable technological opportunities.

Further empirical evidence of path-dependence is provided by Miyazaki's (1993) study of Japanese and European firms entering the field of optoelectronics. Using bibliometric data, US patent data and interviews, Miyazaki shows that competence building in this emerging new technology was approached by different firms according to their differing accumulated knowledge bases.

Path-Dependence in Cognition

The notion of technological path-dependence finds support from other social sciences. Cognitive and behavioural research at the level of individuals has shown that accumulated prior knowledge increases the ability to acquire associated knowledge and use it. (Cohen & Levinthal, 1990: 129-130). Structures of categorisation and linkage of concepts must be in place in order to make sense of newly introduced subjects. If the appropriate contextual knowledge framework is absent, these new subjects are unintelligible.

Theories of social cognition assume that the human mind has a limited capacity to process information. This is consistent with Simon's (1955) `bounded rationality' problem. Rationality is bounded partly because of limits in what is received, but also because of limits of cognition. Cognitive research has shown that information that can be placed within existing knowledge structures *demands attention.* This information may be new and challenging to a degree but is relevant, as it can be processed within familiar frameworks.

Kiesler & Sproull assert "If the information is too discrepant, it will be discounted or forgotten. This joint effect of salience and relevance leads to the prediction that decision makers will best incorporate information that is discrepant enough to capture attention but not so discrepant as to seem irrelevant" (Kiesler & Sproull, 1982: 556-557).

Knowledge structures therefore act as a filter for relevance, and resist new evidence that is incommensurate or inconsistent with what is known. This is the cognitive basis of path-dependence in knowledge acquisition and problem solving. Accumulated methods and heuristics are the prior knowledge required to enable the acquisition of new, but related problem solving capabilities.

4. Path-*In*dependence? The Path-Breaking Power of Visions?

In recent years, the notion of technological path-dependence has been challenged. Martin Fransman has asked about the possibility of "path independence" (1995a). Fransman as well as Swann and Gill (1993) have used the notion of *vision*[1] to explore the extent of the constraints on the direction of firm competence accumulation.

Fransman's definition of vision is "the set of beliefs regarding the firm's circumstances. It is these beliefs (rather than the firm's `objective' circumstances) which shape the leaders' views regarding the activities and knowledge which the firm should have to compete in the future." (1995b: 3). He argues this enables an *ex ante* analysis of firm competences. Vision-construction provides the opportunity for 'competence-creating moments'. These junctures in the evolution of the firm are

[1] As well in technology and innovation studies, the concept of vision has appeared widely in the general management literature. It is characterised as informal, different to, but interacting with strategy, and primarily a device for leadership and motivation inside the firm. It plays a role in directing and unifying the workforce around an agreed future (Westley & Mintzberg, 1989; Oswald *et al*.,1994; 1997; Collins & Porras, 1996; Nutt & Backoff, 1997; Baum *et al*., 1998; Harris & Ogbonna, 1999).

where decisions are made about competences the firm will compete on. This is a contrasting idea to path-dependency, where future competences are dependent on the competences of the past.

Strategies and tactics are shaped by the broad outline of the vision. Fransman's vision then, is not an explicit plan derived from rational planning processes. It is based on beliefs of decision-makers that are intuitive and influenced by perceptions of the environment and of future developments. Such beliefs cannot be rationally processed, because of two complicating conditions: bounded rationality and interpretive ambiguity.

Bounded rationality is Herbert Simon's (1955) notion that describes the constraints a decision-maker faces when attempting to make choices in a complex world. The decision-maker is dealing with a limited information set firstly, because all relevant information cannot be known. Secondly, there are constraints on the cognitive processing ability of the decision-maker, bounding the rationality of choices regarding alternative courses of action.

Fransman's notion of interpretive ambiguity concerns the content of the information set. When this limited information is processed it presents contradictory signals regarding alternative courses of action and their consequences. Inferences are disjunctive and calculations about outcomes are not possible. The world appears "fuzzy" and rational choice breaks down. Under such circumstances of interpretive ambiguity, beliefs, rather than information, influence the construction of visions and consequent strategy (Fransman, 1995a).

Fransman goes on to argue that belief is partly based on processed information, and partly based on knowledge. He insists that knowledge and belief are in fact synonymous, because both are open-ended and change over time. Processed information by contrast, is closed. Fransman's argument is that the know-how and the know-why types of knowledge contained in technological competence are continually being revised. They are no more or less than the beliefs about how to produce a product, and why the effects of certain processes are caused. In this way belief is equated with knowledge, and knowledge embodied in visions is of the same nature as knowledge embodied in competences (Fransman, 1995b).

Vision however, is described as `bounded' in Fransman's 1992 and 1994 papers. The 1992 paper uses the described framework to interpret empirical case studies of major telecommunications companies. Visions of these firms are bounded by beliefs, as well as the past experience of decision-makers within their respective firms. For this reason `vision failure' may occur, where events are not anticipated in the vision and it becomes clear that inappropriate decisions have been made.

While this view stresses rather more the significance of path-dependency, it is not inconsistent with Fransman's later theorising. While Fransman (1995b) states that knowledge and belief is open-ended, this is in the sense of changing over time, rather than encompassing all available inputs. It does show Fransman's explanation of corporate failure, which is rooted in the construction of visions. Furthermore, past experience and path-dependency are implicated in the errors made in constructing the visions.

Swann & Gill's (1993) notion of vision differs from Fransman's. It is similar in that these authors agree that success in innovation and the market is not fully explained by accumulated competence. Like Fransman, Swann & Gill argue that technological and market vision is an important factor in the firm's strategy and performance. Swann & Gill's vision is also bounded and restricts the firm to a range of technological and market outcomes. If technological paths develop too far from the vision then the firm will be disadvantaged.

However, changing the vision in such circumstances is seen as problematic, because of the embeddedness of routines and organisational structure. Vision in the Swann & Gill conception is a source of lock-in (not unlike technological path-dependence) that to a large extent determines the firm's future performance as well as market structure.

Furthermore, Swann's & Gill's (1993) concept of vision is not so dependent on beliefs as Fransman's. On the contrary, they argue that in many cases visions are not believed at all and serve merely as a competitive tactic. For example, Fransman makes much of the fact that IBM was aware of the potential of microprocessors and yet continued to focus their business on mainframes. This paradox Fransman attributes to the intransigence of beliefs.

Swann & Gill argue instead that IBM were fully aware of the threat but were seeking to play it down and defend their position: "For 'no need for computers other than large mainframes' read 'there is undoubtedly a potential market for small computers, but we desperately hope it doesn't take off'."(1993: 25). While the announced vision was destined to turn out wrong, it was the correct statement of strategy for an established mainframe company to declare: "Good Schumpeterians should articulate visions in which their market power is maintained or increased; they should not admit the possibility of scenarios in which their market position is weakened."(*Ibid*.)

Positive statements of intent are also important. Product pre-announcements for example may be a tactical or strategic use of vision. A firm may be signalling to competitors or attempting to deter entry. Alternatively the firm may be encouraging users to wait for the announced product, rather than make investments in a competitor's rival technology. Swann & Gill's categories of corporate vision are presented in the following table.

Table 1: Categories of Corporate Vision (Swann & Gill, 1993: 26)

	Tactical (pre-announcements)	Strategic (long-term visions)
Internal	Commit warring factions to a particular product	Used in reorganising firm for future technical change
External	User: encourage buyer to wait for new product Rival: signal, or entry deterrent	Encourage user to plan and produce around this vision of future technology

The limits of path-dependency are also questioned in recent work by Coombs & Hull (1998). But instead of the vision concept, this is through an attempt to combine the

evolutionary economics view of firm-specific routines with the current discourse on `knowledge management' (KM). For Coombs and Hull the KM perspective stresses the ability of the firm to absorb and use new knowledge, "…it presents a relatively increased possibility of `breaking free' of path-dependency." (1998: 239).

These authors argue that path-dependency in the firm may be manifested in three domains: "*technology-as-hardware*", the outputs of innovation; the firm's *knowledge base*, which is difficult to access and measure; and the firm's *routines*. Routines are the practical activities that develop and apply the knowledge base, and it is this third domain that Coombs & Hull argue is the key to understanding the extent to which constraints of path-dependency may be modified. Routines are the formal and informal practices to collect, disseminate and apply new knowledge throughout the organisation. They are generally operational actions at the level of individuals and teams, built into the continuous and everyday performance of corporate activities.

Coombs & Hull argue that routines exist in all organisations, but not all will contribute to effective knowledge management. They present five categories of Knowledge Management Practices (KMPs) which they argue, contribute to the knowledge base in three ways. Firstly, KMPs constitute and enable discussions regarding the developing technology base of the firm, and possible applications. Secondly, KMPs contribute to the stock of market-based knowledge. Thirdly, KMPs create a stock of knowledge about the firm's own administrative, technical and management processes.

This approach appears to be entirely consonant with Cohen & Levinthal's absorptive capacity model. The focus on routines is a different emphasis rather than knowledge bases, and the reference to the knowledge management ideas and techniques that are popular in the current business zeitgeist. Coombs and Hull argues that KM emphasises the possibility of relaxing the constraints on technological development or "variety generation" that the traditional economics of technical change perspective insists on. Coombs & Hull believe taking KMPs as the unit of analysis demonstrates a greater degree of freedom.

To provide further fuel for these debates around the limits of technological path-dependence, the influence of knowledge and information, and the conditions under which decision-making occurs, we shall now present some illustrative case studies of actual strategies.

5. Case Studies of Strategizing under Uncertainty

The following sections of the paper report on studies of corporate strategies in relation to the technological competences held by firms. To test the degree of technological path-dependence the researcher selected companies making an entry into a new and uncertain area of opportunity. In a more stable and predictable market scenario, the observation of path-dependence would be an unremarkable result.

The cases selected are three firms that in the 1990s entered the uncertain and emerging area of interactive television. These are British Telecom (BT) the telecommunications operator, Acorn Computers, a small but notable British high-tech start-up, and Oracle Systems, the large database management company.

The researcher examined the strategies of entry through interviews with Senior and Middle Managers, company documentation, and statements to the trade and mainstream media. The technological competences were assessed by interviews with engineers and project managers in the firms. The researcher used multiple sources of evidence, and opinion, to achieve some 'triangulation' on the views reported by the practitioners. As the intensive study was conducted over a period of a year, and thereafter through tracking developments in the media, it was possible to analyse the changes in the strategies over time. The cases show that the product market strategies did indeed change, while the underlying technological paths remained much more stable. The next section provides some background to the cases.

Background and Context

Both BT and Acorn in the early 1990s were compelled to search for new markets and foresaw opportunities in new multimedia services. The studies focus on two parallel technical and market trials conducted by the firms that served as devices to guide strategy. The cases show that the actual outcomes of the trials were rather different from the initial "vision" and announced intent.

This is also shown in the third case, Oracle, Inc., the giant software company based in Silicon Valley. Oracle is involved in both other cases, having also moved from an initial interest in interactive TV to a new vision of "network computing". The case shows the creation of a new venture division as a vehicle for the vision. All three cases show the necessary *emergence* of strategy in an uncertain, inchoate area of opportunity.

During the period of 1993-94, discussion and speculation regarding digital media was focused on the potential of delivering interactive services to consumers in their homes. Actual multimedia products at this stage were largely limited to CD-ROMs running on stand-alone computers. The Internet and World Wide Web were not yet significantly used outside of academe. The mainstream and business press speculated on vague notions of "the information superhighway", a popular theme for politicians' speeches. Visions of the "Infobahn" seemed to constitute a new broadband infrastructure that would link businesses, public institutions and homes, although the source of the necessary investment was always unclear.

One popular rationale was that the provision of interactive entertainment services would provide a sufficient incentive for cable operators to invest in broadband infrastructure. Alternatively the same rationale could be applied to telecommunications operators given the necessary deregulation to broadcast. The "killer application' was to be video-on-demand. The idea was that consumers would pay a premium for instant transmission of programming content to their living rooms, thus diverting the significant revenues of the videocassette rental industry. This would provide the stimulus for further investments in other, perhaps more "worthy" interactive television services, which would better exploit the capabilities of the new technology.

During this period, a large number of experimental trials were announced which were to test the technologies enabling interactive TV, as well as the extent and nature of

demand for such services. Many of the proposed ventures were significantly scaled back, delayed or aborted. Some were successfully implemented, such as the two British trials described below.

Since its privatisation in 1981, BT has sought new markets to add to its traditional provision of telephony services. This is in spite of remaining a virtual monopolist in telephony. BT's significant (£345m in 1999[2]) Research and Development activity has always entered into areas adjacent to and sometimes remote from telephony, for example, audio-visual and broadcasting technologies.

Although regulation had prevented BT from broadcasting entertainment services, the company has some history in the cable industry. Having been allowed to bid for local cable operation franchises in the early 1980s, BT took control of several. This was one stage in an ongoing effort to enter new markets since the opening of the British telecoms market.

The cable television industry in Britain did not prove profitable, however. Direct Broadcast Satellite was been more successful with Rupert Murdoch's BSkyB tracking a steady growth in subscribers, content rights and profitability. In the mid 1980s BT came to the decision that satellite was a cheaper technology than cable, and most of its cable franchises were divested or rented out to other operators.[3]

One franchise that was retained is Westminster Cable in central London. This has a unique coaxial cable network, built in a star configuration. This architecture is familiar to telecommunications networks but unique in CATV[4]. 180 intelligent switches in the neighbourhoods receive analogue signals from the head end, and transmit these directly to customers' homes.

At the time the network was built in the early 1980s, a "Video Juke Box" (VJB) facility was installed. This, combined with the star configuration enabled service trials where customers could dial up video content choices and receive them instantly. The video was stored on laserdiscs and played at the head end, in a literal video jukebox.

In 1995 BT decided to run another trial on the Westminster network. This trial would employ the new digital technologies associated with Video-On-Demand (VOD). The software and hardware hooks already in place in the neighbourhood switches and the head end were redeployed to run the new trial. Video content was digitally encoded and stored on a mediaplex server. Video datastreams were then fed into stacks of Set Top Boxes (STBs) where they were processed into analogue signals and transmitted to the neighbourhood switches. The technical trial ran from November 1995 to June 1996, involving 70 homes. The system was found to be technically stable and the necessary interfaces for the consumers were found to be easily navigable. The other identifiable result was that the service was popular.

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[2] The UK R&D Scoreboard (http://www.innovation.gov.uk/projects/rd_scoreboard/database/databasefr.htm).

[3] BT withdrew from a number of disparate areas in the 1980s, considering that the company was spread too thinly in these unrelated activities.

[4] Community Antenna Television, a term used for cable television.

But in addition to the Westminster trial, BT decided to conduct a larger and more ambitious interactive TV experiment, in the East Anglia region where BT Labs is located. This was to test Asymmetric Digital Subscriber Line (ADSL) technology. ADSL is a modem-based system which when overlaid on a traditional copperwire telephone line, enables the transmission of full-motion, full-screen video to VHS quality.

The announcement of the ADSL trial provoked much controversy. Firstly there was the question of BT's motives; some saw the trial as a spoiler to the nascent cable industry, as the American telcos- the Baby Bells- were seeking investment and subscribers for their struggling franchises. If BT could indeed deliver video-on-demand over the national twisted pair network it already controlled, the future of the cable industry looked bleak indeed.

The trials were BT's attempt to show the government that it could competently deliver entertainment services[5]. The company had long been lobbying for the removal of the rules preventing it from broadcasting. The regulatory watchdog agency, Oftel, had stipulated that the VOD and interactive TV trials were permissible. This was because consumers would not be viewing the same programming simultaneously. Transmissions would respond to individual users' requests and the system was therefore defined as "narrowcasting".

There was also considerable scepticism regarding the technical feasibility of ADSL. The technology had not yet been proven outside of laboratories. The proposition of seamless video delivered over copperwire went against the grain of every telecommunications engineer's received wisdom. The improbability of the technology's success favoured the thesis that BT was merely manoeuvring politically.

With the formal strategy agreed by BT's Board, the specifications for the trial were then "contracted" to the Design and Build division at BT Labs. The entire trial was built and completed within one year. It was executed to a strict timetable in two stages. The first, a small-scale technical trial, was built within 100 days. The second stage, the market trial, extended to 2000 home connections and ran from October 1995 to June 1996.

Because this was a venture that was unfamiliar to BT and required competences that the company did not internally possess, various external partners were contracted in. The central participants were Oracle, who provided the video server software, N-Cube, who provided the server hardware and Apple, who provided the set-top boxes to be installed in the homes. BT was the prime integrator, managing the various functions of coding, service creation, customer handling, network management and installation.

Oracle is the world's second largest software company (revenues for 2001, $7.6 billion[6]) after Microsoft. The company was started up in 1977 by Larry Ellison, its CEO, to exploit advances in relational database management systems. Products now offered also include applications development, office automation, end-user accounting

[5] Author's interviews, D.Pincott, Westminster Cable, 17.8.96; T. Patten, BT,17.7.96.
[6] For the nine months ended 2/28/01 (http://biz.yahoo.com/p/o/orcl.html)

and manufacturing applications for client-server environments. Oracle is the leader in the relational database market with an estimated 40% market share.

While UNIX and desktop system platforms account for more than 80% of its revenues, the company's consultancy and new media activities have grown rapidly. Oracle's involvement in the BT trial was indicative of its commitment at that time to interactive television. The company had built a competence in the new area of media server technology. Unlike traditional servers, a media server is able to deliver continuous streams of content to many viewers simultaneously. These streams may consist of broadcast video, video-on-demand, interactive games and interactive information services. Oracle's Video Server Division worked with BT on the trial, and subsequently on the BIB system. Oracle was also leading a forum of fifty STB vendors to promote interactive television, the Set Top Box Alliance.

The second trial shares many similarities, but also has important differences with BT's. Acorn was a small/medium-sized British microcomputer manufacturer based in the "Silicon Fens" of Cambridge. Like BT, Acorn was experimenting with interactive TV as a means of testing new markets. Unlike BT, the situation was rather more urgent, as it was becoming increasingly apparent that the company could no longer sustain significant revenues from its familiar UK education market.

Acorn had enjoyed a relatively comfortable position throughout the 1980s and early 1990s. British schools adopted firstly the BBC microcomputer series, based on Acorn's technology, and subsequently the Acorn Archimedes series. However, in later years there was a sense in which Acorn was living on borrowed time before schools increasingly switched to computers favouring the 'Wintel' alliance.

Acorn's strength was its technological assets, it was a pioneer of the RISC (Reduced Instruction Set Coding) technology that was developed among several institutions in the Cambridge region, such as the Computing Laboratory at Cambridge University and other spin-off companies such as Olivetti Research Laboratories. This core technology became world –renowned and achieved business success with the company ARM, now established in Silicon Valley. Acorn also had a reputation for effectively mobilising its small technical teams. The common perception was that this engineering function was capable of developing innovative technology in extremely rapid time at a low cost. The conventional wisdom was that this engineering effort was usually let down by poor marketing. From the 1993 period onwards, Acorn were in a state of strategic review and re-organisation, where the "making and selling of boxes" function was effectively put out to a new joint venture with Apple called Xemplar. This left the technology core of the company, often working with ARM, the RISC processor technology developer in which Acorn held a 42.8% stake[7].

In 1994, Acorn set up a new division named Online Media (OM). This unit was considered the appropriate domain within which marketing could exploit the interactive TV/video-on-demand hyperbole and secondly, a perceived opportunity to utilise Acorn's technology- a significantly lower cost PC design in a new market application. This new application was the set-top box device, which decodes signals that are then transmitted into the home television set. The inchoate nature of the

[7] This stake was divested in 1999.

interactive television market, together with Acorn's low-cost, efficient technology meant that the company could be well positioned. Acorn's experience of adapting microcomputers to standard television displays -as with the BBC microcomputer and Archimedes- would be useful in developing a set-top box product

OM's first task was for a small team to build a set-top box demonstrator BT had announced its intention to run the ADSL trial. Online Media began discussions with various contacts in the Cambridge region to run a trial in parallel with BT's, in order to "tread on their toes" to some extent.[8]

This trial, however, would attempt to go one technological step better than BT's. Rather than a pragmatic attempt to squeeze more bandwidth out of the copperwire network, the Cambridge Trial would run on two-way, coaxial cable. It would offer consumers unprecedented interactivity by employing the first field implementation of Asynchronous Transfer Mode (ATM) technology. This was at the time a leading edge communications technology. ATM divides digital data into small packets and switches these according to specified connections in the data stream, rather than by time. In this way ATM enables a much faster and more stable quality of service than time-based transmission technologies such as Ethernet. ATM's reliability does not vary according to load; bandwidth cannot be "hogged" by specific servers because the packets are so small and easily interweaved.

The Online Media venture combined Acorn's low-cost technical functionality, with knowledge about digital networks developed in other local institutions such as Cambridge University; Olivetti Research Laboratories and its spin-off company, ATML, (now named Virata). The Cambridge Trial as the result of years of accumulated learning and networking between the people involved in these institutions[9]. Initially, the trial was directed through a steering group including Online Media, who would provide the set-top boxes; Cambridge Cable, the local cable TV franchise operator, who provided access to their network; ATML provided digital ATM switches which overlaid the existing network, as well as an initial media server; and Anglia Multimedia, a CD-ROM developer spun off from the local television station, Anglia TV. Anglia would provide conventional and interactive content for the trial.

As with BT's trial, the Cambridge announcement and launch brought an intense amount of media attention and interest to OM. The interactive TV vision caught the media's imagination, particularly with the additional drama of the competing technologies of ADSL versus ATM. The Cambridge Trial served as a demonstration to promote Acorn's movement into technology design and consultancy services.

After a successful initial technical trial of 10 homes with fibre optic cable all the way to the home, Acorn prepared for the second phase. The company undertook a rights issue on the stock market in early 1995, raising £17m to invest in Online Media and its trial. The full-scale trial was begun late that year, with an end-to-end ATM system overlaid on the hybrid fibre-coaxial network. Around 80 homes, and 12 schools were connected.

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[8] H. Davenport, former President, Cambridge Cable, Author's interview, 9.12.96.
[9] G. Vincent, author's interview, 21.11.96.

6. Strategies and Outcomes

BT

BT's trial was characterised by more formal strategizing than Acorn's. BT's newly formed Multimedia Unit was the organisational driver for the ADSL trial. This was a new venture division set up to develop multimedia services using BT's existing network and largely populated with marketing people. An external consultancy, Boston Consulting Group, was brought in to strategize with the marketing managers at the Multimedia Unit. These exercises produced various business case scenarios for interactive TV. The scenarios included projections of penetration, viewing figures and patterns of usage for a ten-year time frame. The projections were based on conventional television usage. These forecasting exercises equipped advocates of the trials with supporting arguments when presenting proposals to BT's board. Given the uncertainty of the proposal, some business model rationale was needed in order to justify the nontrivial costs of £50m.

The second function was to articulate heuristics that the trials were to test. The projections contained various assumptions of the type; "Lower middle class consumers would be prepared to pay £4 for a premium movie, we may then expect returns of..." These hypotheses about the appropriate pricing of services were to be tested in the trial. . For example, some of the popular soap operas were available which were running concurrently with the terrestrial stations. BT experimented with offering viewers the option of paying a charge to view the latest episodes before they were broadcast on the terrestrial schedule. The marketing people from the Multimedia Unit closely monitored the incoming results, would modify the heuristics and adjust tariffing periodically for additional, unanticipated learning

The initial exercises were aimed at clarifying the questions the trial was asking, so as to better define the range of possible market outcomes for interactive TV. The strategic thinking was trying to simplify the uncertainty by applying frameworks borrowed from existing market models. In this way from a strategist's viewpoint, rather than facing the uncertainty of unproven technology and unknown markets, the trial had established that the technology works- at a price, and that there are a range of programming options that have proven levels of demand. This demand could be analysed through the usage behaviours of a demographic sample. This paper argues that the analysis and sensemaking of this information has effected a major change in the decision-maker's conditions, from a state of ignorance to uncertainty, this is further explored in the discussion at the end of the paper.

The BT case shows a beneficial use of strategizing, and is consistent with Nelson & Winter's (1982) notion of formal strategy exercises as management heuristics. Used in this way, strategy formulation exercises serve to better cope with the problem of uncertainty. The important factor was the *ongoing* monitoring and adaptation, which produced useful information to feed back into the strategy. The original projections did not therefore represent BT's genuine expectations for the growth of demand for I-TV, but rather served the purposes of advocacy and project definition internally, and publicity externally.

In terms of results the trial confirmed that delivering interactive TV via telephone lines using ADSL was still too expensive to justify rolling-out a commercial service. The trial's overall cost of £50m to connect 2000 homes was justifiable for a research exercise but was not economically plausible on an ongoing basis. Consumers simply would not pay significantly more for interactive TV than what was already offered on existing technologies, such as satellite. Although the costs of video servers, ADSL modems and set-top boxes were decreasing at a rapid rate, BT strategy took a different turn from the video-over-the-phone-line vision.

The trial had proven that there is demand for interactive television services. However, rather than the expensive video-over-the-phone-line vision, BT took the view there were existing and cheaper technologies in place which could stimulate and sustain this demand[10]. The eventual Interactive Television product that resulted from the ADSL trial was *Open*, a joint venture with Rupert Murdoch's BSkyB Group (an independent company, British Interactive Broadcasting Limited, BIB was formed in 1997). The joint venture reflects the hybrid nature of the system. Content is broadcast through Sky Digital's satellite service, with interactive services delivered via BT's telephone network. The system is intended to provide some limited interactivity whereby consumers send signals through a remote control to a modem in a digital set-top box, which is connected to the existing telephone line. The service offers shopping, banking, gaming, information services and unlike the ITV services of the trial there is a connection available to email facilities. Most recently, BT's Openworld organisation has announced an agreement with Sky Digital's competitor, ONDigital to provide Internet access through its digital television service.

BT's ADSL experimentation continued, but was overtaken by the growing demand for high bandwidth Internet services, reflecting the shift in strategic urgency from interactive television. Again, this change of emphasis in the strategy arises from the developments in the market; Internet Service Provision has grown exponentially while developments in digital television have displaced interactive television as an immediate market prospect.

The BT case shows the emergence of strategy and the uncertainty of outcomes. Despite the hyperbole in the industry and the press over the ADSL trial, there was no commitment to roll-out a commercial interactive television service based on telephone lines. Instead the trial served as a tool to test out technical systems, deploy existing competences to new applications, and to facilitate learning in a genuine functioning service. The initial strategizing was useful in this context, defining heuristics that were later modified and adapted. This learning was fed back into the strategy.

Acorn

Meanwhile, the main result of the Cambridge trial was that Acorn's set-top boxes performed well. Interviews suggest that the other participants motives were primarily to generate publicity[11]. As with the BT trial, it was recognised that interactive TV of

[10] B. Foster, author's interview, 22.11.96.
[11] Author's interviews, H. Davenport, former President, Cambridge Cable, 9.12.96; P. Coghlan, Technology Licensing Engineer, ATM Ltd, 30.5.97.

this level of sophistication was still too expensive to be a commercially viable proposition. This was accepted early on by the participants, in spite of press announcements envisioning ambitious services and innovative business models. Anyone unaware of the economics of interactive TV was persuaded about one month into the trial.

Technically, the overlay of ATM on the cable network was successful, with a data rate into the home of 2 MBit/s. This was a considerable achievement as the first implementation of ATM in field conditions. Following the trial in early 1996, Acorn's set-top box capabilities won the company a contract to provide the reference design for Oracle's Network Computer (NC). This was a vision that Oracle's high-profile CEO, Larry Ellison has been promoting for some time. Ellison's idea was a `thin client' device, which would have no hard drive for local storage on the desktop, but with the preponderance of processing power and applications at the server end.

Oracle needed a prototype to prove that such a computer could sell for less than $500. The company was aware of Acorn's capabilities in low-cost smart boxes and had invested in Cambridge's RISC technology, as an alternative to Wintel. Acorn produced a prototype for Oracle and won a lucrative ongoing contract to provide reference designs to Oracle's new NCI (Network Computer Inc.) division. This rejuvenated the company and affirmed its focus on technology design. Acorn had become "an extension of Oracle's development effort"[12].

During the period of the early 1990s, Acorn had become increasingly aware that its dependence on education channels was not a sufficient basis for a sustainable strategy. Rationalist-style strategizing involved top management articulating a desire that the company should focus on its capabilities to develop affordable, RISC-based technology[13]. There was also an imperative that this technology should be applied to new markets, particularly intelligent client devices for digital networks.

The Online Media NVD was set up to facilitate product and market development in the new areas of multimedia networks and services. The Cambridge Trial was a strategic device attempting to demonstrate the company's capability to provide intelligent box technology for leading edge high-speed networks. This, like the BT case shows the variety of product market strategies that may be pursued from a stable technological competence base.

By late 1995 it was becoming apparent that Interactive TV was not going to be an imminent rollout service and Acorn's interest shifted to the Internet and the NC concept. In commercial terms the significant result of the trial was Acorn's new relationship with Oracle. The trial had demonstrated the company's proficiency in set-top box technology. While the hyperbole of VOD and interactive-TV had fizzled out, Acorn aligned itself with Oracle's vision of the NC. This adaptability together with its competence base had sustained Acorn in the turbulent hi-tech industrial landscape. As with the BT case, the technological learning derived from the trial has been deployed in the development of other, more promising applications. Malcolm Bird commented that after the turbulent years of volume manufacturing the company was "...back to its

[12] Acorn Network Computing Managing Director, M.Bird, interview, 10.12.96.
[13] Acorn Network Computing Managing Director, M.Bird, interview, 10.12.96.

roots; where it belongs as a technology design and licensing organisation."[14]Since then, Acorn changed its name to Element 14, and last year was acquired by Broadcom, a large US developer of chip technology to enable broadband communications.

However, the sequence of events as reported may give a misleading impression of rationality and purpose. Acorn's is very much a story of the emergence of strategy. In spite of the early discussions regarding a re-direction of the firm's technology assets, what followed could not be said to be the result of planning. The strategy only changed *after* the trial was completed and OM was wound down. This is what Burgelman & Sayles (1986: 145) refer to as "retroactive rationalization", where strategy changes take place essentially after a new venture experiment has been closed; "...top management needs to retroactively give legitimacy to what has been going on in these new ventures by making appropriate changes in the corporate strategy."

Oracle

Our third case company, Oracle, also responded to the growth of the Internet with a shift in strategic emphasis, Pat Kiddle, Product Manager of the Video Server Division commented:

> The BT market trial was ahead of its time, in that it was prior to the Internet explosion. There has been a change of emphasis. In 1994 there was a lot of hype about interactive TV, although those of us who worked in the industry had our feet more on the ground, but we thought it would evolve faster than has happened. What has actually happened is that iTV is actually struggling to get past the technology pieces, but the Internet has exploded in the meantime, and this has reshaped our iTV work[15].

The iTV model was "twisted towards the Web" (*Ibid*.) to some extent. The video server group refocused on delivering video on the Web for electronic commerce applications. Furthermore, all of Oracle's products became "web-centric". For example, *Forms*, a client-side database tool was repurposed as *WebForms* and integrated into the Oracle Web Server. More importantly, the newest version of the Oracle database, *8i* - the company's "cash cow"- was reconfigured so as to work with the Web.

This strategy involved all Oracle's organisation, as the architectures of all products were adapted to network computing. The two developments of the growth of electronic commerce on the Web, and the video server work were formalised in the NC architecture. The prior version of the Oracle database, *7*, was 18 years old. The key new development in the new version was the applications server which enabled the `thin client' to function. Importantly, however, the system continued to support

[14] Author's interview, 10.12.96.
[15] P. Kiddle, author's interview, 25.4.97.

`fat clients'; PCs and workstations[16]. So while Ellison's vision was certainly enabled by new products, the stable revenues for its customary use were not endangered. This strategy shows a willingness to enter uncertain areas of opportunity based on an explicit vision, while managing the inherent risks.

Essentially the Network Computing strategy was a challenge to the Windows- Intel dominance of computing markets. While Oracle did not compete directly with Microsoft in its existing markets, in the longer-term Microsoft was seen as the firm's chief rival[17]. This was also seen in Oracle's continuing relationship with Apple, Microsoft's traditional but struggling competitor. Ellison had considered personally acquiring Apple in 1997. This was also seen by Ellison's funding of alternatives to `Wintel' technology, for example the development of RISC by firms like Acorn and ATML in Cambridge. The Network Computing vision was a high-profile signal to the external world that Oracle was challenging the only software firm larger than itself.

Internally, the NC strategy was announced in 1996 and was very much `top-down'. However, rather than simply announcing the vision and consequent reorganisation, dedicated strategizing was used to explain its implications to all employees. The strategy was "rolled out" throughout the company in a number of seminars. These were 1/2-day off-site strategy retreat meetings. Ray Lane, the Chief Operating Officer, seen as the implementer of Ellison's vision, ran a one-day session for the whole organisation.

During these meetings held over a number of weeks, everyone in the organisation was "presented and educated" (*Ibid.*) about the new strategy. 25,000 employees were involved and given the opportunity to give presentations and feedback. The first top-management led stage was then followed by sessions led by group leaders where there was also the opportunity for feedback and comments. Following this massive strategizing process, all divisions knew where their products and activities fitted into the new strategy.

Eighteen months previously, a similar scale exercise was implemented to educate employees about the prior strategy, the `Universal Server' concept. This shows that while strategies are changed and adjusted in reaction to the trends in turbulent market, every effort is made to ensure that the organisation will implement the strategy accordingly. This concurs with the literature on internal uses of visions and explicit strategies (Kanter, 1984; Swann & Gill, 1993). These strategy exercises were in effect closing the debate after senior management had devised strategy in the overall planning committee. While lower levels of the hierarchy were not involved in the formulation of the strategy, the firm was unified and prepared for reorganisation and redirection of its activities.

The rationale for an autonomous organisation, Network Computing, Inc. was firstly, so that other companies would invest in the business[18]. Secondly, the business could

[16] P. Kiddle, author's interview, 25.4.97; `Ray Lane on Network Computing', *Software Magazine*, Jan.97.
[17] P. Kiddle, author's interview, 25.4.97.
[18] P. Kiddle, author's interview, 25.4.97.

act more rapidly and would be freer from the routines of the Oracle bureaucracy[19]. A third possible reason implied by interviews but not stated, was that should the NC business fail, the ongoing mainstream business of Oracle would not be affected. This again shows that Oracle was "hedging its bets" on the proposed network computing vision. The entry to the new area of hardware products was discrepant with Oracle's mainstream business and so an autonomous division was the chosen organisational mode of entry. This was an astute choice as at the time of writing, network computing is considered unfashionable in the trade press, much as interactive television was declining previously.

7. Technological Competences and Paths

BT

This section shows that for each of the companies, the experimentation with interactive television, although a fundamentally new bundle of technical and market opportunities, was nevertheless dependent on familiar technological competences. This is not to say the trials as technical exercises engendered no learning or knowledge creation, but that this was of an incremental and cumulative nature. There was technological learning on both trials, mainly through working out problems associated with content management. In BT's case, there was 2500 hours of programming content stored on a massive video server to be requested on demand. These included 250 hours of movies and 600 hours of television programming that was regularly updated. There was a range of channels including music, local life, education, sports and an interactive advertising channel.

Aside from the "on-demand" nature of the programming transmissions, the true interactivity of the trail was in the home shopping and banking services. Retailers such as WH Smith, Sears, Selfridges and Thomas Cook offered products and services such as CDs, videos, fashion, sporting goods and holidays. The National Westminster bank offered a home banking service. The management of this content was the greatest challenge to BT as the prime systems integrator. It also required creation of content because interfaces and menus needed to be devised in order to help consumers navigate the system easily from their armchairs. Managing the data on 70,000 priced items, 25,000 still pictures in addition to the 2500 hours video material presented problems that surprised BT's engineers.

In addition the problem was further complicated by the 'churn' of the content, whereby older data would be removed from the server, and newer data added. A small change would generate a multitude of consequent changes elsewhere on the system. If a fashion retailer simply wanted to show a dress's availability in red rather than blue, this would necessitate the changing of pricing and billing databases, their respective interfaces, still and/or video images advertising the product, as well as scheduling. There was no room for error, as BT could not run the risk of having consumers requesting items from the server which were no longer stored there. If the system was unreliable consumers would not use it and the trial would be pointless.

[19] J. Lynch, author's interview, 22.4.97.

Much of the initial technical interest in the trial had questioned whether a sufficient data rate into the home could be achieved. The system succeeded in delivering 2 Mbits per second into the set-top box. This is sufficient for MPEG[20] 1 video, which is VHS quality. The fact that the technology pieces all worked was major news to the external world. But the greater technical difficulty for BT was elsewhere in the system. Network management and switching was routine to BT, but content creation and management was the main competence in terms of technological learning from the Westminster and East Anglia trials.

However, this learning was advancing existing, related capabilities within BT's organisation. There was a deployment of skills from engineers who had previously worked on BT's CallMinder service. This served similar functions of customer account handling; managing the details of information with a constant churn. The same skills and principles used to construct menus and navigation paths on the CallMinder scheme were applied to the customer account management on the interactive TV trial.

So the trials represented a path-dependent advance of prior technological competences, the Co-ordinater of the project, Dr. Alec Livingstone commented: "The technology was an obvious evolution from what BT had done before, there were no `gee-whiz' radical breakthroughs."[21]. There was however, significant incremental learning in content management that built upon prior competences accumulated from the CallMinder scheme; the switching of the original Westminster "video jukebox" and BT's familiar routines of network management and operation. This supports Rosenberg's (1994) notion of path-dependence of technical change, particularly in the telecommunications sector. The investment embodied in infrastructure to a large extent constrains the range of technological options taken thereafter. The same is true of the organisation's competences.

The commercial outcome in the form of the hybrid *Open* service was a different (and more modest) technological solution than using ADSL, but it shares many characteristics of the trial. In terms of technology, the system similarly utilises Oracle's server software and expertise. The same engineers who collaborated on the trial resumed work together on the commercial venture. It also used the same content management and network operation capabilities that BT has accumulated through its experience of the trials.

These competences were also applied in BT's other multimedia products. Another example is the multimedia kiosks installed in public spaces in the 1990s. These applications used the same design studio, menu process and networking technology as the Interactive TV trial. While the kiosks used low data rates in conjunction with CD-ROM to compensate for lack of high bandwidth, the content management is still using the same principles and the same functionality required for managing people buying items. The BT case is an example where technological competences remained stable, but illustrates that there are many product markets and strategies that may be pursued from a given set of competences.

[20] Motion Picture Experts Group, a standardisation body for digital video.
[21] A. Livingstone, author's interview, 22.11.96.

Acorn

For Acorn, the set-top box and Network Computer were developed through repurposing of distinctive technology descended from a long series of developments in the company's history. This is shown through a summary of Acorn's technical history in Appendix B. Essentially Acorn engineers had applied the accumulated competences in RISC technology, as well as expertise developed from early products such as anti-twittering and anti-aliasing. These knowledge bases revolve around a set of techniques to reduce the movement and fuzziness of text images on TV-based screens. This was a competence learned from Acorn's tradition of products, such as the BBC, which used standard television screens as monitors. In addition the ARM (Acorn RISC Machines) chip was extremely useful for STBs as the low power consumption meant there were no fans needed. The noise of fans is especially undesirable for TV viewing. The customary imperative for a low cost solution was also a competitive advantage as set top boxes were notoriously expensive devices. The design for the STB was used as the basis for the NC reference design for Oracle, although the chip needed some improvements in speed and functionality to perform adequately as a NC.

However a direct lineage of Acorn's products can be traced over a 15-year time frame showing a continuous evolution in Acorn's technological development. The central knowledge base has been continually enhanced through the ongoing research into RISC technology. Concerns driving the research have been functionality, low power consumption and affordability. It is from this competence base that Acorn were able to develop the multimedia applications in the Cambridge Trial and the Oracle NC product.

Oracle

Similarly for Oracle itself, the shift in product markets from Interactive Television to Network Computing was "definitely an evolutionary curve" (*Ibid*.; *Oracle Magazine Interactive*, March/April, 1995). The Video Server was essentially a database that could seek and retrieve video and sound[22]. Oracle's existing competences in database development were redirected to this new product market as it emerged. The types of engineers recruited for new media applications such as the Video Server division possessed the same skill sets as those that Oracle previously employed. Pat Kiddle commented:

> What we do doesn't deviate. There is an evolution of the product, there is a need to repurpose and evolve…As we have seen with the Web a whole industry can grow up very quickly, but the underlying technologies develop in an evolutionary, modifying way.[23]

New networks emerged, but Oracle's engineers working on them unified the technologies and related these to the core relational database. The group included people who previously worked on the Oracle *7* database. This expertise was used to incorporate the video capability into the successor, Oracle *8i* product. This shows an

[22] www.wired.com/wired/3.02/departments/reality.check.html (20.4.97).
[23] P. Kiddle, author's interview, 25.4.97

incremental process of technical evolution, even as competences were redirected to new applications and markets.

The cases therefore provide further evidence of the path-dependent nature of technical change (Rosenberg, 1994; Pavitt; 1984; Patel & Pavitt, 1993). Rosenberg (1994) has emphasised that path-dependence is particularly acute in the telecommunications industry. Investment decisions are very costly to reverse, and must remain compatible with existing systems, as capital in telecoms is unusually long-lived. The future evolutionary development of telecommunications systems depends to a large extent on current choices. The "menu" available to the strategist is therefore pre-defined.

8. Summary of the Case Studies

	BT	Acorn	Oracle
Strategy processes	New knowledge and information feeding into ongoing strategy process	Informal strategy	No data on formation, Formal dissemination of strategy
Vision	Internal: advocating allocation of resources to projects External: Signals to media and competitors, (frequently changing)	External: Signals to media, customers, partners and competitors (frequently changing)	Internal: systematic top-down dissemination of vision and direction External: Signals to media and competitors (frequently changing)
Technological path-dependency	Derived from Westminster Cable Video Jukebox trials, CallMinder content management and general network management	Applying RISC technology and TV-based competences to new product markets.	Evolutionary development of database capabilities into video server and network computing architecture
Organisational Mode of Entry	Subsidiary; Trial ➡ Joint Venture	New Venture Divisions; Collaborative trials	New Venture Divisions: Internal and autonomous

Table 2. Summary of Case Studies

The Many Strategic Paths

The cases have all shown changes in strategic path in the light of developments in the market and learning from trials and experiments. While path-dependence was observed at the level of technological competences, it was shown that these could be

applied to a number of product markets. Strategies are more flexible than underlying technological paths. A similar distinction between products and technologies is made by Pavitt (1997). The cases have shown that in each product market the firm's technical contribution is through the same distinctive competences. Other firms' assets and competences may be accessed through externally-oriented organisational modes such as joint ventures, and so the options for strategic choice further proliferate. So while technological path-dependence sets constraints on technical trajectories, there are many strategic paths that may be pursued.

The formal strategizing observed in the cases may be seen as management heuristics, in the sense of Nelson & Winter (1982). They are devices that serve to reduce the problem of uncertainty. Strategizing can provide directions for investment or heuristics for experiments and trials. This was shown in the case study of BT's Interactive TV trial. The formal preparation of scenarios by the marketing function provided the heuristics that were to be tested in the trial. The projections and assumptions were not "set in stone" as results were concurrently monitored and the heuristics modified. This is a use of formal planning which is useful to emergent strategy formation. The results of the trial were presented to top management and a new strategic path was decided on.

The project manager of the Cambridge trial illustrates this point. He argues that management within ICT sectors is now qualitatively different from the past where rational strategy making was practical. It is now more a case of "managing flows and patterns", responding and reacting to information and signals received:

> [T]he common denominator was probably -there is a market for interactive services- we are growing an industry and we can't produce a central plan for it- these are needed, implement these functions, see what they do. Create the environment for experimentation. You don't follow history, plan and procedure. You go in with the knowledge and understanding that you have, and feedback and interaction replace planning[24].

The Cambridge trial was not a sequential, step-based schedule with a clear end-goal, but operated as "a feedback model". The trail was set up as a continual laboratory of experimentation managed through responses to signals received from the process. While BT and Oracle were not so explicit, they too pursued emergent strategies[25].

Visions

The case studies provided evidence to support Swann & Gill's (1993) notion of visions as tactical and strategic devices. For internal purposes visions serve to promote and advocate specific projects in the resource allocation process. This was seen in the BT case study, with the vision of interactive TV using the copperwire network winning support of the top management and consequent funding. The other internal use of visions is to announce policy directions to the people of the organisation and affect closure of debates. This was seen in the case study of Oracle,

[24] Interview, 21.11.96.

[25] This aspect of the strategy process is explored more thoroughly, with other empirical cases in Sapsed (forthcoming) *Restricted Vision: Strategizing Under Uncertainty*. Imperial College Press.

where the vision of Network Computing Architecture was evangelised to all employees, so that each division knew how it fitted into the intended strategy.

The cases also showed external uses of visions also serve purposes of advocacy. Product pre-announcements for example may be a tactical or strategic use of vision. A firm may be signalling to competitors or attempting to deter entry. Alternatively the firm may be encouraging users to wait for the announced product, rather than make investments in a competitor's rival technology. This is particularly important in industries and technologies with high switching costs.

These tactical and strategic uses of announcements and visions are very much in evidence in the first two cases. BT's announcement of the ADSL Interactive TV trial was widely interpreted as a spoiler to investment in the nascent UK cable industry. Whether this was BT's intention or not it had the effect of lowering market valuations of the struggling cable franchisees. The announcement of the *Open* joint venture with Sky one year ahead of the proposed launch was encouraging already bewildered consumers to postpone their decisions on which digital transmission system to invest in, even if with hindsight, the tactic has not achieved the goal.

The Cambridge Trial was partly motivated as a retort to BT, particularly from the viewpoint of Cambridge Cable. Reports in the press quoted the BT and Cambridge camps expressing scepticism about the viability of the other's chosen technology. The decision of both sides not to proceed with those respective models of interactive TV puts these statements in some context. Announcements to the press and hyperbole serve various purposes, but should not be taken to signify genuine intention or even expectation.

The frequency and ease with which visions are disregarded by firms who espouse them, leads to the conclusion that they are ephemeral and rarely self-fulfilling unless supported by accumulated technological competence. This position differs from Fransman's (1992, 1994, 1995a, 1995b) suggestion that vision construction may be seen as "competence creating moments", that beliefs underlying visions are equated with knowledge and that both are open-ended and change. Envisioning may produce a "wish-list" and focus aspirations, but cannot be said to establish the competences that the firm will compete on in the future.

The position that this paper maintains is that technological knowledge is cumulative; it is a stock that is added-to, rather than displaced. Beliefs in visions may be path-independent, but the success of the envisioned competence building is dependent on accumulated capability. The "know-how" aspect of technological knowledge is not ephemeral in the same way as the beliefs in visions. While new techniques replace older ones, this does not invalidate the previous body of knowledge. Proven principles of achieving technical results are not refuted like the beliefs in failed visions. Furthermore `vision-failure` is often due to insufficient accounting for path-dependence, rather than the limitations imposed by this previous experience (c.f. Fransman, 1992).

These recent discussions of visions/expectations arise from the belief that there is a strong social agency in the selection of paths. Swann & Gill (1993) argue that trajectories and paradigms are shaped *not only* by accumulated competence and

technological intrinsics, but also by the third component of technological and market vision. One example they cite is Moore's Law in microelectronics. The Moore's Law case is concerned with the *rate* of technical change. The case studies presented above show a degree of social agency in choices about the *direction* of product strategy. BT possessed accumulated competences in content management that were developed through telephony and text-based data communications. It was a strategic choice to extend these competences into the multimedia domain of integrated video, audio and text. No technological path or trajectory compelled investment and engineering effort into this new area.

This is consistent with Penrose's (1995) original distinction between resources and the *services* rendered by them. The latter are effectively unlimited in number, as they are determined by the creativity of reconfiguration and innovation (Tsoukas, 1996). However, while *theoretically* unlimited in number, services (product strategies) rendered by limited resources (technological competences) are effectively limited by knowledge entry barriers. Product characteristics such as superficial design, styling, application domain, target market profiles, payment and tariffing options may be endlessly adjusted and reconfigured, but functionality and performance afforded by technological competences cannot be radically altered in the short and medium term. Strategic alliances with technically more advanced partners may be pursued, but then the strategy becomes dependent on resource bases that the firm does not control, and a careful balance must be achieved to avoid a vulnerable position.

Similarly Acorn's RISC trajectory did not determine that the company should move into interactive TV STB applications or network computing. These were decisions made within the managerial scope afforded by the firms' inherited competences. It is important to recognise however that there are very real constraints on managerial discretion. Visions need the material substance of investment in technical change to stand any chance of being realised.

They also need genuine demand in the market. At the time of the trials, Acorn's CEO's expectation was that "In the year 2000 there will be as many NCs as PCs sold... It is the next stage of bringing computing power to the masses... We expect smart cards to be ubiquitous..." and so on.[26]. This scenario is not occurring, network computing is on the decline, Oracle reduced their activities with Acorn. Acorn adopted a new strategy based on their chip technology, which has recently led to the company's acquisition by the larger Broadcom corporation. Despite its pioneering research BT dragged it's strategic feet over introducing ADSL, which by now is considered an outdated means of high bandwidth Internet access. This snapshot of a fast-moving set of technologies and markets has illustrated that any advantage in such industries is *temporary* (Eisenhardt & Martin, 2000). This is further explored in the next and final section, which moves the discussion from the specifics of the company cases and tries to use the insights gained to develop a framework of strategic decision-making and knowledge resources.

9. Discussion

[26] Interview, 10.12.96.

An important and incisive contribution to ideas around knowledge and strategy is Winter (1987) which distinguishes between the state variables of a system, that are not subject to choice over a short time span, and the control variables, which are. The plain truth is certain aspects of the organisation and the environment cannot be changed by strategy. It is also true that separating the control from the state variables is not an easy task. If the market demand for radically new products and services cannot be predicted, if the ultimate winners among rival technological standards cannot be evaluated, and if changing lanes is not easy without expensive effort and dedicated time, what can the strategist do, and influence, under conditions of uncertainty?

First, vision statements and strategy statements can be deployed to useful effect. The cases have shown that although some of the claims of the power of visions may be extravagant, they are potent tactical devices. Especially in high-tech, fast-moving markets, “pre-launch” product announcements and statements of strategic intent are often sufficient to disrupt competition or to attract investment. This is evident from the excessive valuations of “dot-com” businesses at the peak of the boom in venture capital availability in the late 1990s. Companies that had no track record of profitability, revenues or even in many cases no actual products, were nonetheless able to attract vast amounts of investment to their stock market flotation. What these companies did have were excellent public relations, media contacts and communications capability in articulating a prosperous and exciting future. Investors were literally buying visions

A second area of strategic manoeuvre and influence is entering into alliances. This has been covered thoroughly in various fields, notably the economic theoretical tradition inspired by Richardson (1960; 1972), and the subsequent strategic management literature. Alliances require careful consideration of the resources that are the source of rents, however, for protection of position. As Lazonick (1991) has outlined alliances provide the advantage of reducing competitive uncertainty – the not-knowing the plans of other actors- simply by converting it into productive (internal) uncertainty, over which the firm has more control.

There are however, other uncertainties. Technological uncertainty is critical to emerging markets such as digital media. The cases have shown how experimentation and trials of unproven technology can reduce this uncertainty substantially. ADSL had not been implemented into a working service in the field before the BT trial, and was achieved by BT’s engineers against considerable difficulty. This involved the resolution of a multitude of unknowns, such as the true bandwidth performance of video streams through copperwire cabling that had been used, abused and exposed to natural conditions over decades, rather than through shrink-wrapped cabling in clean laboratories.

The resolution of uncertainties such as these is a prime stimulus to engineers, and illustrates the subtle but strong relationship between the growth of knowledge and the reduction of uncertainty. Vincenti (1990: 46-47) has argued that decrease of uncertainty is not simply a passive accompaniment to the growth of engineering knowledge, but is itself a driver for the growth of knowledge. The impulse to achieve satisfactory degrees of certainty is often stipulated by customers and users, but is also

internalised by engineers who are motivated as much by this impulse as to improve performance.

A framework is suggested here that attempts to integrate the ideas outlined and show the dynamics between these forces and variables. It is shown graphically in Figure One for the example of technological knowledge resources. The conditions of decision-making are distinguished between the concepts of risk and uncertainty, as described by Knight (1965). Under conditions of risk the decision-maker is sufficiently confident of the probabilities of known outcomes that a numeric quantity can accurately represent the chances of their realisation. Under uncertainty, the decision-maker knows the range of outcomes reasonably completely, but is unaware of the likelihood of their occurring. However, a third condition of certitude has been identified by Loasby (1976), the condition of *ignorance*. Ignorance is the state that laypeople think of as uncertainty, Loasby writes:

> When someone says he is uncertain, what he usually means is not just that he doesn't know the chances of various outcomes, but that he doesn't know what outcomes are possible. He may well be far from sure even of the structure of the problem that he faces. (9)

This is the condition that economists have found difficult to resolve in the theories of rational choice and so Loasby argues, they have hidden it behind the bookcase and made uncertainty more manageable by giving it the strict properties outlined above. In reality, the condition Loasby calls ignorance is what strategists face much of the time, particularly in an emerging and inchoate area of opportunity such as in digital media.

But what the cases illustrate is that through experimentation and learning the conditions of decision-making may be *transformed* from ignorance to uncertainty. Given that firms possess relevant accumulated competence, new information gleaned may be processed, assessed and evaluated and through strategic thinking, outcomes and scenarios may be identified. This is precisely the experience of the BT interactive TV trial where demand and usage patterns were tested and probed, fed-back, assessed, and the service was readjusted to test further heuristics. Technical operations were designed, implemented, reconfigured and performance was monitored under an unpredictable and varying range of service demands. The final results were a series of scenarios with tested and proven demand patterns for interactive television under various tariffing and programming packages. BT's decision-makers had advanced from a condition of ignorance, not knowing the structure of the opportunity and associated pitfalls, to a fairly complete range of possible outcomes based on real-world experience and analysis; a condition of uncertainty.

The possession of appropriate knowledge resources is a prerequisite for this transformation of strategic conditions. Knowledge resources are needed in order to make sense of the incoming information. Knowledge is the opposite of ignorance, Loasby has said[27], but this transformation of strategic conditions is not a passive by-product of time, where ignorance reduces inversely with the growth of knowledge. As Vincenti insists, it is a consequence of activity working at the goal of specifying and resolving uncertainty.

Dierickx & Cool(1989) have argued that firms may sustain their advantages over time through 'asset mass efficiencies', the initial amount of a resource possessed influences the pace at which more of the resource may be accumulated, the implication being that "more is fast". The framework presented here suggests that a similar effect may accrue to *relational* asset mass efficiencies, in other words, because of path-dependency in knowledge resources, the firm may make sense of new information within its own knowledge domain, or in adjacent ones, given sufficient overlap. The knowledge base then advances and the strategic conditions alter in favour of uncertainty. Figure One tries to show this graphically in the case of technological knowledge resources, but similar dynamics should be observed with other knowledge bases. Without the necessary related knowledge resources within the firm, the strategic decision-maker cannot move from the condition of ignorance.

Any advance is however, a temporary advantage, the firm may slip down to ignorance with further events and developments. Work on dynamic capabilities in high-velocity environments has stressed the temporary nature of strategic advantages of this type. Sustained competitiveness is derived from the ability to learn quickly and reconfigure the resource base (Eisenhardt & Martin, 2000; Teece & Pisano, 1994). In effect what activities such as the trials in the case studies, R&D and many external linkages create are strategic options for the firm, providing opportunities for learning with a relatively modest financial commitment (c.f. Mitchell, 1988; Mitchell & Hamilton, 1988; Bowman & Hurry, 1993; Sanchez *et al*., 1996)

The framework attempts to show how knowledge resources can contribute to a better understanding of outcomes. It is assumed within the framework that information is being processed efficiently and that the resulting knowledge is being successfully reported to those making the strategic decisions. This is of course, quite an assumption, as the effective co-ordination of knowledge integration processes are certainly not simple and automatic, and are the subject of Grant's work (1996a; 1996b). Tsoukas (1996) has also observed that firms are decentred, distributed knowledge systems, which creates problems for strategy.

There is also the problem that those making the decisions are not necessarily abreast of the firm's knowledge base. As Tsoukas says the relevant knowledge cannot be known by any single actor *ex ante*, but even with the best information and knowledge integration processes, the wrong strategic decisions can be made. BT failed to take advantage of an early advantage in ADSL for example, regardless of the technical and operational achievement. Also the problems of hierarchical organisational structure

[27] Personal communication, 1999. In this sense, the interpretation of ignorance in the paper differs from Stirling (1998a, 1998b) who takes the ignorance concept further than Loasby, arguing that ignorance may actually *increase* with the accumulation of knowledge (1998b: 19).

according to knowledge specialism break down if knowledge is tacit (Grant, 1996b). It appears that lack of knowledge among the decision-makers is the cause of bad decisions, rather than any lack of imagination or "bounded vision".

The framework is not, however, top-down in the sense that Spender (1996) characterises "older", pre-RBV theories of strategy (*e.g*. Learned *et al*., 1965; Porter, 1980), where top management is privileged in its knowledge, devises strategies and manages by instructing subordinates to implement them. The RBV and the framework presented here recognise the emergence of strategic options through the impetus of the wider organisation, especially those working at the front lines. Engineers working with technology and marketing people working with customers generally have a more privileged position than those on the Boards of companies with regard to forthcoming trends and the opportunities and problems associated with product markets.

The paper has treated *knowledge as resource*, and therefore is perhaps implicated in Spender's (1994) accusation of the RBV concentrating only on the acquisition and protection of core resources, rather than their application. In fact, there is some confusion as to whether the RBV claims that it is the knowledge resources themselves, or the integration and transfer processes that are the pre-eminent source of competitive advantage (Eisenhardt & Santos, 2001). The framework presented here stresses the knowledge resources themselves rather more than the processes, but acknowledge the importance of the latter. We share Eisenhardt & Santos' assessment that the KBV is essentially an off-shoot of the RBV, and does not comprise a complete theory of competitive advantage. What the paper has attempted to show is the influence of knowledge resources on the conditions of strategic decision-making: in identifying opportunities and constraints, and improving the understanding of outcomes.

Appendix A: References

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Appendix B: A Brief Technical History of Acorn

Acorn was formed in 1978 by Hermann Hauser and Chris Curry. Hauser has subsequently founded a number of other high-tech start-ups in the Cambridge region. In its early years Acorn developed microcomputers in kit form targeted at the home hobbyist market of the day.

Acorn's first major success was the BBC Microcomputer. This was an important contract for the company. The BBC was selected by 90% of British schools, and over 1 million units were sold to the consumer, business and education markets. It was an appropriate machine for the early period of microcomputer diffusion, being inexpensive and user-friendly[28].

Acorn's Chief Scientist, Sophie Wilson became frustrated with the BBC's limitations. In 1985 she and a small team developed a RISC (Reduced Instruction Set Coding) processor architecture that could handle both higher level languages, as well as the hand-written software that was customary with the BBC. The chip was called the ARM, the first in a line of architectures.

As a result Acorn had a unique product; the first RISC machine produced on a purely commercial basis. This was prior to the Berkeley and Stanford University work that was taken up commercially by Sun[29]. The ARM was developed with very few engineers; only 4 man-years of effort, illustrating Acorn's ability to utilise small teams of engineers efficiently. The ARM chip performed well, given that its power was limited because of a low number of transistors. But this did mean it had extremely low power consumption that could be adjusted up or down, and was of very small size.

Acorn was adept at fitting functions onto the chip and successive versions were ahead of the rest of the industry. The ARM 3 had embedded on-chip cache in 1988, while the next generation, the ARM 250 had video capability and memory on a single chip. This was used for the Archimedes, the first and lowest cost 32-bit RISC computer, which sold for only £299. This was a significant advance for the time, as Acorn had leapfrogged the 16-bit processor generation. The Archimedes was 10 times faster than the equivalent PC chip, the 386/16.

In 1990 much of the RISC development effort was relocated to a new spin-off company Advanced RISC Machines (ARM) Ltd.; a joint venture between Acorn, Apple and VLSI. Collaborative work between the two organisations produced the ARM 7500, which had video, I/O and memory on the chip. The 7500 provides roughly the power of an Intel 486-66, but is about half the size and price.

The RISC Operating System, RISC OS was launched in 1988. This is a multitasking operating system with a graphical user interface, and has been employed for subsequent RISC computers. It was notable for introducing an anti-aliased font manager, which reduces the "flicker" of text. Anti-aliasing together with anti-twitter

[28] Models A and B cost £235 and £335 respectively.
[29] Development of RISC in the US is documented by Khazam & Mowery (1991).

technology, which smoothes graphical images, enables the display of computer-generated output on a line-based television screen.

Anti-aliasing is a subtlety that few computer manufacturers have been concerned with. However, Acorn have pursued this technology and developed a competence in it. The company's proclivity towards affordability has led research effort towards techniques such as this, which make TV-based computing feasible. This accumulated competence facilitated the development of the Online Media STB used in the trial.

The Set Top Box Application

Following the formation of Online Media, Acorn's engineers began to apply the RISC technology to the set-top box. The ARM chip was extremely useful for STBs as the low power consumption meant there were no fans needed. The noise of fans is especially undesirable for TV viewing. Also the small size of the chip meant that more components could be fitted in the machine. Low cost was another major advantage as STBs are notoriously expensive devices, as BT found with their Apple STBs. Acorn's anti-aliasing and anti-twitter expertise were an important asset for this TV-based application.

The Network Computer

The design for the STB was used as the basis for the NC reference design for Oracle. The ROM-based RISC OS was an ideal operating system, and TV compatibility was also an advantage. The STB had considerable video capability, but did not have enough memory for the computer functions specified for the NC. The ARM 7500 chip needed some improvements in speed and functionality to perform adequately as a NC. The upgraded version was called the 7500FE, which is 1/4 the size of the Pentium and costs only $35 per chip. This was developed specifically for the Oracle NC prototype.

Acorn also made use of their local contacts in the fulfilment of the NC contract. Cambridge-based ANT developed the Web browser for the NC prototype when it was needed it in a hurry, and Icon technology similarly delivered a word processor. A local design company, Design Edge provided the prototype's casing in 48 hours. This was needed because Larry Ellison's preferred "radical" design was impractical to manufacture. ANC's CEO Malcolm Bird speaks of these firms as "partners" and "colleagues"[30].

Links with Cambridge University have also benefited Acorn. In the early days of developing the RISC chips, academics at the Computer Science Laboratory at Cambridge University would send papers about RISC architecture in response to queries. The eminent Computing Science Professor Roger Needham came to give a review of the architecture of the RISC chip, as Herman Hauser wanted some outside verification. However, Acorn's links with its more commercially minded partners in the region have been more important. Sophie Wilson believes that most of the work done in the Cambridge academic network is "very esoteric" whereas Acorn's

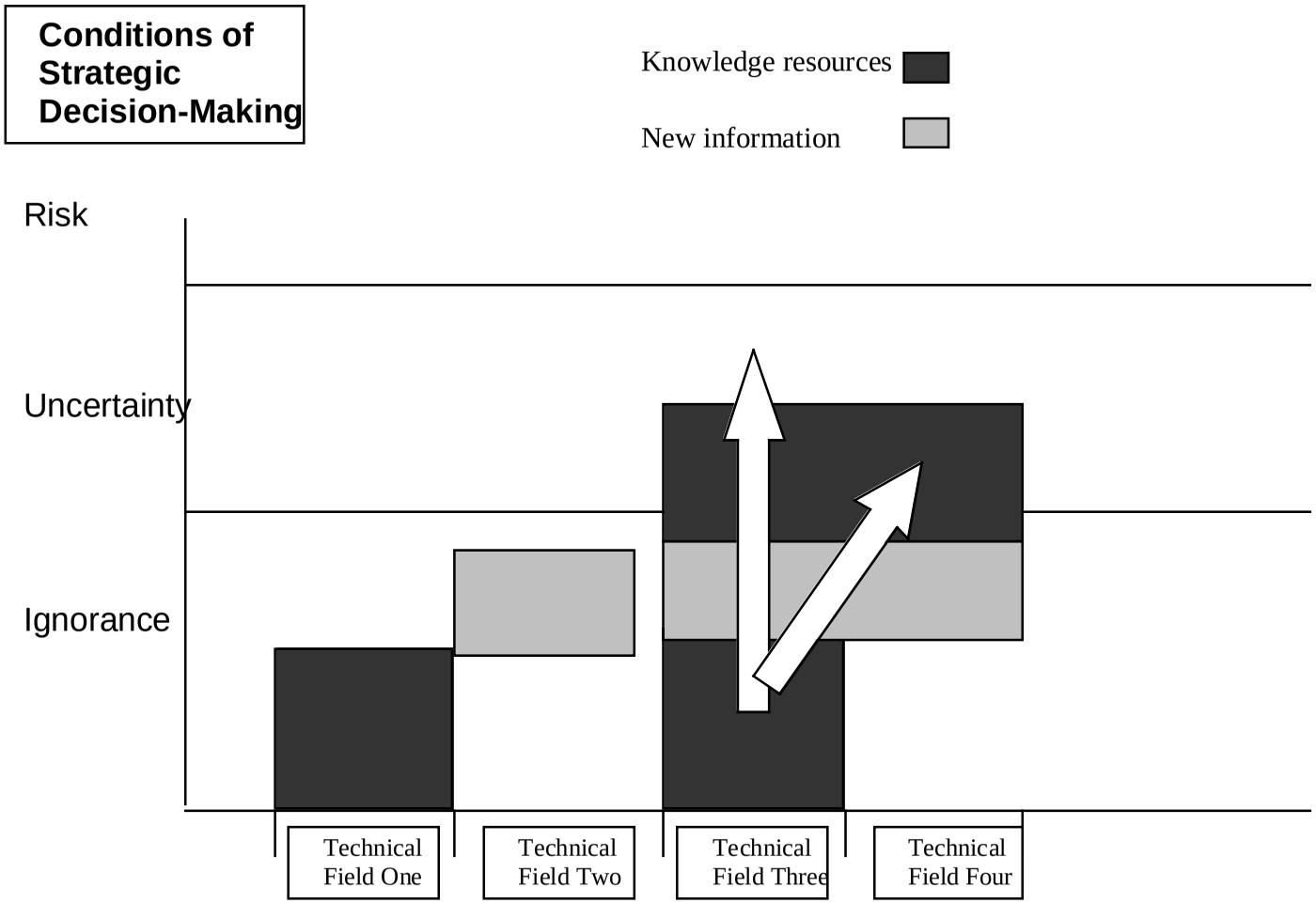
[30] Acorn Network Computing Managing Director, M.Bird, interview, 10.12.96.

concerns are to “develop the technology and sell it to Dixons”[31]. However it is clear Acorn’s privileged contacts with academe have been a source of problem -solving knowledge (*a la* Gibbons & Johnston, 1974).

This brief sketch of the directions in which Acorn’s research efforts were focused over a 15-year time frame shows that there has been a continuous evolution in Acorn’s technological development. The central knowledge base has been continually enhanced through the ongoing research into RISC technology. Concerns driving the research have been functionality, low power consumption and affordability. It is from this competence base that Acorn were able to develop the multimedia applications in the Cambridge Trial and the Oracle NC relationship.

[31] S. Wilson, author’s interview, 10.12.96.

Figure One


Conditions of Strategic Decision-Making
Knowledge resources
New information
Risk
Uncertainty
Ignorance
Technical Field One
Technical Field Two
Technical Field Three
Technical Field Four