LINKING TECHNOLOGY AND BUSINESS STRATEGIES: A METHODOLOGICAL APPROACH AND AN ILLUSTRATION

Arnoldo C. Hax
and
Manuel No

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Arnoldo C. Hax and Manuel No
Sloan School of Management
Massachusetts Institute of Technology

ABSTRACT

Linking technology and business strategies is a demanding task that has central importance in strategy formation. Now that technology is a critical source to achieve and sustain competitive advantage, the ability to incorporate technology into a business strategy can make the difference between a winning or a losing strategic alternative. This paper discusses a methodology that can be used to explore systematically the way to link business and technology strategies. The authors illustrate the application of the suggested methodology in a real life setting.

INTRODUCTION

The role of technology has become so pervasive in the business world that is appropriate to say there is hardly any significant industry that can be classified as low-tech. In fact, technological forces are restructuring industries and defining new ways to compete. Managers are confronted with the demanding task of accelerating the speed at which innovations in new products and processes are translated into profitable commercial ventures.

Though there are many studies that analyze the process and sources of innovation (E.A. von Hippel, 1988), the disruptions introduces by new technologies (W.J. Abernathy and J.M. Utterback, 1978; J.M. Utterback and L. Kim, 1986; P. Anderson and M.L. Tushman, 1990), the concept of core competencies (C.K.Prahalad and G. Hamel, 1990), the strategic management of technology (L. Steele, 1989; B.L. White, 1988) or the human issues related with technology (U.E. Gattiker and L. Larwood, 1988; B. Twiss and M. Goodridge, 1989), there is less documentation on how to develop a strategic plan that integrates technology into the business strategy of a firm. This paper suggests a methodology to accomplish this task. The methodology is consistent with the strategic planning framework proposed by A. Hax and N.S. Majluf (1991), and is further illustrated by applying it to a start-up company in the massive parallel computer (MPC) industry. A brief description of the company, Masscalc, is provided in Appendix I. For a more detailed account of this case the reader is referred to No (1991).

A FRAMEWORK FOR THE DEVELOPMENT OF TECHNOLOGY STRATEGY

The formation of technology strategy takes place at all the key hierarchical levels of the firm: corporate, business, and functional levels. Figure 1 illustrates the primary tasks that we identify as relevant in the development of technology strategy. For a more detailed account of the strategic planning process, see Hax and Majluf (1991).

First, top managers have to decide, as part of the corporate strategy of the firm, what is the role to be played by technology in advancing the firm's competitive capabilities, the amount of resources to be allocated to technology, and the aggressiveness the firm will use in the innovative process and in imbedding technology into the firm's products and processes. Corporate attention is required since frequently a given technology is shared by several businesses and affect various managerial functions. Therefore, its strategic development cannot be totally decentralized at the business and functional levels. The elements of corporate strategy that communicate more pointedly to the technological requirements are the mission of the firm - particularly the statement of unique competencies - and the corporate strategic thrusts - an expression of the primary issues the firm has to address to establish a strong competitive position.

Next, technology strategies are formulated at the business level. During the process of business strategy formation we need to define the technological support required to create or reinforce the competitive advantage sustained by each business unit. This is supplied by the mission of the businesses and their respective strategic action programs. Obviously, a technology strategy cannot be created in isolation from the corporate objectives and the businesses it is intended to support.

Finally, at the technology level resides the task of interpreting all the requirements emerging from corporate and business levels, which will become the critical inputs for shaping the technology strategy of the firm. At this stage it is also necessary to identify the portfolio of specific technologies the firm will be using in supporting its business strategies. This leads to the definition of the strategic technology units (STUs), the central focus of attention in the development of technology strategy. The STU identifies the skills or disciplines that are applied to a particular product or process in order to gain technological advantage. The STUs should contain all the core technologies used now or needed in the future across the whole organization.

The STUs are critical to the execution of the technology environmental scan and internal scrutiny, the next tasks in the planning process. The environmental scan is aimed at obtaining an understanding of the key technology trends, assessing the attractiveness of each STU, and identifying technological opportunities and threats. This form of analysis we referred to as technology intelligence. Its purpose is to generate all the relevant information concerning the current and future state of development of the technology function. It is not only the existing managerial practice and state of technological progress that are important to detect. Even more critical is the recognition of future trends, state-of-the-art developments, and their embodiment in actions by competitors.

With regard to the internal scrutiny, besides the recognition of strengths and weaknesses associated with each STU, we need to determine the specific technological competencies we should build to gain competitive advantage. We conduct this analysis by examining the strategic categories of decisions linked to the technology function. A detailed listing of the decisions is included in Appendix II, taken from Hax and Majluf (1991).

Finally, we have the remaining tasks of defining broad and specific action programs, and budgets. These tasks represent the final output of the technology strategy formation process. They should respond to the corporate and business requirements as well as the challenges emerging from the environmental scan and internal scrutiny activities.

TECHNOLOGICAL REQUIREMENTS

As shown in Figure 1, the first step in developing the technology strategy is to derive a clear, unified statement of coherent strategic requirements that the company places over the technology function. The identification of these requirements helps to create a common understanding among top management of the horizontal nature of the technology function allowing them to identify and exploit potential synergies among distinct but related business units. More importantly, this step provides a mechanism that establishes an effective linkage between corporate, business and technology strategies.

Table 1 shows some of the technological requirements put onto Masscalc's technology function. Although we list those requirements by corporate and business strategies, this distinction is rather blurry in this case since Masscalc is at this time in only one business, the massive parallel computer (MPC) business.

THE DEFINITION OF STRATEGIC TECHNOLOGY UNITS (STUs)

The strategic technological units are a planning tool used to shape the strategic response to the aforementioned technological requirements. Thus, the proper selection of STUs is one of the most critical elements of the proposed methodology.

An STU refer to a discrete technology or group of technologies that are used by the company. The cluster of STUs should encompass any technology which has impact on the company's overall competitive position in the marketplace. To be effective, the authors have found that any STU should:

- be broad enough in order not to leave out potential innovations, yet specific enough so as to allow a clear understanding of the technological position of the company.
- have continuity, i.e. the STU will exist over a relatively long period of time in order to develop expertise and management control. This does

not preclude the underlying product and process technologies included in a given STU to evolve through time.
- be critical to the product or service. It is recognized as a source of competitive advantage.
- require a set of distinctive technical capabilities. Each STU will represent a unique contribution.

Table 2 shows the STUs identified at Masscalc. Note that some of the STUs cut across organization units (STUs 1 and 2 encompass activities of the R&D and the Engineering Divisions). Also, some of them do not relate directly to the core business, but have a strategic relevance in supporting the corporate and business strategies. This is the case of "demonstration technologies" or "service", two supporting technologies with an important strategic role in Masscalc.

ENVIRONMENTAL SCAN

Only a deep knowledge of the intrinsic characteristics of the technologies used by a firm can generate the high-quality strategic thinking required for the healthy, long-term development of technology-based competitive advantages. The objective of the environmental scan is to gain this knowledge and to derive from it the degree of attractiveness of each technology as well as the opportunities and threats that technology presents to the firm. This analysis is done based on the STUs previously identified.

Developing strategic advantages from technology requires to recognize the trends followed by each specific technology, decide which are the innovations the firm is going to incorporate, and set up the internal means to take advantage of those innovations.

An important first step to facilitate this task is to identify the potential sources of innovation for each STU. Eric von Hippel (1988) has generated seminal work in this field. By conducting a large number of empirical studies, he has been able to pinpoint the sources of innovation in a large variety of industrial developments. The source of innovation varies greatly depending on whom is expected to receive the benefits from the innovational efforts. Primary sources are users, manufacturers and suppliers. Of special interest is the ability to identify lead users, if they are relevant to the innovation process. Lead users combine two characteristics: they have a need which is in advance of the general market, and they expect high benefits from a solution to that need. Whenever lead users do exist, it is of paramount importance to follow their innovation progress closely since they could be ahead of the market in their innovation capabilities. Table 3 shows the sources of innovation for each of the STU's of Masscalc.

The second task of the environmental scanning process is to assess the degree of attractiveness of each of the technologies the firm is using or is considering to use in its products and processes. A technology with a high degree of attractiveness is one that, when applied, will enhance significantly the competitive position of the businesses it supports. To assess the attractiveness of the technologies, we have to define those factors, normally

external to the firm, that allow us to analyze the impact of each technology. The factors that we have used in our case are illustrated in Table 4, that shows the current and future profile for the STU number 3, board and systems design.

A similar assessment should be conducted for each of the STUs, leading toward a reflection of the overall opportunities and threats the portfolio of technologies presents to the firm.

INTERNAL SCRUTINY

The internal scrutiny process is a disciplined approach to identify the technological strengths and weaknesses of the firm against its most relevant competitors. The process starts with the identification of the critical success factors associated with each STU. Those factors represent capabilities controllable by the firm in which it has to excel to achieve a competitive superiority in each STU. Once the factors are identified, we conduct a competitive profile, measuring the position of the firm now and in the future. In the internal scrutiny phase the future profile does not represent a trend forecast, as was done in the environmental scan, but a desirable position the firm would like to achieve against its leading competitors.

Table 5 shows the analysis as performed on the STU 3 of Masscalc, the board and system design. Notice that there are two categories of evaluation factors : those that measure the technological capabilities of the firm (knowledge, equipment, patents, etc.) and those that measure its efficiency in embodying this knowledge into products and processes.

A second element of the technology internal scrutiny that we have found particularly useful is to analyze the strengths and weaknesses of the existing policies the firm follows in each of the critical categories of decision making. The taxonomy of decisions that are relevant to technology strategy is taken from Hax and Majluf (1991). They propose to consider seven key categories of decisions: technology intelligence; technology selection; timing of new technology introduction; modes of technology acquisition; technology horizontal strategy; project selection, evaluation, and resource allocation; and technology organization and managerial infrastructure. Brief definitions of these categories of decisions are presented in Appendix II.

Table 6 shows the description of the policies adopted by Messcalc in each technology decision making category and their corresponding strengths and weaknesses. It emerges from these descriptions the high degree of informality the firm has in its technology strategy. This behavior is quite common in start-up entrepreneurial firms.

THE TECHNOLOGY ATTRACTIVENESS-TECHNOLOGY STRENGTH PORTFOLIO MATRIX

Portfolio business matrices have been in use for over twenty years in American industry. They represent useful tools to reflect on the overall strength of the business portfolio of a firm (see, for example, Hax and Majluf,

1984, Chapters 7, 8, 9, and 10). The concept of business portfolio matrices can be extended easily to address the strength of the overall portfolio of technologies available to the firm. the technology portfolio matrix graphically displays all of the STUs of the firm according to two dimensions: technology attractiveness and technology strength. These two dimensions were already assessed in our study on the environmental scan and internal scrutiny processes, respectively. Recall that Table 4 illustrated how to evaluate current and future attractiveness of STU 3, board and system design; while Table 5 showed how to specify the current and future strengths of that same STU. Those tables evaluated attractiveness and strength through the use of several relevant factors. It is now required, either subjectively or by assigning different weights to each factor, to translate these multifactor profiles into a single measure of technology attractiveness and strength.

Figure 2 shows the technology portfolio matrix for Masscalc. The circles identify the existing position of each SBU, the dots the future position. Ideally we would like to have all the STUs in the high-attractiveness, high-strength cell of the matrix, such as STU 1. What is critical is to reflect on the competitive moves that have to be made in order to gain competitive strength in highly attractive STUs such as 2, 11, 3, 4, 5, and 10. The amount of effort and resources to be allocated to each STU depends both on our ability to gain competitive advantage, and the projection of future attractiveness of a given STU. In our example, STU 6 seems to be in a very precarious current position, but since its attractiveness is projected to be improved significantly, it makes sense to intend to raise the firm's competitive strength in it.

It is important to separate the current portfolio representation from its future projection. The current position should be the result of an objective, factual diagnosis of existing technology attractiveness and the firm's technological competencies. The future is more speculative, and needs to be critically examined in terms of the degree of confidence in the future technological trends, and the firm's capacity to improve its competitive standing. We have found the technology portfolio matrix to be a powerful diagnostic tool.

FORMULATION OF STRATEGIC ACTION PROGRAMS AND BUDGETS

Having identified the technological requirements generated from corporate and business strategies, completed the environmental scan and internal scrutiny processes, we are ready to address the last stage of technology strategy formation: the development of broad and specific action programs, as well as the budgets which translate into financial terms the strategic and operational commitments implicit in the technology decisions.

To be consistent with the framework we propose, the strategic action programs should:

- Respond to the technological requirements emanating from corporate and business strategies.
- Seize the opportunities and neutralize the threats identified in the environmental scanning process.

- Reinforce the strengths and eliminate the weaknesses detected in the internal scrutiny process.
- Address all the issues linked to the strengthening of the portfolio of technologies of the firm.

Table 7 provides a rather incomplete representation of the technology broad action programs of Masscalc. In a real-life situation a higher degree of specification and comprehensiveness will be required.

TECHNOLOGY POLICIES

When the strategic analysis uncovers some serious deficiencies in the technology policies of the firm, it might be necessary to reevaluate them. Technology policies tend to be broad guidelines that define the scope in which technology decisions are to be made. These policies have some inherent stability and, therefore, are not supposed to be redefined at the end of every planning cycle. In the case of Masscalc, managers opted for issuing a simple statement of technology policies that group the seven categories of decision making we used for policy evaluation under three headings: innovation policies (including technology intelligence, technology selection, timing of new technology introduction, and modes of technology acquisition), technology dissemination and resource allocation (including technology horizontal strategy, and project selection, evaluation, resource allocation, and control), and technology organization and managerial infrastructure. Table 8 describes Masscalc's technology policy statement.

CONCLUSION

The paper presents an orderly process for the development of the technology strategy of a firm. The methodology has proven to be effective in providing an appropriate diagnosis of the existing state of technology utilization and to reflect on the necessary changes to be made in order to make technology more effective in supporting the competitive position of the firm's businesses. The methodology should be regarded as a process that facilitates communication and discussion among the key firm's managers rather than a rigid step-by-step procedure.

The Masscalc case discussed throughout the paper can only be regarded, for reasons of space and confidentiality, as a highly simplified illustration as opposed to a comprehensive realistic example.

APPENDIX I
Masscalc - A High-Performance Computer Company

The company that is used to illustrate the application of the methodology recommended to link technology and strategy is briefly described in this appendix. In order to protect the confidential nature of the strategic audit we conducted, we have slightly modified its content and used the fictitious name Masscalc. High-performance computers are devoted to applications that require very large computing capabilities. The whole size of the high performance computers' market accounted in 1990 for $10 billion and is growing at 20%. There are about 20 companies that serve most of the world market. The technological environment of the industry is very volatile, with incremental innovations being announced every few months. Also, the cycle of major innovations in the technologies used is short, requiring a sustained effort to improve actual models while working in the development of the technology of the next series of products.

Massive parallel computers (MPC) are a new family of high performance computers representing one of the most recent and significant technological breakthrough of the industry. Most of the companies manufacturing MPC are new companies, and none of them sell any other type of computers. Nowadays, MPC competes in the market arena with two much more mature technologies (supercomputers and array processors), and though MPC still accounts for a very small share of the market, most experts predict a very impressive market share increase.

Masscalc is a start up company committed to designing, producing and selling MPCs. Its primary target is to provide computers to support the production rather than the R&D function of its customers, as most high-performance computer companies do. Masscalc'c challenge is to be able to produce large volumes of MPCs that are affordable, user friendly, and able to operate with commercially available software. This will transform the company from a design-focused organization into a massive producer of MPCs.

At the time of this study, Masscalc had successfully introduced its first model, which received an excellent review by the industry experts. All the computer parts were subcontracted and manually assembled in-house. A well-conceived and implemented technology strategy is critical to Masscalc's success.

APPENDIX II

Major Categories of Strategic Decisions Linked to Technology(**)

1. TECHNOLOGY INTELLIGENCE

An effort oriented at gathering information concerning the current and future state of technology development. Some of the tasks associated with it are: Identification of strategic technical units (STUs), evaluation of competitive technical strengths by STU, detection of the focus of innovation by key product areas (users, manufacturers, suppliers, others), collection and comparison of expenditures in technology by key competitive firms.

2. TECHNOLOGY SELECTION

It addresses the issue of selecting the technologies in which the firm will specialize, and the ways in which they will be embodied in the firm's products and processes. Some of the issues to be recognized are: selection of the technologies needed for product and process innovation, assuring the congruency of technology development with the business life cycle and with the desired business strategy, and assigning the appropriate priorities to resulting technological efforts.

3. TIMING OF NEW TECHNOLOGY INTRODUCTION

It involves the decision as to whether to lead or to lag behind competitors in process and product innovations. Issues to be addressed are : identifying the benefits and risks associated with a leadership and followership strategy, and assuring the congruency of the selected technology strategy with the generic business strategy.

4. MODES OF TECHNOLOGY ACQUISITION

The extent to which the firm will rely on its own internal efforts in developing internal capabilities, versus resorting to external sources. The options available for the modes of technology acquisition of products and processes are: internal development, acquisition, licensing, internal ventures, joint ventures or alliances, venture capital, and education acquisition.

5. HORIZONTAL STRATEGY OF TECHNOLOGY

It consists of identifying and exploiting technological interrelationships that exist across distinct but related businesses. It is a mechanism by which a diversified firm enhances the competitive advantage of its business units. Sources of technological interrelationships are: common product technologies, common process technologies, common technologies in other value-added activities, one product incorporated into another, and interface among products.

6. PROJECT SELECTION, EVALUATION, RESOURCE ALLOCATION, AND CONTROL

The principal concern in in this case is the appropriate allocation of resources to support the desired technological strategy. Issues to be addressed are: criteria for resource allocation, project-oriented resources versus loosely controlled funds to support and plan projects, the degree of fluctuation in technology funding, and the magnitude in the profit gap to be filled by new products.

7. TECHNOLOGY ORGANIZATION AND MANAGERIAL INFRASTRUCTURE

It is oriented toward the definition of the organizational structure of the technology function. It includes the identification of the horizontal coordinating mechanisms needed to exploit the technological interrelationships existing among the various business units and the activities of the value chain. Issues to be considered are: centralization versus decentralization of the technology function, development of career paths for scientists and technical professionals, use of project team, use of lateral mechanisms to facilitate sharing technological resources, design of motivational and reward systems for scientists and technical professionals, degree of involvement of top managers in technological decisions, decision making process for resource allocation to technological projects, protection of technological know-how, patents policies, and publication policies.

(**) Extracted from: A. C. Hax and N. S. Majluf (1991). For useful references in technology see R. A. Burgelman and M. A. Maidique, *Strategic Management of Technology Innovation* (Homewood, IL: Richard D. Irwin Press, 1988); M. Horwitch (ed.), *Technology in the Modern Corporation: A Strategic Perspective* (New York: Pergamon Press, 1986); M. E. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance* (New York: The Free Press, 1985), Chapter 5; E. B. Roberts (ed.), *Generating Technological Innovation* (New York: Oxford University Press, 1987); D. J. Teece (ed.), *The Competitive Challenges: Strategies for Industrial Innovation and Renewal* (Cambridge, MA: Ballinger Publishing Co., 1987); B. Twiss, *Managing Technological Innovation* (London: Longman Group, 1982), and E. von Hippel, *The Sources of Innovation* (New York: Oxford University Press, 1988).

REFERENCES

Abernathy, W.J., and J.M. Utterback, "Patterns of Industrial Innovation", *Technology Review*, Vol. 80, no. 7, pp. 40-47 (1978).

Anderson, P., and M. L. Tushman, "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technology Change", *Administrative Science Quarterly*, Vol. 35, pp. 604-633 (1990).

Burgelman, R. A., and M. A. Maidique, *Strategic Management of Technology Innovation* (Homewood, IL: Richard D. Irwin Press, 1988).

Gattiker, U. E., and L. Larwood, *Managing Technological Development: Strategic and Human Resources Issues* (Hawthorne, NY: Walter de Gruyter, 1988).

Hax, A. C., and N. S. Majluf, *Strategic Management: An Integrative Perspective* (Englewood Cliffs, NJ: Prentice Hall, 1984).

Hax, A. C., and N. S. Majluf, *The Strategy Concept and Process: A Pragmatic Approach* (Englewood Cliffs, NJ: Prentice Hall, 1991).

Horwitch, M. (ed.), *Technology in the Modern Corporation: A Strategic Perspective* (New York: Pergamon Press, 1986).

No, M., "Developing a Methodology for Technology Strategy. An Application in the High Technology Industry", M.S. Thesis, Sloan School of Management, MIT (1991).

Porter, M. E., *Competitive Advantage: Creating and Sustaining Superior Performance* (New York: The Free Press, 1985).

Prahalad, C. K., and G. Hamel, "The Core Competence of the Corporation", *Harvard Business Review*, Vol. 90, no. 3, pp. 79-91 (1990).

Roberts, E. B. (ed.), *Generating Technological Innovation* (New York: Oxford University Press. 1987).

Steele, L., *Managing Technology* (New York: McGraw Hill, 1989).

Teece, D. J. (ed.), *The Competitive Challenges: Strategies for Industrial Innovation and Renewal* (Cambridge, MA: Ballinger Publishing Co., 1987).

Teece, D. J., "Profiting from Technological Innovation: Implications for the Integration, Collaboration, Licensing and Public Policy", *Research Policy*, Vol. 15, no. 6 (1986).

Twiss, B., *Managing Technological Innovation* (London: Longman Group, 1982).

Twiss, B., and M. Goodridge, *Managing Technology for Competitive Advantage. Integrating Technological and Organizational Development: From Strategy to Action*, (Aulander, NC: Pitman, 1989).

Utterback, J. M. and L. Kim, "Invasion of an Established Business by Radical Innovation", Proceedings from *The Management of Productivity and Technology in Manufacturing*, pp. 113-151, edited by P. R. Kleindorfer (New York: Plenum Press, 1986).

von Hippel, E. , *The Sources of Innovation* (New York: Oxford University Press, 1988).

White, B. L., *The Technology Assessment Process. A Strategic Framework for Managing Technical Innovation* (Westport, CT: Quorum Books, 1988).

Figure 1. A framework for the development of technology strategy

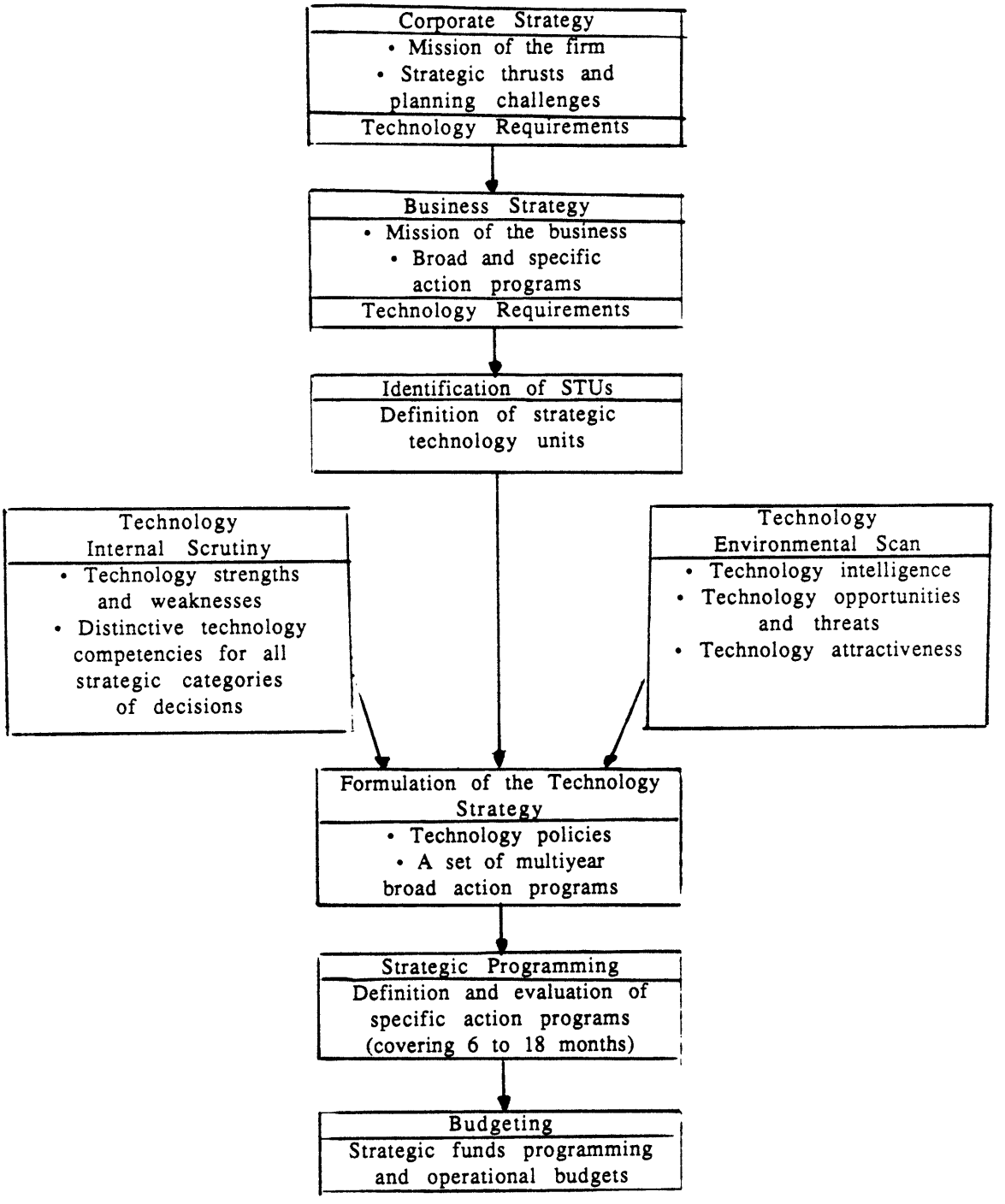


Table 1. Technological requirements

Implied by	Technological requirements
Corporate Strategy	• Acquire and develop those technologies and procedures required to ensure high quality and reliability in large scale production of existing Massive Parallel Computer (MPC) product line. (period of accomplishment: 12 months). • Develop the technological capabilities needed to design and bring to the market a new generation of MPC. Time period: 3 years. • Enhance existing product line with minor innovations every six months.
Business Strategy	• Reduce board and system manufacturing cost by 10% every six months by better use of available technologies. • Acquire technical capabilities (human and equipment) in the area of demonstration technologies to serve actual marketing needs. • Bring to the market high speed input/output and video devices in 9 months

Table 2.
Identification of all relevant STUs to support competitive advantage

1. *System architecture:* Technologies related to the definition of the basic architecture of the computer.
2. *Chip design and engineering:* Technologies related with chip design and manufacturing. It includes alternative technologies to the one used right now.
3. *Board and system design and engineering:* Board and system design and manufacturing.
4. *Support software:* Includes microcodes, compilers, and basic libraries.
5. *Application software:* Technologies to support companies that develop software to run in Masscalc machines.
6. *Management of Information Systems:* Information systems to support all activities of the company, including marketing, sales and service.
7. *Process Technologies:* Procurement and control of suppliers' production processes as well as in-house assembly.
8. *Testing Technology*: Technologies used to test subassemblies and the whole system.
9. *Demonstration technologies:* Includes video and communications vehicles to help preparing and delivering shows, demonstrations, etc.
10. *Peripherals*: Technologies required to design or subcontract the design of high speed peripherals for visualization and image processing.
11. *Service*: Technologies and methodologies for delivering service to the computer industry (e.g.: remote diagnosis, education of technicians, etc.)

Table 3. Sources of innovation by STU

STU	POTENTIAL SOURCE OF INNOVATION
1. Systems architecture	Competitors, universities
2. Chip design and engineering	Suppliers, competitors, and other computer companies
3. Board and system design and engineering	Suppliers, and electronic and computer companies
4. Support software	Lead users, suppliers, competitors
5. Application software	Lead users, suppliers, competitors
6. Management of information systems	Suppliers, industry in general
7. Process technologies	Suppliers and companies with analogous production processes
8. Testing technologies	Electronic companies and suppliers
9. Demonstration technologies	Lead users, competitors and other computer companies
10. Peripherals	Lead users, and electronic and peripherals companies
11. Service	Lead users, and competitors

Table 4. Technology attractiveness

X: 1992
O: 1994-95

STU 3: Board and system design

FACTORS	=	-	E	+	++	COMMENTS
Potential for enhancing competitive advantage in						Most of the innovations are incremental, so a small group of people can keep up with them.
– products				XO		
– process				XO		
Rate of technological change			O	X		
Potential for long term value added			XO			
Impact on:						It is a key technology in terms of cost, performance, and quality. It drives most of the manufacturing and assembling processes and has strong implications in procurement
– cost					XO	
– performance					XO	
– quality					XO	
– differentiation				XO		
Impact on entry barriers			XO			The technology has a moderate impact on changing the industry structure, the barriers to entry, and the industry standards.
Impact on setting industry standards.			XO			
Impact on improving industry			XO			

Key:

= : The STU is not relevant as a source of competitive advantage.
- : Potential for minor support.
E : Even - The STU supports average performance.
+ : Potential for mild competitive advantage.
++ : Potential for strong competitive advantage.

Table 5. Technology strength.

X: 1992
O: 1994-95

STU 3: Board and system design
Major competitor: ABC

FACTORS	=	-	E	+	++	COMMENTS
Technology capabilities						Masscalc has low level of human resources in this area. Its intentions
Human resources		X		O		are to change that due to the
Equipment and laboratories		X		O		technology importance
Access to external sources			XO			in cost reduction and
Recent patents			O	X		reliability of the final product.
Technology embodiment:						The company is selecting technologies that not optimize cost
Cost reduction in design		X		O		and that increase risk, focusing only
Cost reduction in manufacturing		X			O	on higher performance, contrary to
Effective use of manufacturing standards			X	O		the business strategic focus.
Procurement eagerness		X				
Quality of product			XO			

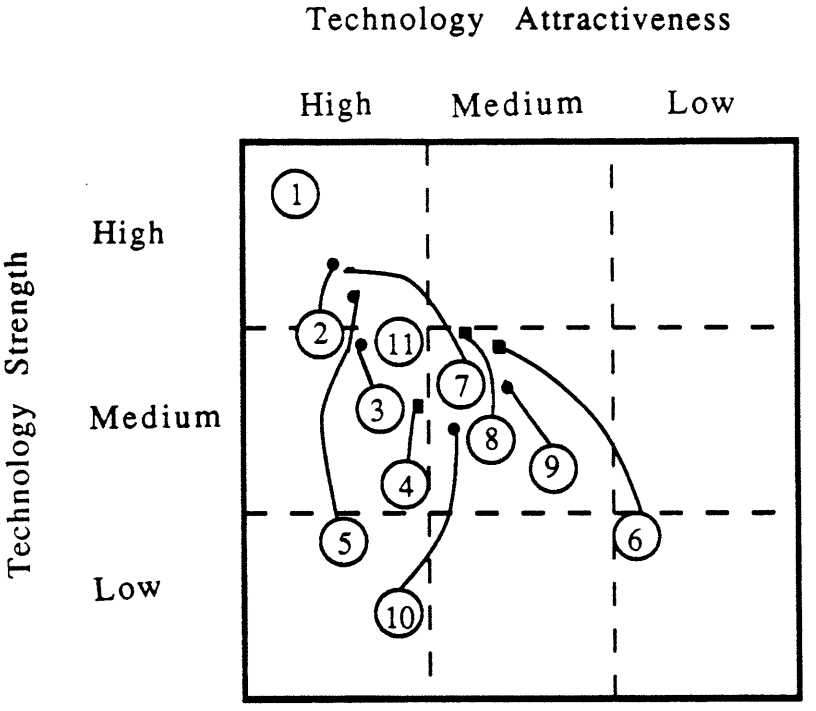
Key:

= : The STU is not relevant as a source of competitive advantage.
- : Potential for minor support.
E : Even - The STU supports average performance.
+ : Potential for mild competitive advantage.
++ : Potential for strong competitive advantage.

Table 6. Characterization of present technology policies regarding the major categories of decision making

Decision Category	DESCRIPTION OF POLICY	STRENGTHS	WEAKNESSES
Technology intelligence	There is no action plan to capture external innovations nor any measure of how much information is coming in and how is disseminated through the company	The informal policy may be very adequate now that the company is small.	It is very dangerous because many important innovations, requirements, or problems with the product, will probably not be captured on time.
Technology selection	With the exception of STUs 1 and 2, technologies are selected without consideration of the business mission.	None	Cost ineffective. May endanger some of the key business objectives.
Timing of new technology introduction	Incorporate advanced versions of the technology once less sophisticated, safer ones are already in the product.	Low technological risk. Leverage of experience	By not defining the policy in terms of STUs and its support to the business, there is a risk of missing the right time for technology introduction.
Modes of technology acquisition	Basically internal, with very few exceptions.	Easier coordination of proper development and use of technologies	Sub-optimization of resources. Very unlikely to be able to excel in all areas.
Technology horizontal strategy	Relies basically on informal communications.	Better disposition to share technology	Requires a strong culture to maintain this approach as the company grows.
Project selection, evaluation and resource allocation	Projects selected based on market inputs	Supports the company market driven approach.	Potential for losing long term innovations.
Technology organizational & managerial infrastructure	Most of the responsibilities for long and short term rely on the same people.	Gives control over what is going on, and facilitates coordination of previous policies.	May generate large decision problems as the company and the breadth of products grow.

Figure 2. Technology portfolio matrix



STU representation:

1. Systems architecture
2. Chip design and engineering
3. Board and system design and engineering
4. Support software
5. Application software
6. Management of information systems
7. Process technologies
8. Testing technologies
9. Demonstration technologies
10. Peripherals
11. Service

Table 7. Technology broad action programs

ACTION PROGRAM	RESPONDS TO(*)	1st MILESTONE
Define the specific needs of people in engineering and procurement for compiling with short product cycles and incremental innovations	TR, IS	June 1992: the specification of needs
Define the specific technologies to be used in board design accordingly to the established innovation policies.	TR, ES	September 1992: critical analysis of available technologies rated by cost, performance and riskiness.
Develop and launch a program to acquire the next generation of board design and manufacturing techniques with special focus on cost reduction and quality.	ES, TR	September 1992: critical analysis of new developing technologies.
Create a unit fully responsible for board design and manufacturing.	IS	December 1992: description of needs to be covered by this unit and means needed to achieve it.
Set up review meetings for chip and architectural design each six months. The purpose of these review meetings should be to track and evaluate external upcoming innovations.	IS	First review meeting in September, 1992.
Introduce demonstration technologies according with technology policies and marketing requirements.	TR, IS	In two months there should be a specification of what the company needs in the near future and which companies can provide the service.
Establish a program to develop a new generation of chip and architecture within three years.	IS	Define project by June 1992.

(*) This column identifies the appropriate state of the technology planning process process a particular action program is responding to, according to the following convention:
TR = technology requirements generated by corporate or business strategies
ES = environmental scanning process
IS = internal scrutiny process

Table 8. Technology policies

Innovation policies

- Be leaders in introducing incremental concepts in system architecture and chip design.
- Be followers in major innovations in chip manufacturing and board design and manufacturing technologies.
- Select those technologies that lead the company toward standards, mainly in those technologies that are not the core of the business.
- Select standard hardware and software available in the market or that can be designed and manufactured outside without interfering with company's proprietary knowledge.
- Acquire from outside all the support software that is not crucial for the proprietary technology or expertise of the company.
- With regard to demonstration technologies and other non-crucial activities, look for an agreement with some external company and an internal coordinator.

Technology dissemination and resource allocation

- Set a program for temporal rotation of people. It should include:
  - Interchange between people at R&D center and engineering.
  - People working at the R&D center should be allocated one month every three years as marketing support personal, in a rotational basis.
- Maintain policies regarding resource allocation.

Technology of organization and managerial infrastructure

- Establish a program for evaluation of new changes in current designs, to ensure that each new innovation included is appropriate in terms of factors such as market needs, cost reduction, better service to either final customers or software companies, etc. Establish priorities among these factors.
- The R&D organization will be under the Engineering and Manufacturing department. But, R&D will be seated at all the top-management committees to ensure that its long term objectives are pursued.
- Lower down the organizational level at which technological decisions are made
- Set up, within the evaluation program, an analysis of technological decisions made and its agreement with satisfaction of technological requirements and technology policies.