ASSESSING THE COMPANY'S TECHNOLOGICAL BASE

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INTRODUCTION

A key success factor in accomplishing the strategic and operational goals of the organization is the adequacy of its technological base -- its technological know-how and the organizational levers for effectively building and deploying that know-how. Just as important as the quality technology base itself is management's ability to correctly assess its strengths and weaknesses:

*Exhibit A: when IBM decided to enter the personal computer business, an assessment of its technological base showed that it was well prepared for that move, with the skilled computer and electronics people and the right values as regards technology, quality, service, and customer orientations. However, IBM decided that it did not have the appropriate structure for this new product line. An effective PC business would need to be much more "agile" than most of IBM core businesses. So when it established the new division for the PC business, it was structured as in Independent Business Unit, more autonomous than most of IBM's divisions from Corporate control. Despite IBM's impressive PC market share, it is still unclear whether they can sustain the rapid pace of technological and product change.

*Exhibit B: When the Swiss watch industry faced the introduction of digital watches by American and Japanese companies in the early 1970s, they discovered only belatedly that they were not prepared for the new electronic era. Most Swiss watch companies knew very little about the technology of either integrated circuits or digital displays embedded in digital watches, and they had neither the right organizational structure for developing electronic devices nor the appropriate project management processes and decision-making procedures to deal with the much faster pace of technical product and market change associated with the new technologies. Not only where they unprepared, but most of the industry did not even realize how unprepared they were. As a result, the world preeminence of the Swiss watch industry was shattered.

As these examples show, whether a company is contemplating a strategic change or just evaluating its implementation of a given strategy, a thorough assessment of the strengths and weaknesses of its technological base is a critical task. But what are the dimensions and elements that need to be considered in assessing the technological base? We know how to assess the financial strength of an organization, as represented by the firm's cash flow, lines of credit, equity, and so forth. Managers should be able to define and evaluate the organization's technological base in an equally rigorous way. Unfortunately, when it comes to assessing their technological base, managers often find that they must rely on intuition.

In this article, we will define the technological base concept, describe its elements, and identify some key managerial issues in evaluating, establishing and maintaining it.

FOUR DIMENSIONS OF THE TECHNOLOGICAL BASE

The technological base is what enables an organization to develop new products to meet the current market needs identified by the company, to manufacture these products using the appropriate process technologies, to develop or adapt new product and process technologies to meet projected future needs, and to respond promptly to unexpected competitive moves or to unforeseen opportunities that require actions involving technology. This functional specification of the technological base implies that in addition to evaluating its current products, processes and projects, the management team must assess whether the organization is technologically equipped to meet its strategic objectives (Roberts and Berry, 1985), and further, whether the organization is technologically strong enough to create new opportunities for itself and to meet the opportunities and threats created by its environment and its competitors.

What kinds of questions should the managers ask themselves as they attempt to assess their technology base? Our framework groups the elements of this assessment into four dimensions, each contributing to the organization's technological capability in a different way (see Figure 1):

[PUT FIGURE 1 ABOUT HERE]

1. Technological assets: these are the most immediately visible elements of the technological base, the set of reproducible capabilities in product, process and support areas.
2. Organizational assets: these are the resources that enable the business to develop and deploy the technological assets, specifically: the skill-profile of employees and managers, the procedures for getting things done, the organizational structure, the strategies that guide action, and the culture that shapes shared assumptions and values.
3. External assets: these are the relations that the firm establishes with current and potential allies, rivals, suppliers, customers, and political actors.
4. Projects: these are the means by which technological, organizational and external assets are both deployed and transformed. They should be considered part of the technology base insofar as the organization's *modus operandi* in its projects is a learned behavioral pattern that can contribute to or detract from technological and business performance.

To illustrate of these dimensions and to identify some of the key managerial issues involved in each, we shall use the example of two companies we have studied in the defense industry -- we'll call them Electro Corp. and Ammo Corp. Both decided, at about the same time, to enter the missile (guided weapons) business; but they had quite different technological bases to work with, and they therefore had to adopt quite different strategic approaches to their entry into this sophisticated military business:

* *Electro Corp. was previously focussed on military computers, communication, command and control, and avionics. Most of its work was subcontracted from other weapons systems houses and most of its products were subsystems in the electronics field. It had a very good reputation for rapid adjustment to changes in customer needs, and was for many years a leader in military computer technology. It had experienced R&D teams in all aspects of advanced electronics, integrated circuits, VLSI and computer peripheral equipment. Electro Corp. managers were highly competent technical people. They were proud of their company's technological leadership and of its ability to forecast technological changes. The management team felt, however, that*

their business was headed toward saturation because the cost of avionics was increasing almost exponentially and competition was becoming increasingly intense.
** Ammo Corp. designed and produced ammunition, shells, bombs, gunnery and related materiel and marketed turn-key products domestically and overseas. It had an excellent record in efficiency, quality and safety. It had also developed good relationships with its military customers and extensive experience in the effective use of test fields and ranges. Ammo Corp. managers were generally more conservative and older than Electro Corp. managers. They believed in slow and steady growth, and were not used to frequent changes either in products or technology. They felt, however, that world trends were moving against substantial increases in most countries' inventories. At the same time, they knew that advanced generations of their products would have to incorporate new guidance systems.*

Both companies undertook careful assessments of the strengths and weaknesses of their respective technological bases as a part of their decision to move into the missile segment. We shall use them to illustrate the key issues involved.

TECHNOLOGICAL ASSETS

** Electro Corp. had extensive experience in computers, electronics, airborne radar, communication, command and control, and microwave technology. All these technologies were well known in the company's laboratories. Every new advancement in these areas was immediately recognized by its engineers; new components were purchased and tested regularly, and almost all of its new products incorporated some of the most advanced state-of-the-art technologies in its previous technological areas.*
** Electro Corp. lacked experience and knowledge in guidance technology, optical sensors, missile structures and packaging, and trajectory simulation. Although most of these technologies are moving somewhat slower than Electro's previous experience in electronics, and their development takes usually much longer, many of them were completely orthogonal , however, to Electro's existing knowledge.*
** Ammo Corp. had excellent mechanical design skills. They had solid experience in packaging, thermal protection and simulation. They also had some experience in aeronautical technologies. These "hard core" technologies were developed and studied by Ammo Corp. over a long and steady process of slow advancement, testing and improvements. Ammo Corp. had some of its own secrets in these technologies. Being a military contractor, these "secrets" were never patented, but rather, used as specific features in Ammos products and giving them a reputation of a company who's products are well designed, reliable, easy to use and keep improving. But they lacked expertise in computers, electronics, sensors, radar and microwave. These rapidly changing technologies were rarely incorporated in Emmo's products. If at all, they were used to subcontract work in these areas or had the customer (the military) doing the integration between the two different kinds. Going into the guided weapons domain required however, some in-house capability in these electronics related areas; a capability which, as mentioned, was unknown at Ammo.*

Technological assets are the specific technologies in which the organization can claim competence. They fall into three main activity areas: product, process and support. An assessment of the organization's technology base should encompass all three main areas. (A more refined breakdown can be based on the value chain (Porter, 1985):

companies should evaluate their technological strengths and weaknesses in inbound logistics, operations, outbound logistics, marketing, sales and service, as well as in cross-cutting areas such as procurement, technology development, human resource management, and the firm's infrastructure.) While the relative importance of each area will depend on the firm's strategy and competitive situation, there are almost always enough positive and negative synergies across the areas to make a commitment to their joint strategic management a good investment.

The first step is therefore to develop a list or "map" of the relevant technologies (Jasper, 1980). Sometimes this is easy and obvious; but in more diversified businesses, mapping confronts two challenges. First, the organization must find the appropriate aggregation level for the hundreds and sometimes thousands of discrete relevant technologies. Strategic planning cannot encompass more than dozen or so major groups. Second, and more difficult, is the challenge of identifying the right dimensions along which to aggregate. The best mapping is rarely that given by the academic disciplines (mechanical vs electrical, etc) or by the organizational chart (hardware vs software, etc). It typically takes several iterations before the organization develops a technology map that is neither too detailed nor too aggregate, and neither too functional nor too product-oriented. But these iterations are extremely valuable not only for the map they produce but also for the common understanding and vocabulary that they create between technologists and managers (Mitchell, 1986).

One dimension of aggregation that has proven very useful is the distinction between base, key, pacing and emergent technologies. Base technologies are those that are necessary for being in the game, but do not provide any competitive advantage because all the industry players have equal access to them. Key technologies are those that can provide competitive advantage in the current game. Pacing technologies are those that, while not currently being deployed in your industry, have the proven potential of displacing one of your key or even base technologies. And emerging technologies are on the horizon, as yet unproven, but potentially important. (A.D. Little, 1981; Booz-Allen and Hamilton, 1981a). The importance of pacing and emerging technologies should not be underestimated: in assessing your technological assets, it is vitally important not to restrict your vision to technologies you are currently active in. It is tempting to think that you can strategically manage your technology assets "bottom up" -- through the right methodologies for selecting the most promising projects among those proposed by the technologists; but this is to forget that the most strategically significant technologies might be ones for which the organization is not currently generating any project proposals.

The state of the firm's technological assets can be evaluated along two dimensions. First and most obviously, the business needs to assess its technological strengths and weaknesses relative to the external world -- to its competitors and to the evolving technological frontiers. Here the technology life-cycle notion (Foster, 1986) is very useful. In some industries (such as chemicals), patents are a powerful competitive lever, and an assessment of the firm's relative patent position is needed. In other industries, other indicators of competitive technological standing need to be developed. Beyond the assessment of each individual technology, the organization needs to assess its ability to deal with the interdependencies between technologies. Second, the resulting map of the organization's technological strengths and weaknesses should then be related to the firm's current and projected product portfolio. There may be imbalances between your technological strengths and the product market opportunities.

ORGANIZATIONAL ASSETS

The organizational dimension of the technological base can be broken down into five key elements: skills, procedures, structure strategy and culture (Adler, 1989a).

Skills

Possibly the single most important factor in the assessment of the organization's technology base is its skill base -- its mix of technical and managerial skills. The organization only "knows" what its employees and managers have learned, not what is stored in its computer files:

**Electro Corp. had excellent electrical engineers, computer scientists, and software engineers. These engineers were usually young and newly recruited, the kind of workers usually met in high-tech computer industries. They kept a strong contact with the outer world, and were usually up-to-date on each development in the electronics and computer world. They lacked aeronautical engineers, physicists and missile systems engineers. These engineers are usually harder to find. Most of them are less flexible than electronics people and their skills are usually developed over many years of working for the same company. When Electro Corp. decided it needs these kinds of skills it found out they are not as available as its normal workforce of electronics people.*

**Ammo Corp. had first-rate mechanical, aeronautical and chemical engineers. Most of them, like their managers, were older than Electro's engineers, and they have stayed with their company for a long time, acquiring deeper and better skills and sophistication within their expertises and naturally, as related to Ammo's products. Ammo lacked electronics, computers, radar and microwave engineers. As mentioned above these kind of people are of a different "bread". Young, sometimes bright, non-conformist, and not only they were not present in Ammos' workforce, Ammos managers didn't even have a common language with such people, making it more difficult to interview them, evaluate their skills and integrate them into their project groups. This point will be mentioned again later when we discuss the notion of "culture".*

**Both companies lacked people with the appropriate project management skills: at Electro Corp., they had no experience with large systems and the associated project complexity, and at Ammo Corp., they had no experience with advanced development projects which incorporate newly developed technologies of substantial technological uncertainty. Again, these capabilities can only be acquired through many years of experience in managing projects and in moving from one project to another, usually in the same line of projects. Very rarely do project managers or systems engineers of large projects move between different kinds of projects. And as before, they tend to stay within one company most of their career. The two companies found it rather difficult to locate and recruit such engineers out of the manpower market and similarly, they had no experience in the in-house development of such skills.*

The organization should have a clear map of the technical skill base available to it through its engineers and scientists, as well as through its technicians and non-technical personnel. Clearly, this map bears a close resemblance to the technological assets map; but there may be equipment in place that is not fully exploited due to skills deficiencies, and there may be skills that may be too "tacit" -- to close to the "art" end of the art/science spectrum -- to be included under technological assets. Two dimensions are the technical skill mix need careful study. First, what types of skill does the organization tap? To what professional groups do your people belong? What types of degree do they possess? What types of experience do they bring to the task? Second, what level of skill can you tap in these domains? What is the mix of educational levels? Of experience levels? Types and levels are both difficult to assess. As with technological assets, the more challenging part is classifying the relevant types of skills. This cannot typically be determined from the organizational chart or from the personnel classifications. These may serve as a first cut; but ultimately the organization needs to refer to its strategic direction and the external environment of opportunities and threats to know whether to classify engineers as mechanical vs electrical or product vs process designers.

Of particular importance is an assessment of the management team's technical skills. Managers lacking the needed skills can remedy the situation by some individual knowledge-building and/or by the inclusion in the team of a technologist capable of translating between the business and technical worlds.

Managerial skills are critical to an organization's technical performance. Do you have the people to provide leadership to your engineers and scientists? Do you have experienced project managers who can undertake complex and advanced projects, who have sound technical judgement and intuition, and who can make the needed tradeoff decisions? Do you have managers on the factory floor who understand how to implement new manufacturing automation?

At an aggregate level, the organization needs to ask questions such as: do you have the right mixture of technical and managerial skills in the organization? How effective is the dual ladder (if the organization has one)? At the more micro level, it is important to ensure the correct mixture of personalities in your work groups. Ed Roberts and his associates at MIT have written extensively on the need for a balanced mixture of "critical functions" in innovative organizations (Roberts and Fusfeld, 1981; see also Frohman, 1980). The lack of one or more of these functions may seriously reduce the probability of successful innovation.

Procedures

* *Electro Corp. had a well-oiled procedure for assessing and selecting new products. Being in the electronics business for many years, it's managers understood well the need for a continuous flow of information, a rapid processing of new ideas and a fast process of selecting new products and launching new projects. When an engineer in Electro had a new idea he knows where to go: They have established several committees for new products evaluations, at various levels - within, and across product lines; they had an executive strategic "think tank", that met twice a year, to discuss new products and technological trends, and establish strategic directions for the company.*
* *Ammo Corp. by contrast had never needed a sophisticated planning procedure; being in a slow moving business, their decision normally emerged from the normal evolutionary slow process of usual work. A decision to launch a new product would*

usually take several years, and by the time it was made, it was crystal clear to everybody, both within the company and to its customers that this is going to be the next step. This format of decision making did not require a fast dissemination of information on new technologies (which actually changed very slow). Facing the new era, they found however, that their old scheme of planning and decision making must be changed.

Procedures are the "organizational technology" -- the routines through which things are accomplished. There are two broad classes of procedures -- planning and control, in other words, decision-making and information flows. Planning procedures should be assessed in technology forecasting, budgeting, project selection, and project management. Control procedures should be assessed in personnel evaluation, organizational performance criteria, and project control mechanisms.

The key criterion for assessing these procedures is, we believe, whether they facilitate or impede organizational learning. A project selection procedure, for example, can be designed to encourage the right mix of creative bottom-up initiative and rigorous review, or alternatively it can become a bureaucratic deterrent creating unnecessarily formalistic hurdles and politicized project promotion games.

Structure

** Electro Corp. was organized into product-based business units, each with its own engineering function. In addition they had some central engineering services that included software, packaging, analog electronics, power supplies etc. They had also a central strong manufacturing capability serving all business units. Each business unit was managed as a separate profit center, with a lot of autonomy to product line managers.*

** Ammo Corp. was also organized by product line, but not as separate divisions, since there was a lot of common technology and marketing across products. Despite of its size, it was managed as a family with lop managers sincere involvement in each product line and almost in each product. This resulted however in a strong centralized form of management and low autonomy to project and product line managers.*

The structure of the organization has a great effect on its ability to meet new challenges in technological development and project management. The basic dilemma in organizational structure is between (a) the need to keep people who are focused on the same types of tasks together, so as to ensure that they remain up-to-date in that functional field, and (b) the need for collaboration across different functions, so as to ensure that projects do not suffer for lack of timely information or appropriate incentives. As suggested by Tom Allen (1986), the basic parameters of choosing the appropriate structure are therefore: the rate of change of the functional knowledge-base (faster change indicating great reliance on the functional dimension), and sub-system interdependence in the projects and the duration of the project assignments (both indicating greater reliance on the product dimension).

Many organizations find that they need to attend simultaneously to both dimensions. Formal structures for doing this are called "matrix" structures. There are many organizational and behavioral barriers to the effective operation of a matrix structure (Lawrence, Kolodny and Davis, 1977), and many managers are therefore reluctant to adopt that organizational form. But whether or not they are formalized, matrices are often unavoidable, and instead of backing away from the matrix form, organizations should accompany its introduction with complementary changes in the four other organizational elements that can enhance its benefits and limit its costs: new management skills and procedures are often needed, as well as greater strategic consensus and cultural integration.

One could also include under structure a second component: geographic location. The physical structure of the organization plays a key role in enhancing or impeding the informal flow of information between groups both within and across functions (Allen, 1977). Indeed, some firms achieve the goals of matrix by having an exclusively functional organization chart but geographically dispersing the functional people into product organizations. Here the informal communication created by colocation balances the formal communication channels of the reporting structure.

The assessment of the structure component of the technological base is difficult: there is typically no one obviously correct organizational design; every design has its strengths and weaknesses; and there needs to be a good fit with the other four elements of the organizational dimension. The two key channels of structure's influence on performance are information and incentives. So the two key criteria for assessing structural component of the technology base are: is our structure facilitating or impeding the needed communication flows, and is it creating useful or counter-productive incentives?

Strategy

* *Electro Corp.'s prior strategy was that of a subcontractor whose competitive edge was in fast reaction to changes in customers' requirements and in gaining advantage out of recent technological developments. Practicing this strategy for many years made them a quite attractive contractor in the eyes of customers and main contractors that have used their services. Quite different strategic priorities would need to characterize its missile systems business.*

* *Ammo Corp. had traditionally thought of itself as specialized in low-cost mass production, in which its competitive edge was in particularly high quality and safety standards. They have emphasized their reliable products, their long shelf-life, their easy-to-use capability and rapid training cycles for new users. In the missile business, however, it would need to differentiate its product on additional performance dimensions. Accuracy, lit-rate and especially the compatibility with additional systems (airborne, naval and land platforms) had to play a major role in their new strategy of product deployment.*

In what sense is strategy part of the technological base? Conventionally, strategy is viewed as a more or less deliberate pattern of decisions about the development or deployment of that base. But looked at more closely, the organizational processes of formulating and implementing strategy and the even the substantive content of that strategy are typically deeply embedded in the organizational fabric of the business. As a result, they are typically not amenable to particularly rapid change -- top management's desires notwithstanding. It is true that some organizations put a premium on strategic flexibility, and in some environments such flexibility may be particularly valuable

(Bhide, 1986). But flexibility is only one criterion amongst others for assessing the strategic element of the technological base.

We can identify at least two other criteria. First, there is the fit between the various sub-elements that should be included under strategy. Many firms have learnt over the last few decades how to elaborate explicit business strategies. But despite the burgeoning literature, few firms have so far elaborated strategies for specific sub-functions (such as engineering or manufacturing) and even fewer have elaborated cross-functional strategies in areas such as technology. Obviously, the technology strategy sub-element is of particular importance to the technology base, but it will be of little use unless it is well integrated with both the business strategy and with the functional strategies, especially with the strategies of those functions such as R&D, manufacturing, information systems and marketing that contribute most to defining and implementing the technology strategy.

In order to ensure an adequate fit, two sub-criteria are useful. First, the content of the strategies have to be reasonably comprehensive (without being so obsessively detailed as to inhibit action). Ten-line strategic statements have the appeal of concision. But to serve effectively as a guide to daily decision-making, the strategy should be specified at a more detailed level, so that it can guide decisions in the distinct policy domains that middle managers are responsible for. Too often, strategy is seen as an overall direction that is implemented in a set of projects. This misses a crucial intermediate step -- the policies that can link the myriad daily decisions made about the conduct of projects and on-going operations to the strategic direction. Adler (1989) discusses ten policy domains for technology strategy.

Second, an adequate fit between the various strategies will typically require a more participative process of strategy formulation. The elaboration of functional strategies draws functional managers into a more active role in the strategy process; ensuring that these various functional strategies are compatible requires a higher degree of dialogue across the functions and across management levels.

Apart from flexibility and fit, one other assessment criterion is worth highlighting: is the form of these strategies that of a detailed itinerary or a compass heading? Hayes (1985) makes a compelling argument that the itinerary form can only be an effective guide if the environment is stationary and well-known. Fewer and fewer industries offer such easy environments. In a dynamic environment characterized by a lot of uncertainty, flexibility may be very valuable; but the organization stills need to trace substantive lines of development for itself, and in a dynamic environment these lines of development can only be specified as an overall compass heading. This requires that the management team build real insight into the nature of their organization's current and projected capabilities and into their fit with the evolving market needs. The need for such insight explains the value, particularly in more dynamic environments, of strategic focus -- a clear sense of what the organization needs to master and what it can afford to let others do for it -- as opposed to unconstrained and unrelated diversification. Strategic focus and the quality of the insight that focus makes possible are key criteria for evaluating the strategy component of the technological base, because the greater the focus and insight, the longer the effective strategic planning time-horizon (see also Burgelman, 1984). One of the key factors inhibiting technological dynamism is U.S. firms is their short planning horizons (Booz-Allen & Hamilton, 1981b).

Culture

** Electro Corp. had a culture emphasizing technological leadership. It required a close tracking of all recent technological advancements. Its engineers were "hands on" each new technology, they read (or at least subscribed to) all the journals in their field. They traveled a lot and some of them had close contacts with colleagues in other industries. In combination, they had a strong commitment to rapid response to customer needs. This meant they spent considerable amount of time with their customers -- debugging new systems and agreeing upon new features, improvements or modifications. They lacked a total systems integration culture and the kind of quality and safety standards needed for missile systems. Their engineers were good at detecting and debugging local subsystems problems. Very few of them could see the whole system, let alone the complete battlefield in which the entire system would be used and cooperate with other systems.*

** Ammo Corp.'s culture was technologically conservative. Their values emphasized durable technologies, accuracy, and most of all reliability and safety. No one in this company was impressed with new technologies. They were always suspicious of gimmicks or shortcuts. They appreciated on the other hand a technology that was well tested and maintained for many years. Like in old wine, they only believed in well established and thoroughly thought-off experience. This culture was obviously too conservative to compete effectively in the faster-paced missile segment. There you may often need to adopt a new technology in a short time, replace previous technologies and modify your systems by building them modular and enabling often the replacement of subsystems*

Culture is usually the most difficult organizational asset to evaluate. In defining culture, Schein's (1984) approach is particularly useful. He distinguishes three levels of visibility: first, the visible and tangible artifacts of an organizational culture are such things as pay scales and office space; second, underlying these artifacts are the normative values of the organization; and third, beneath different values there are typically different assumptions about how the world works. An assessment of the cultural element of the technological base should explore all three layers.

Two key assessment criteria are particularly useful. First, the organization can be described as segmented vs unitary (Kanter, 1983). A segmented organization, one for example in which design engineers enjoy a higher status than manufacturing engineers, will have great difficulty ensuring the producibility of its designs and the rapid manufacturing ramp-up on new products. Innovative organizations are usually characterized by a unitary culture that encourages different subunits to act as team.

A second criterion is whether the organization is focused on "learning" -- continual innovation and improvement -- or only on shipments. A company that competes on new product innovation, for example, can ill afford a manufacturing unit that views dynamic change in product specifications as an interference to be resisted. The culture should reflect an appropriate balance of objectives, and the evaluation and reward procedures -- elements that reappear here as cultural artifacts -- should reflect that balance.

EXTERNAL ASSETS

** Electro Corp. had excellent access to the units in Department of Defense that were relevant to its previous product lines, but they had no relationships at all with the quite different units responsible for missile systems and they had no experience in using military test ranges. For them the military market was that of military computers and communication systems. The people dealing with weapons were quite different, and unknown to them. They even didn't know the people in their competitive firms. Although it didn't seem of great difficulty at the beginning, it turned out to be one of their most difficult tasks in establishing them new business line.*

** Ammo Corp.'s relationships with Department of Defense and the test fields were very suitable for their new missile business. Their close and frequent interaction with weapon systems departments made it very easy for them to be involved in new ideas about forthcoming systems and made them a natural candidate to go into these new fields at least in the eyes of customer, and something that was completely non-existent for Electro Corp.*

An assessment of the business's technological base should include its external assets. Some of these assets can easily be identified when one thinks of all the direct linkages the business has created or could create:

* Downstream links to customers: How much effective access do you have to the decision makers? And since customers can provide precious new ideas (von Hippel, 1986), how well do you learn from users?

* Upstream links to materials and component suppliers, equipment vendors and potentially relevant sources of scientific and technological knowledge: you should assess whether your organization has built appropriate links with the best people and whether those relations are sufficiently collaborative .

* Horizontal links through alliances, industry associations and informal networking: these linkages can be precious assets in the firm's technological base, providing valuable knowledge that can fuel its internal technological assets (see, for ex., von Hippel, 1987).

Building and maintaining these external links requires, however, an appropriate set of internal organizational assets. Managing downstream linkages, for example, requires: skills to interpret customers' comments, procedures to ensure the systematic collection and analysis of field information, organizational structures to ensure that results of this analysis flow to the appropriate people and that these people have some incentive to act on it, a strategy framework that focuses people's attention on learning from users, and cultural context that avoids the "not invented here" syndrome.

Apart from the linkages that the firm itself creates, there are less voluntaristic relations with competitors and with the political environment. These relations can, however, make important contributions to the organization's technological base, just as they can severely weaken it. Porter (1985) discusses the role of "good" competitors in improving your competitive advantage, industry structure, market development and entry barriers, and through these means, your technological base can be enhanced. It is therefore important to assess the quality and configuration of your competitors as well as the efficacy of your organization's efforts to influence your competitors.

In some industries, regulations have a considerable impact on product innovation (for ex: FDA approval for new drugs) or on the organization's internal operations (for ex: EPA or OSHA regulations). Both types of regulation can have a considerable impact on the firm's projects and internal assets. The organization's technological base should therefore also be assessed in terms of the appropriateness of internal compliance policies and the productivity of relations with the regulators.

Finally, in some industries, the political environment can play an important role in shaping the firm's technological base. Recent years have seen industry players mobilize to seek protection from foreign competition -- including technologically-based competition -- and to seek government support for domestic technology development. Ansoff (1984) offers a useful discussion of how to assess your "societal" strategy.

PROJECTS

Projects are the means by which the organization's internal and external assets are mobilized and transformed. An assessment of the technological assets generates a "state" view of technical activity -- the balance-sheet; assessing the projects gives a "process" view -- the profit-and-loss statement. It is therefore critical to assess your organization's project management strengths and weaknesses in the behavioral processes that constitute the projects:

* *Electro Corp's. experience in new electronics applications gave it considerable advantage in the management of projects based on less-than-mature technologies, including in evaluating and selecting project proposals. They had a well-established form for pre-project activities, in which they have developed and tested often new capabilities and in which engineers were used to try their new ideas. Once a project was approved, it had moved past, employing efficient means for control and a well-planned process of transferring.*

* *Their manufacturing department was flexible enough to accept and incorporate frequent changes and to timely introduce their new product in the market. However, all of their project (and process) capability related to electronic equipment which was more or less in one category. Once they needed to plan, design and manage interdisciplinary larger projects they found this task was quite difficult.*

* *Project activities had to be scattered now on various technologies (as mentioned in the technological assets section), and managing these interdisciplinary programs was almost as a nightmare to the newly appointed and inexperienced project manager and to the top management who had to make new kinds of decisions related to interdisciplinary system.*

* *Ammo Corp. excelled at establishing the most efficient, high-quality, safe production process for new products based on rather mature technologies. But they did not have much experience in selecting or managing projects based on newer technologies and necessitating complex systems engineering. Their experience in pre-project technological activities was also almost non-existing. Testing a newly discovered technology or developing a capability for future products was a completely unknown process at Ammo Corp. Everything that was done was related to some existing project, and if needed they would extend the projects schedule until the new capability was well learned and adopted.*

* *Their projects which obviously were longer lasting, were performed along many stages where each stage was accompanied by a careful study of its results and consequences Transforming a product into production was also a lengthily process,*

and it included a close look at their reliability and quality measures. All this of course was quite fit for the new "missile era", however, naturally they needed to expand on their interdisciplinary systems capabilities, which was probably easier to do in their case than in Electro's.

There are two types of criteria for evaluating projects as part of the technological base -- external and internal. The external point of view evaluates the project portfolio in terms of whether it (a) leverages and (b) enhances the organization's technological, organizational and external assets. Managers should therefore examine the project portfolio to see whether it adequately reflects the mix of technology thrusts identified under the technological assets rubric and whether the projects undertaken reach a happy conclusion as frequently and as fast as the enviroment demands.

The internal point of view merits more elaboration. Whether the end result of the project is a new product, a new manufacturing process or a management decision, we can identify several logical phases through which each project progresses. The projects real stages -- as opposed to its logical phases -- will reflect the importance of iterations and parallelism between phases; but logically one might distinguish the following phases: pre-project, idea generation, evaluation, selection, implementation, and post-project.

The pre-project phase provides a direct link to the organizational technological assets, since it encompasses the assessment and mapping of technology and products (Hayes, Wheelwright and Clark 1988, Ch. 10, Willyard and McClees, 1987), as well as setting the "structural context" (Bower, 1970) and the "strategic context" (Burgelman, 1983) for innovative projects. These pre-project activities focus the organization's attention on certain issues and opportunities, and thus play a critical role in shaping the subsequent outcomes. The key factors for effective pre-project activities are maintaining links to external knowledge sources and across internal boundaries.

Within the project itself -- the idea-generation, evaluation, selection and implementation phases -- Hayes, Wheelwright and Clark (1988) suggest three key evaluation criteria:

(a) Organization: does the project manager have enough authority to ensure both continuity of resource commitments and consistency of decisions over the whole project? Too often new product projects are defined too narrowly, so that the project leader is responsible only for the generation phase, and implementation is left to a manufacturing operations manager. If new products are your life-blood, new product projects should be managed by business managers.

(b) Problem solving: is there sufficient trust and technical competence to enable engineers in the generation phase (product design) to cooperate with engineers focused on preparing implementation (process design)? Too often, the product designers refuse to communicate specifications that are not yet "firm" out of fear that manufacturing engineers will protest later changes, even though such early information, even in its provisional state, is extremely valuable for process designers. It is still very rare in U.S. industry, although common in Japan, for product designers and process designers to sit down together to negotiate optimal trade-offs (and to discover unforeseen synergies) between performance, cost, and quality criteria.

(c) Conflict resolution: when, where and how do the inevitable disagreements and conflicts get resolved? Too often, the productive value of such conflicts is ignored in the name of organizational prerogatives. As a result, conflicts are sent up the hierarchy for resolution, which further politicizes them and slows down their resolution and thus the project. One technology manager has told us how he keeps his finger on the pulse of the conflict resolution process in his organization -- by watching the number of projects that are in limbo, neither scrapped nor moving ahead.

Imai, Nonaka and Takeuchi (1985) suggest a fourth criterion for evaluating projects: "multi-learning," that is, capitalizing on the opportunities created in the projects for participants to develop new skills.

The post-project phase governs what the organization will learn from past projects for its subsequent activity: does the organization systematically conduct post-project reviews? Does it collect data that enables it to compare this project's performance against that of comparable projects in the past? How objective is the assessment? The key factors for effective post-project activities are the expectations communicated by senior managers and the culture that rewards good decisions and not just good outcomes. The organization's project capability can only truly become a part of the technological base if management commits the organization to "learning across projects" (Hayes, Wheelwright and Clark, 1988).

FROM ASSESSMENT TO ACTION

Electro Corp.'s and Ammo Corp.'s assessments of their respective technological bases led them to quite different strategic plans for their entry in their new business:

* *One of Electro Corp.'s key technological weaknesses was remedied by the acquisition of an optical equipment company, while the other technical deficiencies were remedied by recruitment of new people. Their procedures and structure were deliberately retained -- with the addition of a new missile division -- but their strategy concepts and cultures remained largely unchanged -- by default rather than by design. In order to remedy their lack of DoD relationships, they established a joint venture with an established weapons systems house for marketing their new products and managing the test cycle. This venture initially encountered some opposition from the DoD, but the opposition was overcome through an extensive lobbying effort.*
* *The weaknesses in their technological assets led Ammo Corp. to establish several joint ventures and to subcontract some particularly challenging sub-systems. They also recruited numerous technical people in the electronics, computers, radar and microwave areas. In order to derive the full benefit of these new skills, they adopted a matrix structure in their new missile product line. But the remedies for weaknesses in their strategy process and cultural were more difficult to find: they resolved to use their relationships with their partners in their joint ventures and sub-contractors as learning opportunities -- to let some of their entrepreneurial habits rub off on them.*

Five years after their move into the missile business, both companies have acquired the key technologies, skills and established effective linkages with partners, customers and suppliers. Both, however, are still struggling with systems integration problems and they are both somewhat behind in their testing schedules. Managers in both companies are still unsure of themselves in both strategic and project-level decision-making. The innovation-oriented culture at Electro Corp. has impeded the development of the kind of discipline needed for complex systems. The efficiency-oriented culture at Ammo Corp. has not been much changed by daily contact with their new partners, and it has proven very difficult to establish the behavior patterns need for high-tech project management.

In this history, Electro Corp. and Ammo Corp. appear to fit a pattern we have observed in numerous other cases. It is a pattern that managers should consider as they move from assessment to action: of the four dimensions we have identified, it is usually -- although not invariably -- the organizational assets that prove to be the limiting element. Technological assets can be acquired, external relationships can be contracted, but if the organizational assets are not appropriate, the right projects will not be forthcoming or, if they are forthcoming, they won't be successful.

Moreover, among these organizational assets we have often found a hierarchy:

* The most direct determinant of the benefits realized from new technological opportunities is the skill base of the organization: do the personnel have the skills required to effectively select, develop, operate and maintain the technological assets?

* Whether or not sills are effectively deployed will depend on prevailing procedures, in particular the procedures for coordinating in different functional departments.

* Whether these procedures -- which prescribe certain roles -- are maintained in the spirit or on the contrary are respected only in the letter and therefore degenerate over time will depend on their congruence with the incentives created by the organizational structure: what specialized functions have been established? To whom do they report?

* These structures in turn will evolve to reflect the priorities embodied in the organization's strategy: what are the competitive priorities of the firm? How are these formulated? How are they translated into resource allocation decisions?

* And behind these priorities, we often find culture -- the values and assumptions that bind the organization and give it continuity over time.

These five factors can be thought of as five levels of organizational learning. Two factors argue for thinking of them in these terms. First, with increases in the magnitude of the change in technological assets that the organization seeks to effect, the organization needs to make adaptions at progressively higher levels in this hierarchy (Pava, 1983). Simple technological changes typically require modest changes in skills and procedures. More radical technological changes, on the other hand, typically call for organizational changes not only in skills and procedures, but also in structure and strategy. And revolutionary technological changes -- such as those undertaken by Electro Corp. and Ammo Corp. -- usually call for changes in all five levels, including culture.

The second reason for thinking of these factors are a hierarchy is that the lower levels of organizational learning are typically amenable to faster change than the higher levels: the higher levels are more "viscous." New skills can be recruited in a matter of weeks or months. New procedures typically take several months to develop and implement. New organization charts can be drafted overnight, but getting the organization to work effectively in the new framework usually takes six months or a year. New strategies can be decreed, but effectively mobilizing the organization to implement them typically requires personnel shifts and changes in structure and incentives -- usually taking a year or more. And culture, if it is manageable at all, usually takes several years to change. Electro Corp. and Ammo Corp., still struggling to reorient their strategies and cultures to their new technological and business environment after five years intensive activity, are good examples of the viscosity of organizational assets. (see Figure 2.)

[PUT FIGURE 2 ABOUT HERE]

There are, of course, exceptions. But more rapid change in the organizational fabric can only be effective in very peculiar circumstances. In the mid-1980s, a large, New York based financial services organization that had been plagued by poor processing performance realized the urgency of completely overhauling its back-office technological and organizational assets and its new system development project capability. They could see that the magnitude of change they were seeking would necessitate not only equipment, skill and procedural changes but also a major transformation of their structures, strategy and culture. So they decided to replace the entire operations top management team, nearly half the other managers, and one-third of the employees. The change proved highly effective, but it still took two years to digest. Even this two-year time span was only possible because they were located in Manhattan where there is a large pool of experienced financial industry operations expertise, and because their activity -- processing commercial paper -- is a very well-established "factory" activity with exceptionally well-defined technology. And its not obvious what level of enthusiasm the management team will find when they announce plans for the next major systems upgrade!

This exception thus "proves the rule:" companies that want to capitalize on technology's ability to make a positive contribution to their performance -- rather than seeking merely to minimize technology's negative impact -- need to carefully assess the strengths and weaknesses of their technological base as well as the time it takes to remedy those weaknesses and build new strengths.

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