Chapter 9
Building a New Market System: Effective Action, Redirection and Generative Relationships

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9.1 Introduction

In this chapter, we describe some episodes in the early history of LonWorks, a technology for distributed control networks.[1] LonWorks was introduced in December, 1990 by Echelon, a Silicon Valley start-up company. The launch generated considerable enthusiasm: the editor of one leading control engineering trade journal even predicted that LonWorks would do for control what the microprocessor did for computing. While that prediction still remains to be realized, LonWorks has found many applications in the past 18 years, and Echelon has enjoyed a steady if not spectacular growth over the same period. By end of LonWork's first decade, over 3000 companies had purchased LonWorks development tools, and more than 5000 products incorporating LonWorks technology had been brought to market. Annual sales of these products now probably exceed $1.5 billion. Since August 1998, Echelon has been a public company, whose shares are traded on NASDAQ. Many leading producers in the building automation and some in the process and discrete control industries now manufacture devices and systems incorporating LonWorks technology. But the adoption of LonWorks technology is by no means limited to companies that belong to these three traditional control industries. Rather, LonWorks has been successfully applied in a wide variety of industries, from transportation[2] to semiconductor manufacturing[3] to food services[4] to intelligent meter

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[1] See Lane and Maxfield (2005) and Chapter 10 of this volume for treatments of later episodes in this story.
[2] For example, the NY Transit Authority specifies LonWorks for train braking systems, LonWorks has been declared the standard for European gas station forecourts, and Raytheon has developed a fiber optic airplane control system based upon LonWorks.
[3] For several years, Echelon's largest-volume customer was a manufacturer of vacuum pumps for semiconductor manufacturing. In 1996, LonWorks was declared a standard for control networks by SEMI, a semiconductor manufacturing trade organization.
[4] One of the earliest LonWorks applications was by TruMeasur, who used the technology in 1991 to control a liquor dispensing-and-billing system installed in several Las Vegas casino-hotels.

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reading.[5] Partly directing this movement of LonWorks across vast tracts of agent-artifact space,[6] and partly in response to exigencies that this movement has generated, a new *market system* is emerging, organized around LonWorks technology itself. This chapter is about Echelon's early approach to building this market system.

What is a market system? By a market system, we mean a set of agents that engage with one another in recurring patterns of interaction. These interactions are organized around an evolving family of artifacts. Through their interactions, the agents produce, buy and sell, deliver, install, commission, use and maintain artifacts in the family; generate new attributions about functionality for these artifacts; develop new artifacts to deliver the attributed functionality; and construct, augment and maintain new agents and patterns of agent interaction, to ensure that all these processes continue to be carried out, over time, even as the circumstances in which they take place are changing in response to perturbations from inside and outside the market system itself.

A central theme in our story is the distinction between a market system and "the market," that abstract entity defined formally by economists and employed informally in the popular vernacular. "The market" is a locus of impersonal exchange activities, where agents buy and sell products with defined characteristics, at prices that – according to standard economic theory – reflect supply-and-demand induced equilibria. Economic theory accords these prices the role of principal communication media between agents, who use the information prices convey to drive the actions they take in the economy. Relationships between agents do not count for much in "the market". What matters is how each agent separately values each artifact in "the market", values that "the market" then aggregates into prices for these artifacts. Frequently, in popular narratives about developments taking place in business and the economy, "the market" is assigned the central causal role. Indeed, many of the people we interviewed and the documents we read to construct the story we tell here claim that it is "the market" that will determine LonWorks' destiny.

Certainly, "the market" is always lurking behind all of the activities we relate in our story. In the end, the success of LonWorks will be measured by the number of purchases of devices, machines and control systems that use this technology – and the success of Echelon, by the profits it generates from the sales of the LonWorks products and services that it provides. Yet it is striking how relatively minor a role "the market" actually plays in the story we have to tell. It is frequently being upstaged by activities and processes that bear little resemblance to that abstract entity that we described in the preceding paragraph. We will find participants in the emerging LonWorks market system constantly negotiating the *meaning* of artifacts,

McDonald's specified LonWorks for its experimental "Kitchen of the Future" project in 1993. Recently, LonWorks has been adopted by several large European manufacturers of catering and food dispensing systems.

[5] See Chapter 10 for an account of the Echelon-ENEL joint venture in this area, the largest single application in LonWork history. Over the past two years, Echelon has repositioned itself as an intelligent meter reader company.

[6] For a discussion of agent-artifact space, see Lane and Maxfield (2005), and Russo (2000).

both those currently in use and those that are being conceived or designed. As a consequence of these negotiations, LonWorks and its associated artifacts *take on* value – not just inside the heads of individual agents, but through social processes that require concrete social settings, which the emerging market system has to provide. Moreover, the agents in the LonWorks market system learn much more from each other than they do from prices, and beyond learning *information* that other agents already know, these agents jointly construct new *interpretations* of themselves and the artifacts around which their activities revolve, interpretations that drive action in hitherto unexplored, even unimagined, directions. Finally, the agents carry out these activities in the context of *relationships*, the most important of which are those we call generative (Lane & Maxfield, 2005).

The relationships between agents are constructed upon *scaffolding* that the emerging market system must provide: *agent-space structures* like standards organizations, users groups and trade fairs; *communication media* like journals, newsletters, and web sites; *rules* that govern both "market" and non-market interactions between the agents and artifacts that participate in the market system; and *shared attributions* about agent *roles* and artifact *functionality*. Without such scaffolding, to speak of "the market" deciding for or against LonWorks makes little sense. And it will not be "the market", but a complex network of agent interactions that will bring the scaffolding and the system it supports into existence.

How are market systems constructed? The problem we have to consider in our story is not just what a market system *is*, but how it is *constructed* – or, better, *emerges*, since the structure it assumes is frequently quite different from what the agents whose interactions are directed towards bringing it into being intend. In this chapter, we seek to understand some of the difficulties in generating *effective action* for agents that participate in the construction of the market system. To study effective action, we concentrate on the actions and attributions of the people who work for Echelon. We do this for two reasons. First, we have access to considerable information about what Echelon actors did and what they said about why they did it. We have interviewed many people associated with Echelon intensively and repeatedly, from February 1996 through November 1999. In addition, our interviewees have provided us with various internal documents, by means of which we have been able to monitor some processes that leave no trace in the public record. Second, Echelon not only developed the core LonWorks technology, but also has taken a position of leadership in building the market system around LonWorks. Hence, it has played an important role in many, though by no means all, of the processes we seek to understand.

In our discussion of effective action, we highlight three concepts: the role of *generative relationships* in constructing new attributions about the identity of agents and the functionality of artifacts; *redirection*, the process by which an agent changes orientation in mid-course, on the basis of attributions about where current interaction streams are flowing; and *aligning attributions*, processes in which particular agents attempt to bring everyone involved in the market system to share certain attributions about the identity of key system agents or artifacts. Section 9.4 describes an important Echelon redirection episode. Section 9.5 tells about some difficulties

Echelon encountered in establishing generative relationships with other key agents in the LonWorks market system.

Why the LonWorks story? The LonWorks story has two features that make it a particularly interesting case study of the processes through which market systems come into being. First, LonWorks is a network technology, and market systems organized around networked artifacts play an increasingly important role in modern economies. Some of the most interesting features of the LonWorks story involve the construction of the material and cognitive infrastructures that all market systems organized around networked artifacts require. Second, LonWorks is about distributed control, and in following its story we may gain insights into how control is distributed: in artifact space, in the construction of ever more complex local operating networks; and in agent space, in the construction of a market system by the heterogeneous agents that will populate it.

Network infrastructure Like railroads, electric power, telephony, and data communications, LonWorks is a network technology. Like these other network technologies, LonWorks has the potential to change the way many different economic activities and processes interact with one another, and in so doing to generate new kinds of economic processes and functionality. However, this potential can only be fully realized after a great deal of network infrastructure is already in place, and the costs of putting all this infrastructure in place must be borne by someone, in some way.

Unlike railroads, electric power and telephony, distributed control technology does not require a huge upfront investment in physical infrastructure, like railroad tracks, power grids and telephone lines. In fact, the costs of wiring and control modules in a distributed control system may be lower than those for alternative technologies that lack the potential to deliver the extra functionality that distributed control makes possible.

But there are two other types of infrastructure that are necessary for distributed control technology and are very costly to produce. First, there is the core technology on which distributed control depends: communication protocols, integrated circuit designs, network operating systems, application interfaces, media-specific communication hardware, general and application-specific control algorithms, and tools for developing, installing, debugging, monitoring and maintaining control networks. This core technology constitutes infrastructure, in the sense that it provides the essential building blocks for distributed control networks, but unless embedded in such networks it has no value in itself. Someone must bear the cost of developing this technology before it can be instantiated in physical artifacts, which may be combined into control networks that deliver functionality that others may come to value.

The second kind of network infrastructure is cognitive, and its associated costs may be substantial. What allows control to be *distributed* is that there are many different control points – sensors and actuators – in most modern control systems. In principle, at least with LonWorks, control can be distributed down to the level of the individual sensors and actuators. Herein lies one of the greatest advantages of distributed control: the possibility of enabling previously distinct devices, perhaps components of separate systems, to communicate directly with one other and to control directly one another's operations. In this way, whole new levels of system functionality may be achieved. This possibility can only be realized if all the devices to be combined are already equipped to function as nodes on a distributed control network. The simplest and cheapest way to guarantee this is to internalize the control potential of each device – that is, to design and produce the devices with all the necessary control hardware and software already in place. As we shall see, this is the strategy adopted by Echelon, based upon the Neuron chip.

But here we encounter a serious chicken-and-egg dilemma. To create the potential for their artifacts to generate new kinds of functionality through connection to a distributed control network of other artifacts, producers must be already convinced that this possibility warrants the expense of incorporating the necessary equipment. Clearly, the strength of this conviction depends upon how many other producers of artifacts share it. Thus, the more producers that incorporate the distributed control technology, the easier it becomes for the next producer to decide to incorporate it as well. For the technology to be widely adopted, a kind of *belief infrastructure* has to be constructed: enough producers have to believe that their products' value will be sufficiently enhanced by incorporating the necessary equipment to justify that belief; and then the success of the technology in generating new functionality by combining products produced by the believers must convince enough other producers to equip their product for the technology, until an avalanche of adoptions is generated, and the technology takes off. LonWorks' promoters must figure out how to construct this belief infrastructure – and how much it will cost to do so.

Distributed control in agent-artifact space We shall argue that control of the LonWorks market system is in fact distributed among a number of agents and structures in agent space. In 1988, when Echelon was formed, the company constituted the entirety of the proto-LonWorks market system and hence, tautologically, "controlled" it. Building the market system entailed distributing this control, a process fraught with difficult choices for Echelon executives, with consequences that, we shall argue, would have been impossible to foresee *a priori*. Discovering where the loci of control of the market system lie, and how control is exercised from and among these loci, are recurrent problems in our narrative – for us, as well as for the agents about whom we write. In our story, there will be a continuing counterpoint between distributed control in artifact space, achieved by LonWorks technology – and distributing control in agent space, to construct a functioning LonWorks market system.

9.2 Planning for Control: 1985–1988

Our story begins in the early 80's, with an idea. A.C. "Mike" Markkula, co-founder and then president of Apple Computers, contemplating the decreasing size and cost of computers, asked himself, "What will happen when a computer costs only $1 and weighs only a few grams?" At that size and price, he thought, most things can have their own embedded computer. But what would these little computers *do*?

Markkula imagined two broad classes of applications. First, by adding intelligence and memory to the things in which the computers are embedded, these things may be able to perform their accustomed functions better and faster. A thermostat, for example, could be programmed to switch automatically between different heating and cooling modes for different times of day, days of the week, and months of the year. Second, and more important, if the computers in *different* things could *communicate* with one another, the things might in combination provide new functions that neither could provide alone. For example, an occupancy sensor, a light switch and a thermostat might "cooperate" to begin heating or cooling a room as soon as someone enters it – and to turn off the lights after everyone leaves. Or when an alarm clock rings to wake a person up, it might also send a message to a coffee pot to begin brewing that person a cup of his favorite morning beverage. In general, by *combining* different kinds of things, and allowing them to *control* what each other is doing, a *new kind* of thing, delivering a *new kind* of functionality, can be created.

In 1985, Markkula set up a private company, called ACM Research. The company hired a small group of engineers from Apple to begin developing a prototype for a small, embeddable computer and a communications protocol that would allow these computers to talk to one another and control aspects of one another's operations. By mid-1988, the ACM Research engineers had designed an integrated circuit, called the Neuron, which could be connected together by means of a variety of different media to form a Local Operating Network (LON), which they believed was capable of handling any problem involving "on/level/off" control. At that point, Markkula decided to form a new company, to be called EcheLON,[7] which would develop the Neuron, the communications protocol and the other technology needed to implement the LON idea, and would then bring LONs to the market.

Markkula and his associates drafted a business plan for Echelon, which they circulated to prospective investors in November, 1988. The plan began by making explicit the analogy between the LON idea and the on-going revolution in data communications, which was then in the process of creating the new workplace paradigm of distributed computing, based on Local Area Networks (LANs). "Personal computers are tools for our intellectual being," the plan proclaimed. "They extend our ability to think. Echelon networks are tools for our physical being. They extend our ability to do."

Through LONs, society would have available to it "millions of tiny computers that help us do things." These "things" fell into three conceptual categories: communication, identification, control. The networks would allow the artifacts in which the computers were embedded to communicate to each other what they sensed of their own states and their local environments. Since each computer would have a unique identification number, any artifact with a computer inside attached to a communication network could be "located" and distinguished from otherwise apparently fungible artifacts. These artifacts could then be armed with appropriate programs stored in their computers' memories. Finally, the computers could execute control actions with respect to the artifacts to which they were attached – for example, if the artifacts were light switches or motors, by turning them on or off or changing their levels of brightness or speeds of rotation.

[7] Soon to be simplified to Echelon, as we do hereafter in our narrative.

The core LON technology would consist of four elements: the *Neuron chip*, an integrated circuit with four processing units, shared memory (RAM, ROM and EEPROM) and three input-output ports;[8] a standardized communications protocol, subsequently called *LonTalk*, by means of which Neurons could formulate and interpret messages for and from other Neurons; *transceivers*, by means of which communication channels in various media (twisted-pair wire, coaxial cable, radio frequency, infrared – even a.c. power lines) could connect Neurons into a network; and a *development tool*, with which networks could be designed and nodes programmed and commissioned. A first essential task of the new company would be to develop this core technology, building on the work already accomplished by ACM Research.

According to the Business Plan, the primary advantage of LON, as compared to existing models of control, was a trio of related concepts: *universality, standardization*, and *interoperability*. The artifacts around which control systems were constructed differed markedly among the various control industries of this period: pneumatic and electrical signaling; PLC's, FCU's, and centralized computers; as well as unlimited numbers of "dumb" sensor and actuator devices . The universality of the LON solution provided the way out from this Babel in the world of control: all control systems – whether from the control industries, buried inside machines,[9] in cars, airplanes, homes or factories – would consist just of networks of sensors and actuators, each equipped with a low-cost Neuron chip.

Universality in turn implied the possibility of *standardization*: if every control system were a LON, they could all speak the same language and share the same basic architectural principles – and even, if it were desirable, be connected onto the same network. Just as Ethernet was rapidly becoming the standard for computer LANs, permitting different kinds of computers to share data, programs and peripheral resources, LonTalk as a universal standard would allow virtually any kind of device to share status and control information with any other.

Finally, standardization implied the possibility of *interoperability*. Devices belonging to different systems, manufactured by different companies, would be able to work together to deliver new functionality. For example, if a building's security system and lighting system were on the same LON, an occupancy sensor from a security system could notify all the light switches in a room when the room was empty, and the switches could be programmed to turn off their lights in response to this message, even if the systems were manufactured and installed by companies that knew nothing of each other's products.

To the authors of the Business Plan, the advantages to be gained from universality, standardization and interoperability were as substantial as they were self-evident. They predicted a very rapid and widespread adoption of LON technology. The markets they expected to penetrate with LON technology included residential

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[8] Which included programmable analog-to-digital and digital-to-analog converters.

[9] Or standing adjacent to the machine it controlled, as a separate "box," as in computerized numerical control (CNC) for machine tools.

construction, vehicles, retail and distribution, building automation, factory control,[10] aircraft, agriculture and medicine. The most important functions to which the technology would be applied included security, identification, HVAC (that is, heating, ventilation and air conditioning), inventory, illumination, electronic control, and recording and monitoring.

To recruit companies to adopt LON technology, the Business Plan foresaw two stages of activity. First, Echelon would target a small number of important players in the key industries listed above. About a half dozen of these companies would become "alpha" partners, who together with Echelon would develop first-generation LON products, which would "PROVE the technology and showcase real products for real markets." These partners would benefit from the usual first-mover advantages in their markets. Next, Echelon would carry out a "blitzkrieg" strategy, with a highly public launch, featuring testimonials from their early adopters, followed by seminars for engineers and end-users held around the world. These seminars would be essentially open to all-comers, and it was anticipated that what would emerge, would emerge: better not to try to foresee all the ways in which ingenious designers might use LONs to solve their industries' problems.

How could Echelon position itself so that it could stay on top of the distributed control wave? The Business Plan raised three problems that Echelon must solve. First, it must take care that LON and not some competitor became the standard distributed control technology. Second, it must guarantee that interoperability could be achieved among all the products from every supplier who adopted the LON standard. Third, Echelon must earn substantial profits from growth in the markets for products that used LON technology.

With respect to the first problem, one of Echelon's first priorities must be to find *allies* to quickly capture the market for LON and the Neuron. Echelon, after all, had to start small, and yet the battle for LON would have to be fought over a huge swath of agent space. The most important allies – even more important than the early adopters – would be semiconductor manufacturers, to whom Echelon would license the right to produce Neurons. Semiconductor manufacturer partners were important for two reasons. First, they already had the equipment and the competence to produce integrated circuits, neither of which Echelon could hope to achieve without a huge infusion of initial capital. Second, semiconductor manufacturers were large companies, with extensive marketing and sales resources they could devote to LON technology, in which they, as well as Echelon, would have a stake. To make an Echelon alliance more attractive for semiconductor manufacturers, Echelon would charge a very low royalty rate for the Neuron chip. This would also accelerate the rate of adoptions of LON, since the cheaper the chip, the greater the sales – and the greater the sales, the more the semiconductor manufacturers would be able to drive production costs even further down. As a consequence of this policy, though, Echelon would need to find its own profit sources elsewhere than from Neuron sales.

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[10] Little was made in the Business Plan of the distinction between discrete and process control, since from the abstract LON point of view, the differences seemed only questions of detail.

The semiconductor partners were also the key to the proposed solution to the problem of guaranteeing interoperability. Every standard, at least in information technology, leaves some design leeway for manufacturers to differentiate their products from competitors'. The problem is to make sure that these differentiating features do not compromise the ability of different products based on the standard to interoperate with one another. The Business Plan's solution to this problem lay in its licensing agreements with semiconductor manufacturers and with original equipment manufacturers (OEMs) – the companies that produced artifacts that incorporated LON technology. The OEM license would require that the artifacts they produce "comply with Echelon specifications and that new features, etc., be approved by the LON Systems Standards Committee (LSSC) before they are released." The Plan did not spell out the constitution of the LSSC. It was clearly meant to be a standards committee with a mandate broad enough to cover all the industries to which LON technology might be applied. Its task would be "to maintain standards, arbitrate conflicts, and coordinate network issues so that all users are assured of compatibility."

Of course, without some sort of teeth, merely signing a license agreement could hardly ensure that OEMs would comply with LSSC interoperability standards. The Business Plan proposed to supply these teeth through the license that the semiconductor partners sign with Echelon. This license would require the semiconductor manufacturers to sell Neurons only to customers approved by Echelon. If that provision were enforced, any rogue company producing non-interoperable LON artifacts would be unable to purchase Neurons.

Why should the semiconductor manufacturers allow Echelon to veto potential Neuron customers? Two reasons: the semiconductor manufacturers would be Echelon's partners, tightly bound to them through engineering, marketing and sales co-ventures, and so could be won over to act in what Echelon regarded as the interests of the whole LON community; and, guaranteed interoperability would be in the semiconductor partners' *own* interest, since interoperability was the key to the continuing expansion of LON functionality and hence the market demand for Neurons. In contrast, Echelon could hardly expect to exercise much direct control over the anticipated horde of OEMs, some of whom might well prefer to produce systems that did *not* interoperate and hence whose components could not be substituted with cheaper or better products made by competitors.

Where would Echelon's profits come from? The Business Plan put forward three possibilities. First, Echelon would develop several product lines, consisting of devices and tools for constructing LON networks: the Plan mentioned explicitly development tools and "subassembly modules," for example Neurons mounted together with transceivers. Second, "at some time in the future, the company may elect to enter one or more of the end markets that have developed around Echelon technology." Third, Echelon may invest in companies that plan to develop LON applications. In this way, the company can hold a "small percentage stake in the entire LON industry."

As we have already noted, the Business Plan is a very optimistic document. Its market analysis predicted that Echelon revenues would exceed $1 billion by 1995. The next step was to make Echelon happen – and start building.

9.3 The Birth of Echelon – Raising Capital, Recruiting People: 1988-June 1989

In mid-1988, Echelon was just an idea, a handful of employees, and designs for a chip and a communication protocol. To build a company that could develop and market control network components and systems, Markkula thought that he needed to raise about $15 million in capital and recruit a management team. Given his current commitments at Apple and elsewhere, he had no intention of leading the company himself. His choice to head Echelon management was another successful Silicon Valley veteran, M. Kenneth Oshman, founder and ex-CEO of ROLM Corporation, the company that introduced digital switching and computers to telephone PBX's and successfully challenged the American telephonic giant AT&T for leadership in that business (Lane & Maxfield, 1997).

Like Markkula himself, Oshman was frequently described in the popular and business press as a "Silicon Valley legend." ROLM had been the first Silicon Valley start-up to take on an established, traditional monopolist like AT&T in one of its key product lines and win. Though he had proved to be an astute businessman, Oshman was by training an engineer. A native Texan, he graduated from Rice University, and then earned a Ph.D. in electrical engineering at Stanford before founding ROLM in 1969.

In 1984, IBM acquired ROLM. Less than two years after the sale, Oshman left IBM. While he was serving on the board of several companies, including Sun Microsystems, he had no current full-time commitments in 1988. Markkula approached Oshman before the business plan was completely drafted. The two men came to an agreement: Oshman would purchase a major stake in the company from Markkula and would become CEO of Echelon, while Markkula would serve as Chairman of the Board.[11] The two would collaborate on the final revisions of the business plan and would raise the rest of the capital they thought Echelon would need before the company could support itself from its own revenues.

Many a hopeful entrepreneur with an idea and a prototype faces the step of raising capital, necessary though it may be, with considerable trepidation. After all, most venture capitalists turn down many more proposals than they accept, and even when they do provide funds, the entrepreneur must as a consequence accept a diminished share in whatever financial rewards his ideas eventually generate and in the control over the company he has set up to bring his ideas to market. More than one entrepreneur has even found himself ousted as head of his own company by a Board of Directors controlled – or at least strongly influenced – by representatives

[11] Within a year, Oshman became Chairman and Markkula Vice-Chairman of the Echelon Board.

of his venture capitalists, anxious to salvage their investments with a timely and profitable exit strategy. Even when the entrepreneur keeps his position, he may have to abandon a cherished development strategy if it comes into conflict with the venture capitalist's exit strategy for the company.

Markkula and Oshman had no such problems. Between them, they had close relationships, both personal and professional, formed over many years, with most of the leading Silicon Valley venture capitalists. Based on their respective past business successes and the intrinsic merits of their project, they neither foresaw nor encountered any difficulty in obtaining the amount they sought. In fact, so as not to disappoint some of their prospective investors, they actually raised more capital, around $25 million, than they had originally intended.

Several venture capitalists were allowed to invest in the new company. Among them were Kleiner Perkins Caufield and Byers, probably the premier Silicon Valley venture capital firm; Arthur Rock, a pioneer Silicon Valley venture capitalist, who had been the lead investor in all three of the start-ups for whom Markkula had previously worked – Fairchild, Intel and Apple; and Venrock Capital Partners, the Rockefeller brothers' venture capital arm, which had important connections among financial and industrial concerns outside the Valley that would later prove valuable to Echelon. In fact, in 1994, Peter Crisp of Venrock, who was the one representative of the venture capitalists that Oshman and Markkula placed on the Echelon Board, was instrumental in obtaining an additional $10 million in capital from George Soros' Quantum Fund, at a time at which both the capital and the prestige associated with its source were important for Echelon's continuing development.[12] In addition to the venture capitalists, Markkula and Oshman gave a few Silicon Valley friends the opportunity to invest in Echelon.

By mid-1989, the members of Echelon's Board were Markkula, Oshman, Rock, Crisp and Robert Maxfield (a ROLM co-founder and Oshman's closest collaborator there). Larry Sonsini, head of the powerful Silicon Valley law firm Wilson Sonsini Goodrich and Rosati, joined the Board in the spring of 1993. As in most Silicon Valley start-up companies, the Board played an important role in Echelon's development. Rock, Markkula, Oshman, Maxfield and Sonsini were all linked to the network of successful Silicon Valley entrepreneurs, and thus they were connected to leading executives in most of the important Valley semiconductor and computer companies. These connections frequently vastly amplified Echelon's actual "market power", and provided the still-small and profit-less start-up access to key people in these companies, through which negotiations could be undertaken and, occasionally, partnerships attained. For example, in 1993 Rock arranged a meeting between Oshman and the CEO of PG&E, whom Rock had interested in LonWorks technology. As a member of Intel's Board of Directors, Rock also helped to catalyze a joint Intel-Echelon demonstration project in home automation for the Comdex trade show in 1994. Sonsini helped initiate discussions between Echelon and Packard Bell over

[12] In 1995, Crisp also helped convince the president of Otis Elevators to adopt LonWorks technology.

home automation strategies in 1995. Oshman, a member of Sun's Board, initiated several cooperative projects between Echelon and Sun and various Sun initiatives, like GINI and JavaSoft. In addition, Sun CEO Scott McNealy presented a rousing keynote address at the May 1996 LonUsers show, in which he launched the concept of JavaLon, the union of LonWorks control networks with TCP/IP-based communication networks. Later, this idea was further developed in partnership with Cisco, the leading manufacturer of hardware for the internet. The link with Cisco was first established through an ex-ROLM employee, Steve Behm, Cisco Vice President for Global Business Alliances. On several occasions, Behm helped push along temporarily stalled negotiations involving Echelon and Cisco employees lower down than he in the company hierarchy. A final example: in 1995, lobbyists of the EIA (Electronic Industries Association), a powerful trade association, attempted to insert a clause into the massive federal bill de-regulating the telecommunications industry that would have effectively mandated a competitive standard (CEBus) for home automation. Echelon was able, with the active participation of its Board members, to put together very quickly a powerful cross-industry coalition, including Apple, Intel, Sun, Stratacom,[13] Detroit Edison,[14] Scientific Atlanta, Motorola[15] and others, which blocked the initiative – an action unthinkable for other companies of Echelon's small size (about 120 employees in 1995) and relatively minor market presence (1995 annual revenues about $20 million).

For Board members to exercise their personal networks in behalf of Echelon, they had to be kept informed about Echelon activities, projects and strategies on a regular basis. Oshman sent a letter to Board members every month, in which he summarized recent performance and prospects for the company and occasionally raised deeper strategic questions that he wanted to discuss at the next Board meeting. Moreover, from the company's inception, the Board met regularly, usually every other month. At these meetings, they heard reports from Oshman as well as other key executives, in particular the Vice-Presidents of Marketing, Engineering and Finance. In addition, Oshman frequently solicited their opinions, advice and concurrence, especially on financial and key strategic questions. So Board members knew a lot about Echelon's activities, projects and strategies, at least from the point of view of the company's top management. But because of their ties of friendship and collaboration with Oshman, much preceding their work together at Echelon, and their genuine deep respect for his intelligence and management ability, the Board rarely challenged Oshman's ultimate authority in the company: they were his friends, advisers, helpers, not impersonal skeptical overseers.

After Oshman became CEO in November 1988, he started hiring his new management and engineering teams. ACM Research had been dominated by ex-Apple employees; Echelon quickly took on a new, ROLM flavor. The Vice President

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[13] Stratacom's CEO had been a ROLM Vice President, who later accepted a seat on Echelon's Board of Directors.

[14] Detroit Edison had invested $10 Million in Echelon.

[15] Motorola was a semiconductor partner and investor in Echelon, with a seat on the Echelon Board of Directors.

for Finance, Oliver ("Chris") Stanfield, had worked for ROLM, as had two of the four people that comprised Echelon's marketing department in 1989. But the real focus of new hires, and of ROLM influence, was in Engineering. By the beginning of March 1989, Echelon had twenty-seven full-time and two part-time engineers on staff. The four key engineers – the Vice-President of Engineering, the System Architect, and the Directors of Hardware and Software Development – had all been ROLM employees. Every other engineer, many of them also ex-ROLMans, reported to one of these four men. The ex-Apple engineer who had directed engineering for ACM Research stayed on awhile as head of project planning, but he left Echelon in 1990. Several others from the ACM Research days stayed longer. In 1996, a recently hired new Vice President of Engineering (another ex-ROLMan) reported to us that there was still some resentment among these people about alleged "favoritism" granted to ex-ROLMans. Favored or no, the ROLM engineers who took over Echelon Engineering had excellent academic backgrounds, a record of superb engineering accomplishments at ROLM and later ports of call – and a measure of financial security, obtained from their ROLM stock options. It was a group accustomed to one another and to success.

One thing, though, that the group lacked was any prior experience in the techniques and problems of bread-and-butter control engineering, as practiced in the existing control industries. Not a single one of the new Echelon employees was hired from these industries. This pattern endured. As it expanded, Echelon continued to hire from Silicon Valley. In marketing as well as engineering, Echelon sought smart engineers who knew a lot about computers, digital logic and analog electronics. Given that most engineers who worked for the mainly Midwestern-based control companies had neither the academic backgrounds, computer experience nor Valley style that Echelon sought, they would have been unlikely to get jobs at Echelon – or to prosper, had they somehow been transplanted there. Not until fall, 1994 did Echelon hire its first employee with a controls industry background (see Lane & Maxfield, 2005 for the story of how he landed there and what happened as a result).

In this respect, Echelon was carrying on a Silicon Valley tradition, and specifically following ROLM's example. ROLM started as a militarized computer company. Its founders understood computers and what one could do with digital logic. When they looked about for a business into which they could expand, they were intrigued by the possibilities that digital switching and computer control might open up for telephony. But they did not know very much about telephones. Even when they hired an engineer to design their first PBX, they recruited Jim Kasson from Hewlett Packard, the Silicon Valley digitizing company par excellence, rather than seeking someone from AT&T, Western Electric, or Northern Telecom, who knew something about PBX's and what they did. In the Valley in general, and ROLM and, later, Echelon in particular, there was the sense that if you had a group of smart, technologically avant-garde engineers, you could solve any problem. Too much "application area" experience often turned out to be more a hindrance to creativity than an advantage in itself.

The first important task facing the new Echelon engineers was to review the existing designs for the Neuron chip and the LonTalk protocols. At the same time, the small marketing group began making contact with potential early adopters in a variety of industries, sounding them out about their interest in applying LonWorks networks in their products. Through the first months of 1989, a picture began to emerge, considerably at variance with the rosy vista of the Business Plan.

9.4 Crisis and Redirection: June 1989–1992

By June 1989, the engineering and marketing reviews were nearly complete, with discouraging results. The logic of universality, standardization, and interoperability, leading to steadily decreasing prices for Neurons and increasing numbers of new markets for LonWorks, no longer seemed compelling to the Echelon management team.

To begin with, different applications seemed to have very different control requirements. For example, HVAC (heating, ventilation and air conditioning) control algorithms appeared to require more memory than the current Neuron design could provide, while many industrial control applications seemed simply too complicated to be configured in Neuron-based networks. In fact, potential customers from the process control industry seemed interested in the Neuron only as a communications device, for which they would be willing to pay only $1–$2 per node. Moreover, at the other extreme of application complexity, most embedded control problems could be solved more cheaply with application specific integrated circuits, and so the additional but unused capabilities of the Neuron would price it out of this market. And there were other, more specific problems with respect to particular applications. For example, home security companies were less interested in the possibility of integration of security systems with other home automation systems than they were in the costs of power. Since security systems are always on, customers wanted them to consume as little power as possible, and the Neuron's power requirements were several times higher than the current industry norm.

Some of these problems were tied to specific Neuron design decisions that could be corrected in the design revision that now seemed inevitable. However, the deepest problem seemed not to be about the Neuron design, but with the very concept of distributed control networks as a universal control solution. Distributed control networks might just be too complicated to be economical for embedded control, while a hierarchical control architecture might actually function better than a flat network architecture for controlling complex systems. If this were indeed the case, the potential market for distributed control networks had still to be defined, and would certainly be much smaller than envisioned in the Business Plan.

As if all this were not enough, the Echelon marketing people had encountered two other unanticipated difficulties in their interviews with potential customers. First, they found that initial enthusiasm about the possible advantages of distributed control networks all too frequently dissolved into skepticism as soon as the discussion turned to implementation details for particular product lines. Second, when the potential customer's technical staff was brought into the discussion, symptoms of the dreaded NIH syndrome ("not invented here") appeared, and the temperature would begin to cool considerably. Forging partnerships with customers to develop LonWorks-based products was beginning to appear substantially more difficult that it had originally seemed to the authors of the Business Plan.

All these problems meant serious trouble for Echelon. First, it was now clear that the time it would take to develop the core technology would be substantially longer than originally anticipated, since the Neuron and LonTalk would have to be redesigned from the ground up. Second, while a huge potential market might still exist for distributed control networks, it was no longer obvious that penetrating the *existing* control industries – especially industrial controls, HVAC and embedded controls – was feasible. Thus, the work of building wholly new control markets would have to assume a higher and earlier priority than had been envisioned previously. So the problem was not just what to do and when to do it, but how to pay for it as well, since the hoped-for revenue streams from Echelon products now appeared shallower and farther off in the future than they had six months before.

The Echelon management team outlined four possible courses of action to the Board. The first option was to go back to the drawing boards and invent a new solution. Second, Echelon could select and then enter a few niche system businesses for which the present solution seemed most promising. Third, the company could try in any case to create a "networking business for control systems," with a restricted definition for the target control problems to which such networks might be applied. Fourth, the Board could decide to fold the company and return to the investors what remained of their investments.

The management team advised against folding the company. The idea of distributed control networks still seemed too promising to abandon. Moreover, semiconductor partner Motorola was becoming very enthusiastic about LonWorks' future and was very eager to press forward, eager enough to agree to help fund Echelon research and development costs over the next three years in the form of licensing and prepaid royalty fees.

The Echelon management team's proposal to the Board combined elements of each of the other options they had outlined. First, Echelon should narrow its focus to applications that "involve simple on-off, message-based control, and possibly ID applications as well." Within this focus, it could then target a small number of specific markets and evaluate the possibility of creating a system business in each of them. Then, "after we are successful in establishing one or more revenue producing businesses, we will [re]examine the possibility of developing and promoting a general solution to our targeted subset of applications, and of making the establishment of this general solution a good business opportunity for Echelon."

The management team offered examples of niche system businesses within the proposed focus area, all of which Echelon marketing people were currently investigating. These examples included efficient diagnostic services for LANs, shelf tags for retail and warehousing applications, load-shedding devices to redistribute demand for electricity and thus lower the cost of power, commercial lighting, home automation systems (to compete with X-10, the current leading network technology), transceivers, smart office furniture, a home controller with a television interface accessed via touch-tone telephone, and traffic monitoring. Echelon management emphasized two particularly attractive features about entering one or more of these businesses as quickly as possible. First, it was the quickest path to a revenue stream that could pay for developing more general LonWorks technology. Second, wrestling with the real problems of an application might help Echelon learn how to define better just which features that general technology ought to have. For both of these reasons, finding the right niche system businesses and plunging into them could boot-strap Echelon from its present difficulties to a position from which it could regenerate its quests for standardization and interoperability.

At the same time, though, the management team advocated redesigning the core LON technology and, with better designs in hand, continuing to pursue OEM business opportunities.[16] The way to manage the redesign, they argued, was to "optimize the protocol, neurons, development system and transceivers [that is, the core LON technology] for communications, simple control, and identification" applications. From this optimized core technology, Echelon could begin to produce "generalized products for OEMs." Such products might include modules that integrated neurons and transceivers in a form factor suitable for a particular application environment, as well as network management software tools.

At this point, a redirection was certainly underway at Echelon, but it was much too early to speak of any strategy shift. Rather, the management was proposing several parallel lines of search-through-action, with a rough ordering on which lines to pursue first. In fact, several projects were already underway, each aiming to find a partner to explore a possible LonWorks-related business opportunity. Meanwhile, several different groups of Echelon engineers were simultaneously fixing problems in the existing neuron design and rethinking the neuron architecture and the LonTalk protocol.

In addition, another process was underway at Echelon. For the management team's proposal to the Board represented not merely a redirection of Echelon's *activities* but of its emerging attribution of its own *identity*: its collective sense of "who" Echelon was, what it did and how it did it. In particular, the critical review that Echelon had undertaken challenged two fundamental assumptions about its identity as set forth in the Business Plan. First, Echelon was abandoning its claim that LonWorks represented a universal solution to the problem of control. Second, the company was reversing its temporal business priorities from the order announced in the Business Plan: it would seek *first* to enter specific "niche" businesses, and *then* to develop a general control networking business. As such, Echelon would not be, first and foremost, a "technology provider," the primary role the Business Plan had assigned to it.

Of course, agent identities do not change quickly. In particular, while they may be partially *shaped* by documents like the management team's proposals to the Board, they are hardly *established* by them. They emerge from histories of interactions and

[16] Both the revised LonTalk protocol and the Neuron 2 design specifications were completed by November 1989. First silicon versions of the Neuron 2 were completed late in 1990. The revised Neuron had three instead of 4 processors, two to handle communication and one for applications; RAM, ROM and EEPROM memory: and 11 I/O ports.

attempts by the participants in those interactions *collectively* to make sense out of what has happened to them, providing patterns to induce an order out of the ebb and flow of contingency.

In fact, neither of the attributional shifts about Echelon's identity described above stabilized within the company. Paradoxically, they were undone in the course of the very activities that were initiated as deliberate attempts to enact them. To see how this happened, we focus for the rest of this section on two of the processes set in motion by the crisis and ensuing redirection: the search for a *system business* to enter; and the emergence of an *identity* that made sense of, and provided a future orientation to, the activities in which Echelon found itself engaged in the course of its redirection.

Searching for a system business: the Smart Office Furniture story In the summer of 1989, the Echelon marketing group tried to find partners for several system business development possibilities. The guiding assumption was that the partner would pay a substantial portion of the development costs and would do the lion's share of the marketing, installation and maintenance services associated with the resulting product. Only one of these efforts survived as a viable action option at the end of 1989. The product was to be "smart office furniture", and the partner SCI,[17] the office furniture market leader.

RK, one of the new hires in Echelon's marketing group, had conceived and developed the idea of smart office furniture in the context of conversations with a lock manufacture that eventually decided against adopting LonWorks for its own products. RK noted that competition among the leading companies that manufactured and installed office furniture was intense and that the companies' dealers were eager to find ways to differentiate their products from their competitors'. RK's idea was to target the "work area" sub-market, in which office furniture companies produced (and their distributors sold and installed) an entire suite of furnishings, from electric outlets to desks to file cabinets, for the work sites occupied by individual white-collar workers. A LonWorks network connecting such sites might allow each worker more individual control over his own working environment, while at the same time permitting monitoring and control services that could deliver more efficient management of the facility in which these sites were located. RK found a receptive audience for his idea among product development people at SCI's Grand Rapids MI headquarters.

By September, RK and his SCI allies had put together a preliminary plan for the smart office furniture project. Electric outlets that were also nodes on a LonWorks network would perform such services as turning off lights when employees left their work areas, as well as continuously monitor energy usage and load. Smart locks for desks and filing cases would help with security management. A Neuron in each article of furniture would simplify asset management. Finally, each worker could use the LonWorks network to control the lighting intensity and temperature in his own workspace.

[17] We have changed the name of this company in our narrative.

Through interviews with a number of SCI employees, dealers and customers, the plan's concepts were tested and refined. By November, RK was able to assert that customers would be willing to pay for smart outlets if they could be assured of a two-year payback period. Given that one large SCI customer estimated that merely turning off their graphic workstations over the weekend would save $400 per station per year, a short payback period seemed likely. Customers who had defense contracts were willing to pay for smart power locks, so long as they met Department of Defense specifications. SCI dealers were enthusiastic about the project, since it would provide an important product differentiator that would make their selling job easier. Moreover, SCI management was anxious to adopt at least the smart outlet idea, since the cabling scheme they had been implementing had been recently found to be in violation of another company's patents. As a result, Echelon managers had already assigned three engineers to begin working on hardware and software for the outlet nodes and developing a personal computer user interface for the system.

By May, 1990, negotiations with SCI had progressed far enough to plan to assign five engineers, full time, to the smart office furniture project. Late in June, Chris Stanfield, Echelon's lead negotiator, and SCI Executive Vice President agreed on the terms of a contract between the two companies. According to their agreement, SCI would pay Echelon $3.4 million to design hardware and software for the facility management system. In addition, Echelon would be the sole-source supplier of system components. In return, Echelon agreed not to sell a similar system to any other furniture manufacturer in six countries for four years. Oshman wrote to the Echelon Board, "This has taken a long time but I believe it is well worth the effort. We will get experience with a real application. We will begin the process of learning how to manufacture modules. We may create a $30–50 million profitable business."

Unfortunately for Echelon, SCI's top management team was divided over the Echelon alliance. After two weeks of internal discussion, SCI's CEO, his Vice President for Engineering, the SCI lawyer, and the Executive VP called Oshman to tell him that they had decided not to go through with the project. SCI's Executive VP, however, still believed in the concept, and after another several weeks he managed to convince the others to give the project a second chance. In August, SCI's Executive VP, CEO, and Vice President for Engineering visited Echelon for discussions and to view the demos Echelon engineers had prepared. The visit was a success: on September 15, Oshman announced that the contract with SCI was signed. "Now we get the opportunity to staff the project and really wow SCI with the results. . ."

But the opposition inside SCI was not interested in being wowed. Within a few months, it again had the upper hand, and at the end of February 1991, the SCI CEO notified Oshman that SCI was discontinuing its support for the LonWorks Facility Management System.

We do not know what actually happened within SCI to undo the smart office furniture alliance. An Echelon manager told us in February, 1996, that opposition to the project was led by an engineering manager, who was unwilling to commit to a new direction for a major SCI product line that depended on a technology from the outside – that is, "NIH." Another Echelon manager simply referred to "SCI politics." Of course, it is quite possible that some SCI executives were simply not convinced that a compelling business case could be made for the project, or that the LonWorks technology was really sufficiently well developed to deliver the necessary functionality for a price that SCI was willing to pay.

What we are certain about, though, was the effect that the cancellation had on some key Echelon managers. For them, the episode provided vivid proof of the danger of concentrating a lot of Echelon resources on developing a system business. Too much depended on the good will and intentions of the partners, whose business territory Echelon would be entering. The partners would have all the connections and all the competences connected with promoting, selling, distributing, installing, and maintaining the systems they produced. Inevitably, it would be the partner who would control how the system that Echelon developed would fare in the marketplace. The temptation for the partner to do it "their way" would be strong. In particular if the partner lacked sufficient networking expertise to realize just how important and how difficult would be the contribution that Echelon could bring to the project, Echelon would have a hard time obtaining its fair share of revenues from the partnership. So the SCI story endured in Echelon's collective memory as a signpost pointing the company in another direction: away from developing system businesses, back to being a "technology provider." All the possible advantages that had induced the management team to propose the re-ordering of company priorities in June 1989, were forgotten, or at least heavily discounted. After 1991, no-one in Echelon was looking for a system business to enter any more – at least until another, different kind of crisis, led Echelon again, temporarily, back to that particular road (see Lane & Maxfield, 2005).

Searching for an identity During the three years following the June 1989 crisis, the Echelon management team spent substantial time and effort trying to define just "who" Echelon was. One sign of this introspective activity was the plethora of explicit strategy and mission statements that were produced in this period. By the end of 1992, this spurt of identity-formation-by-formulation had run its course. After that, mission and strategy would be *enacted* more than they would be discussed and transcribed. Here, we trace three elements of the Echelon identity that emerged during these critical three years – and contrast them with what the Business Plan had envisioned and with the immediate response to the 1989 crisis.

The most striking change was the abandonment of the idea to enter system businesses. This change reflected more than the frustration associated with the rocky course and ultimate failure of the SCI partnership. The new solutions that chief architect Bob Dolin and his group had developed for the Neuron, the LonTalk protocol and network management services renewed confidence in the generality of LonWorks technology. As a result, the 1989 restriction to "simple, on-off applications" disappeared. By May 1990, Oshman was writing to his fellow investors that Echelon's mission was "to create the framework, plus tools and components, for low cost, reliable, distributed sense and control applications" – without the modifier "simple." The mission statement prepared by the Echelon management team in January 1991 went even further: "to establish the *de facto* worldwide standard for intelligent, distributed control."

The strategy document that accompanied the January 1991 mission statement, though, introduced another kind of restriction: no longer on the relative *complexity* of the control problems to be solved, but on the identity of the *market system* to which the relevant applications belonged. The proposal was to focus especially on applications for buildings, industry, machines and the home – that is, the "traditional" control industries (building automation and industrial control), plus embedded control and home automation. These were the best-organized market systems with respect to control artifacts of the eleven potential LonWorks application areas mentioned in the Business Plan. The process of restriction-by-market-system continued. Later in January 1991, a business case prepared by Echelon's marketing department declared that the primary areas of marketing activity would be buildings, industry and machines, while merely staying "active" in home automation, the least well-organized of the market systems still on Echelon's focus list. In May 1991, Bea Yormark, Echelon's Vice President for Marketing,[18] informed the Board that her group was ready to "make the transition from broad seeding in the marketplace to a combination of broad and targeted selling," where the targets, for now, would be "intelligent buildings" and "factory automation."[19] That is, Echelon would concentrate on penetrating the most established control market systems and downplay efforts to create a whole new control market system organized around distributed control networks. Note that Echelon's principal focus would now be the very application areas that in June 1989 were judged to be too complicated to solve with Neuron-based distributed networks. Another key element in Echelon's emerging identity was a new orientation to standards. The Business Plan had acknowledged the necessity of dealing with standard-setting committees that were developing control network technologies for particular market systems. These committees were initially not receptive to substituting LonWorks for their own proto-solutions. Indeed, Echelon came to regard the paper standards emerging from these committees as LonWorks' primary competition. The novel idea that emerged in 1991 was that LonWorks might become a standard just by *declaring* itself a standard, frequently and vociferously enough to convince other companies to believe it – and then to adopt LonWorks for their products. "If we claim it, and others agree, we've won." The January 1992 strategy statement prominently featured a new marketing slogan that succinctly summed up this approach to becoming a standard: "Win the air wars!"

Of course, Echelon would have to back up its claim to be "the" standard. Yormark proposed a simple strategy to accomplish this task: it might be enough, she reported to the Board, just to set up a "LonMark certification committee," and then wait for

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[18] Since January 1990.

[19] There was another reason for dropping embedded control from the list. The most important embedded control application area was automobiles, which had represented 25% of the total available control market estimated in the 1988 Business Plan. By December 1992, though, it was clear to Echelon management that LonWorks could not penetrate the automobile control market, which had already converged to an alternative protocol, CAN, developed within the automobile industry itself (MKO Board letter, December 1992).

prominent Echelon customers to bring maybe four or five highly visible, certified products to market. Actually, it would take much more than this (see Lane and Maxfield, 2005, for the story of ConMark International). But the insight that being *perceived* as a standard is essentially the same thing as *being* a standard is a powerful idea. Echelon's internalization of this idea in 1991–1992 helped to shape the way in which it fought standards wars in the ensuing years – and probably contributed substantially to some of the standards battles that it won.

During 1989–1992, Echelon made a significant change to its attribution about LonWorks' "core technology." Before 1990, "core technology" meant the tools and instruments necessary for design and *operational* control of a network: the Neuron, the LonTalk protocol, transceivers, and the LonBuilder development tool. In a January, 1991 strategy document, an addition to this list appears: network management tools. These tools would allow network supervisors to install the network, to monitor its performance, and to make changes when desired. Network management tools require a *system* view of the control network, which includes the *human beings* who interact with the network and who exercise *supervisory* control over it. As the product marketing group explained to the Board in November, 1991, the design of network management tools must take into account who will be using them, including field installers and repairmen, system integrators and end-users. Thus, these tools must be portable, easy-to-use, and with a friendly user interface. By March 1993, network management was perceived not only as an essential part of the LonWorks core technology, but as the key to "positioning for a bigger market." The "*control and monitoring market is much bigger than installation*." It took quite some time before Echelon network management artifacts managed to embody the attributions that emerged in 1989–1992, but a key step had already been taken in this period, when Echelon actors began to understand that network management and network managers constituted essential parts of LonWork systems.

9.5 Who's a Customer, and How do we Relate to Them?

On December 5, 1990, "the day everything began to work together,"[20] Echelon introduced Local Operating Networks – LONs – in a public relations bash at the Equitable Center in New York. Over 300 business leaders and journalists attended the event. Markkula, Oshman, and Yormark explained how Lon technology worked and suggested some of the ways in which it might transform homes, buildings and factories. Spokesmen for Motorola and Toshiba lauded the new technology and predicted that their companies' Neuron chips would be available by mid-1991, with initial prices under $10. But the real highlight of the carefully orchestrated presentation were videos in which executives from nine potential LonWorks customers[21]

[20] Title of the video Echelon produced of the launch.

[21] Lighting systems manufacturers Advanced Transformers and Lithonia Lighting; switch and lighting fixture producer Leviton Manufacturing; factory controls market leader Allen-Bradley;

described the critical challenges their companies faced and explained how the LON concept might contribute to meeting these challenges in the future. Oshman emphasized the differences in the roles that Echelon and such companies would play in building the LonWorks market system: “It is not Echelon that will be making smart products or systems. Echelon’s business is to *support* the companies that make these products and systems. Echelon’s job is to do the research and to provide easy-to-use, low-cost enabling control technology, in the form of tools and components that other companies can use. . . *It’s the customer who’s the innovator.* We expect it will be our customers, our adopters in many industries, who will show us the different things you can do with a LON – and I’m sure many of those will be things we can’t even imagine today.”

Echelon executives were euphoric after the launch. As Oshman described it to the Board two weeks later, “Our early adopters were impressed. . . The audience understood our message and went away convinced we were real. . . We are swamped trying to sort out good leads. Our two salesmen are in heaven.” The articles that appeared in the technical press serving the various control industries were in general enthusiastic. The business press, though, had a more tempered reaction. In particular, Business Week was skeptical: “There’s a good chance that Echelon’s low-cost, do-it-all strategy will fall flat. Some network experts question whether its technology can be economical and effective for both a light socket and an industrial robot.” The article went on to claim that even Echelon’s early adopters were not “champing at the bit:” Johnson Controls, one of the companies represented in the launch videos, “says it has no firm plans for using Neurons in its building controls.” The article implied that the relationships between Echelon and LonWorks “early adopters” were a bit more ambiguous than the upbeat, partner-like impression that Echelon had tried to convey to the launch audience. In this section, we will trace the evolution of these relationships from 1989 to 1993.

First contacts Of course, relationships between Echelon and potential LonWorks adopters began well before December 5, 1990. Echelon had been organized two years before the launch, and by March, 1989, the new hires in engineering and marketing had already made contact with a number of potential customers. For Echelon, the main aim of these initial contacts was to evaluate where and how LONs based upon the Neuron chip design inherited from ACM Research might be applied. The companies with whom Echelon representatives talked came from a variety of different industries: home security systems, manufacturing control, process control, remote meter reading, network diagnostics, office furniture, home automation, building automation, and agricultural automation.[22]

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military system integrator CACI; Johnson Controls and Landis & Gyr, two of the three largest producers of control systems for building automation; the leading office furniture manufacturer, Steelcase: and Ziatech, a producer of industrial and board-level computer products.

[22] Respectively: Radionics and Unity Systems; Allen-Bradley, the largest producer of discrete control devices and systems, and Square D, another large player in the manufacturing controls market system; Honeywell and Accurex; Itron and Metrocom; 3-Com; Intelock; Leviton Manufacturing,

The Echelon marketing group whose task it was to understand this heterogeneous collection of companies and businesses numbered only four people in April; two more people came on board in July. The understanding that these people obtained about "typical" applications in all these areas were discussed with members of Echelon's engineering group, who then tried to design similar applications using Neuron-based networks. As we saw in Section 9.4, the results of this process were so discouraging that Echelon's management team seriously considered shutting the company down.

However, not everyone inside Echelon was convinced that the discussions had yielded a sufficiently deep understanding of Echelon's potential customers to justify such pessimistic conclusions. RK, one of the most active participants in the process, expressed such a view in a June 8 memo circulated to key Echelon managers:

"To date, our interactions with customers have centered around delivering the LON vision and attempting to gain customer buy-in with this vision. We postulate that since all control problems reduce to "on, off, or in-between," a general solution exists; and then we assert that ours is the right general solution. The principal benefit of this process is that it tends to quickly reveal those assertions which potential customers find most offensive or which potential suppliers find most limiting. However, there is no reason to suspect that the results of this "assertion/refutation" process are the same as those which result from, say, studying a number of control systems in great detail, and then attempting to generalize from the data. It should thus come as no surprise that we don't have a qualified understanding about what the LON System does well: we've never implemented a process which yields such information as its result. Instead, we've implemented a process that tends to tell us what we can't do particularly well. While this information is extremely useful it tends to have a notably negative ring to it, and we tend to find ourselves on the defensive more often than we'd like. . . It is very difficult to determine the applicability of the LON System to an entire class of applications, all at once. One needs tremendous insight and experience in a field to be qualified to make such broad judgments, and even then, the validity of the conclusions is highly sensitive to inaccuracies in the simplifying assumptions."

RK went on to suggest alternate processes, designed to "gather good data about a specific application:"

1. hire a consultant "who is an expert in the area and, after fully explaining our concept, charge him with developing specific solutions to particular industry problems using our system;"
2. "approach customers with a specific proposal to investigate a LON-based solution to a particular problem," and then work closely with the customer "to learn about their industry and their concept of how the LON System is used and the benefits which result;

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which not only manufactured switches and other lighting devices but also held a license to sell X-10 control equipment, the leading current home automation technology; and Priva.

3. propose to do a pilot development project with a customer to demonstrate “key aspects of our solution” and test and validate key assumptions.

RK concluded that all these solutions had a “common theme:” working closely with an expert or “real customers” towards a “well-defined target” to “flush out the key issues.” In this way, “we will gather the information we need to fully assess an application, we’ll identify points that may lie within the boundary of a general solution, and we just may learn enough to build a good systems business along the way.”

RK’s memo criticized Echelon’s way of relating to its potential customers. In RK’s view, Echelon representatives were proselytizing the gospel of distributed control, presenting Neuron-based LONs as a revolutionary universal solution to all control problems. But to RK, Echelon people did not yet understand in sufficient detail what concrete control problems potential customers solved, and hence the reasons behind the artifactual forms that embodied their solutions. As a result, Echelon was not yet in position to understand how Neuron-based control networks might contribute to these companies’ business. To RK, this understanding could be gained only through intense, temporally extended relationships, either with a consultant steeped in a particular control industry or directly with one or more customer-partners.

To understand how such relationships between Echelon and customer partners might have been constructed, it will be useful to analyze the five components of what Lane and Maxfield (1997) called *generative potential* for interfirm relationships:

1. *Aligned directedness*: the participants in the relationship need to be oriented towards similar transformations in the structure of agent-artifact space. We might assume that Echelon and potential partners would share an orientation toward developing, together, a new control artifact or a better solution to an existing control problem. But there might be obstacles in determining just which kind of artifact or what would constitute a control solution. Here, issues of cost, of intellectual property, of the importance of interoperability with other artifacts and systems, perhaps developed by the partners’ competitors, on attributions of artifact or system functionality might provide stumbling blocks to alignment.
2. *Attributional heterogeneity*: the participants need to have different ways of looking at the problem to be solved if the relationship is to generate solutions that neither could provide alone. Between Echelon and its potential partners, there was certainly considerable attributional heterogeneity. Echelon’s abstract concept that “the network is the controller” and the deep understanding that some of Echelon’s engineers had of communication protocols were certainly not yet shared or even grasped by people in control businesses. The regnant vision of controls inside control businesses was quite concrete, embracing not only intimate working knowledge of myriads of sensors and actuators and hydraulic, pneumatic, electrical, analog and digital control signaling technologies, but also an understanding of the expectations and desires of their customers, the users

of control systems[23] – all of which were outside the experience of Echelon's team of Silicon Valley engineers and marketeers. The real problem for Echelon and its potential partners was to develop modes of discourse through which their attributional heterogeneity could surface and find expression in a new language that they jointly developed.

3. *Mutual directedness*: the participants need to have a positive orientation towards one another, feelings at least of joint comfort if not of trust. This requirement was particularly problematic for relationships between a small Silicon Valley start-up and large Midwestern control companies. Could they learn to appreciate each others' better qualities?
4. *Permissions*: groups of people from each participant with the requisite interests and competences to forge working relationships must be allowed to engage in the kinds of interactions – both talk and joint action – that can lead to common and then new understandings and embed these understandings in new artifacts and system solutions. In principle, the engineers and marketing people from Echelon and potential partners could be granted the necessary permissions; in practice, problems often arose, from the delegation of people lacking necessary meshing competences and knowledge to interact, through the prohibition on the part of the partners to solutions "open" enough for Echelon, to disagreements about who must bear the cost of necessary research and engineering.
5. *Action opportunities*: a relationship cannot be generative on talk alone. At a certain point, concrete projects for new artifacts or systems must emerge. Frequently, relationships between Echelon and potential partners did lead to action opportunities, but only at the demonstration level.

It is interesting to note that these conditions for generativity are satisfied very well for the Silicon Valley insiders who initially directed the construction of Echelon, its financing and its engineering successes. RK's memo, and the story of the relationship with SCI, indicates that the early relationship with potential customers was anything but generative. In fact, too much heterogeneity and too little aligned and mutual directedness seemed to characterize many of these relationships. We can interpret RK's memo as a suggestion that Echelon re-orient its relationships with potential customers, away from a mode in which verbal interactions were essentially acts of proselytizing, to a mode of on-going co-involvement in artifact and system development. The key question is whether such relationships would actually turn out to be *generative*. Certainly, as we saw, the first serious attempt to establish such a relationship, with SCI, failed to generate anything except disappointment and misunderstanding. One possible reason for this is that Echelon had very limited resources to deal with a very large number of problems, and hence it would have been extremely difficult to concentrate the kind of human and material resources necessary to construct a relationship satisfying the five criteria for generative potential discussed above even with one other company.

[23] Refs to books and manuals.

But a closer reading of RK's memo reveals an attitude toward potential relationships that RK himself shared with the dominant Echelon point of view his memo critized: the assumption that the problems to be solved all lie in *artifact space*. That is, the problem is just that some physical system needs to be controlled by some particular concatenation of control artifacts. It is as though all that Echelon needed to know about their customers' business is what type of technical problems they were trying to solve. In fact, the situation is much more complicated. To understand what customers recognize as problems, and what counts for them as solutions, it is necessary to understand how the customers are situated in *agent space*: with what other agents they interact, about what. Control problems, that is, cannot be construed either as "natural" or as purely technical. The social context in which they are embedded can determine to a large extent what gets identified as a problem and what makes a solution acceptable. A generative relationship between Echelon and a control company would have to explore how the participating agents are situated in agent space, and how their situation there informs their *identities*: their understanding of what they do, how they do it, with whom.

Shortly after RK wrote his memo, Echelon hired a consultant, TW, to comment on its engineering analysis of a possible LonWorks application in process controls. TW's report highlighted some of the social facts Echelon would have to face if it expected to play in the process control market system. TW observed that "the history [of process control systems] emphasizes the importance of having tools and/or architecture which allow for the configuration of a large control system by technicians with a low level of training and skills. This has become one of the primary elements considered by customers in choosing a control system vendor for a project... The three most important considerations when choosing a vendor for a new system [are] ease of maintenance, flexibility, ease of calibration and configuration. System cost is near the bottom of the list."

A LonWorks-based process control system would have to satisfy these essentially social constraints from day one, or no one would ever buy it. More generally, Echelon would have to know, for every market system in which it expected to operate, what sorts of people and organizations specified, designed, installed, used and maintained the relevant control systems, and how the experiences and preferences of all these agents affected the decisions of whoever it was who purchased the systems. Some of the difficulties involved in trying to do this, and the resistance of established market systems to radical changes in their structure, will be explored in the next chapter.

References

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