

Adapting Your Technological Base: The Organizational Challenge

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A COMMON mistake in assessing an organization's technological base is narrowing the review to matters of technical competence. This article presents a step-by-step guide that leads the manager through all four components of the technological base: technological assets, organizational assets, external assets, and project management. Case studies of organizations in the defense industry illustrate how two companies' strategies for moving into a new business were shaped by the strengths and weaknesses of their respective technological bases.

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AN ORGANIZATION cannot accomplish its strategic and operational goals without an adequate technological base—that is, technological know-how and the organizational levers for effectively building and deploying that know-how.

- When IBM decided to enter the personal computer business, its technological base was well suited to the task; it had skilled computer and electronics people and strong values regarding technology, quality, service, and customer orientation. However, IBM decided that it did not have the appropriate organizational structure for the new product line. An effective PC business would need to be much more agile than most of IBM's core businesses. So IBM structured the new division as an Independent Business Unit, more autonomous than most of IBM's divisions. This allowed the unit to develop their PC exceptionally fast and win market share.

- When Swiss watchmakers faced the introduction of digital watches by American and Japanese companies in the early 1970s, most 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, 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. Not only were they unprepared, but most managers did not even realize it. The world preeminence of the Swiss watchmaking companies was destroyed.

As these examples show, whether a company is contemplating a strategic change or just evaluating the implementation of existing strategy, it must thoroughly assess the strengths and weaknesses of its technological base. But what are the elements that need to be considered in conducting this assessment? We know how to assess the financial strength of an organization, as represented by cash flow, lines of credit, equity, and so forth. We know, similarly, how to assess its marketing, manufacturing, and human resource capabilities. Managers should be able to define and evaluate their organization's technological base in an equally rigorous way. Unfortunately, the assessment of this technological base is too often limited to a review of the patent position, the investment in leading-edge technologies, or some other equally narrow area. Managers need a framework for assessing the much broader question of how well their organizations are positioned to derive competitive advantage from technology.

In this article, we will define the elements of an organization's technological base and identify some key managerial issues for evaluating it.

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Four Dimensions of the Technological Base

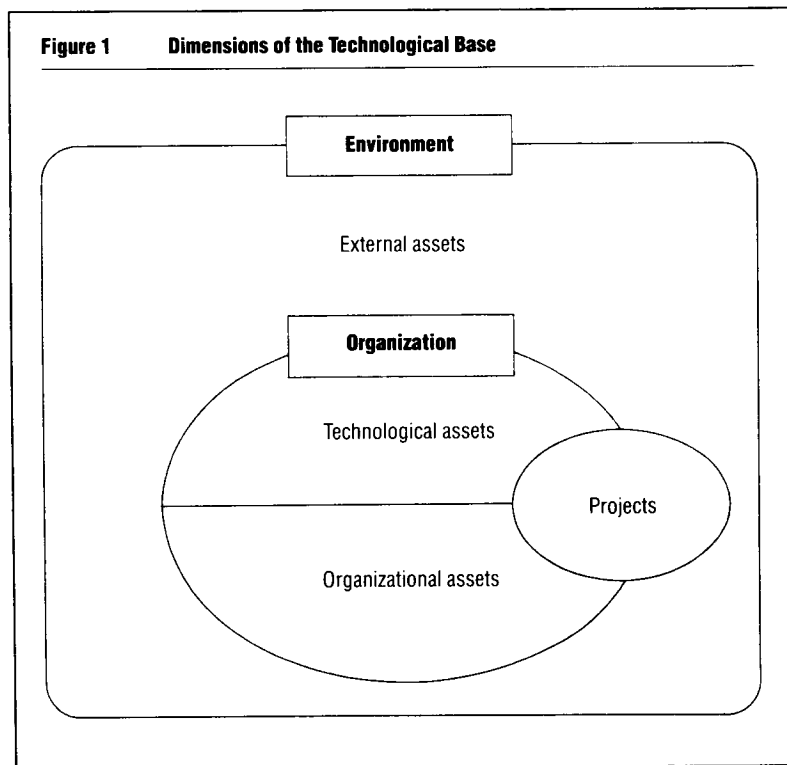
The purpose of assessing an organization's technological base is to determine its ability to develop new products that meet current market needs, to manufacture these products using the appropriate process technologies, to develop or adapt new product and process technologies to meet projected future needs, and to respond promptly to unexpected technology moves by competitors and to unforeseen opportunities. This functional definition of the technological base implies that in addition to evaluating the organization's current products, processes, and projects, managers should consider whether the organization is technologically equipped to meet its stated future strategic objectives,¹ and further, whether the organization is technologically strong enough to create new opportunities for itself and to respond to the opportunities and threats created by its environment and its competitors.

What kinds of questions should managers ask themselves as they attempt to assess their own organizations' 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):

- **Technological Assets.** These are the most immediately visible elements of the technological base—the set of reproducible capabilities in product, process, and support areas. Technological assets can be more or less reliably reproduced; the other elements are, by contrast, fundamentally relational, which makes them much more difficult to replicate.
- **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.
- **External Assets.** These are the relations that the firm establishes with current and potential allies, rivals, suppliers, customers, political actors, and local communities.
- **Projects.** These are the means by which technological, organizational, and external assets are both deployed and transformed. Projects should be considered part of the technology base insofar as the organization's *modus operandi* is a learned behavioral pattern that can contribute to or detract from technological and business performance.

To illustrate these dimensions and to identify some of the key managerial issues involved in each, we will use as examples two companies we have studied in the defense industry—we will call them Electro Corporation and Munitions Corporation. Both decided, at about the same time, to enter the missile (guided weapons) business. But they had quite different technological bases, and therefore had to adopt quite different strategic approaches to their entry into this sophisticated business.

- **Electro Corporation** was previously focused 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 electronics subsystems. It had developed a good reputation for rapid adjustment to changes in customer needs, and for many years had been a leader in military computer technology. Its R&D was strong in all aspects of advanced electronics, integrated circuits, VLSI, and computer peripheral equipment design. Electro managers were highly competent technically, proud of their company's technological leadership and its ability to forecast technological changes. The management team felt, however, that their



business was headed toward saturation because attractive growth prospects were leading to greatly intensified competition.

- **Munitions Corporation** designed and produced ammunition, shells, bombs, gunnery, and related material, 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. Munitions managers were generally more conservative and older than their counterparts in Electro. They believed in slow and steady growth and were not used to frequent changes in products or technology. They recognized, however, that world trends were moving away from substantial increases in most countries' materiel inventories. And they knew that advanced generations of their products would have to incorporate new guidance systems.

Each company undertook a careful assessment of the strengths and weaknesses of its technological base as part of its decision to move into the missile business. We shall use their assessments to illustrate the key issues.

Technological Assets

Technological assets are the specific technologies in which the organization can claim competence.

- **Electro Corporation** had extensive experience in computers, electronics, airborne radar, communication, command and control, and microwave technology. It quickly identified new advances in these areas and regularly tested new generation components. Almost all of its new products incorporated state-of-the-art technologies. However, Electro lacked experience and knowledge in guidance technology, optical sensors, missile structures and packaging, and trajectory simulation. Although most of these technologies were evolving somewhat more slowly than Electro's previous core technology—electronics—many of them were completely new to Electro's engineers.

- **Munitions Corporation** had excellent mechanical design capabilities. Its personnel had solid experience in packaging, thermal protection, and simulation, and some experience with aeronautical technologies. Munitions had developed these core technologies over many years, through a steady process of slow refinement. It had accumulated some valuable trade secrets. Because Munitions was

a military contractor, these techniques had never been patented, but were instead used to buttress the distinctive strength of Munitions's products, giving them a reputation for being well designed, reliable, easy to use, and continually refined. Munitions lacked expertise, however, in the rapidly changing technologies of computers, electronics, sensors, radar, and microwaves. If these were present in their products at all, they were left to subcontractors. Moving into the guided weapons domain would require some in-house capability in these electronics-related areas.

Both Electro and Munitions had some of the key technologies that their new business demanded but lacked others. A more detailed assessment of an organization's technological assets should encompass all three main activity areas: product, process, and support technologies. (An even more refined breakdown can be based on the value chain: Companies can 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 resources, and the firm's management and information infrastructure.²) While the relative importance of each area will depend on the firm's strategy and competitive situation, there is almost always enough synergy, both positive and negative, 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.³ Sometimes this is easy and obvious, but in more diversified businesses, mapping confronts two challenges. First, the organization must find an appropriate way to classify the hundreds and sometimes thousands of discrete technologies. Organizing the various technologies into clusters makes them more manageable. 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 versus electrical, etc.) or by the organizational chart (hardware versus software, etc.). It typically takes several iterations before the organization develops a technology map that is neither too detailed nor too aggregated, 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.⁴

One dimension of aggregation that has proven particularly useful is the distinction between base, key, pacing, and emergent technologies. Base technologies are those that are common to everyone in the industry, but that do not provide any competitive advantage because all the industry players have equal access to them. Key technologies can provide competitive advantage in the current state of the industry. Pacing technologies are those that, while not currently deployed in the industry, can reasonably be assumed to have the potential to displace one of the key or base technologies. And emerging technologies are on the horizon, as yet unproven, but potentially important.⁵ The importance of pacing and emerging technologies should not be underestimated: It is vitally important not to restrict the assessment to technologies in which the organization is currently active. It is tempting to think that technology assets can be managed from the bottom up—through the use of clever methodologies for selecting the most promising projects among those proposed by the technologists. But the most strategically significant technologies might be ones for which the organization is not currently generating any proposals.

Having classified the technological assets in a meaningful way, the organization can now evaluate them. Most obviously, this means assessing technological strengths and weaknesses relative to both the external world (current and potential competitors) and to the relevant evolving technological frontiers.⁶ The business can then estimate how rapidly it might overcome its weaknesses and buttress its strengths. In some industries (such as chemicals), patents are a powerful competitive factor, and the assessment must consider the firm's relative patent position. In addition, the organization needs to evaluate its ability to deal with opportunities and threats associated with new technologies and emerging areas of technological fusion.⁷ The resulting map of the organization's technological strengths, weaknesses, opportunities, and threats should be related to the firm's current and projected product portfolio. There may be imbalances between the technological strengths and the product market opportunities.

Organizational Assets

The organizational dimension of the technologi-

cal base can be broken down into five key elements: skills, procedures, structure, strategy, and culture.⁸

Skills

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

- **Electro Corporation** had excellent electrical engineers, computer scientists, and software engineers. These engineers were usually young and recently recruited from the best schools—the kind of employees typically encountered in high-tech computer industries. They maintained strong contacts with their colleagues in other firms and were familiar with the most recent developments in the electronics and computer world. But Electro lacked the aeronautical engineers, physicists, and missile systems engineers necessary to achieve its ambitions in the guided weapons field. Excellent engineers in these domains were often difficult to find. Their skills were usually developed over many years of working for the same company and, as a result, were profoundly shaped by the specific projects they had worked on. The right skills for Electro's new thrust were not readily available.

- **Munitions Corporation** had first-rate mechanical, aeronautical, and chemical engineers. Most of them, like their managers, were older than their counterparts at Electro, and they had typically been with Munitions for most of their career, progressively refining their skills through experience with Munitions's products. But Munitions lacked electronics, computers, radar, and microwave engineers. Young and often nonconformist, such engineers were scarce among Munitions's workforce. Munitions managers didn't even share a common language with such people, making it more difficult to interview them, evaluate their skills, and integrate them into their project groups. (This issue resurfaces in our discussion of culture.) Both companies lacked people with the appropriate systems integration and project management skills. Electro had experience with neither large-scale systems nor the associated project complexity; Munitions had no experience with the advanced development projects that incorporate substantial technological uncertainty. The systems integration and project

management skills that both companies would need could be acquired only through years of experience in the relevant types of projects. Moreover, project managers and systems engineers who work on large projects tend to stay within one company for most of their careers since there are many firm-specific aspects to their task. Both companies thus found it difficult to locate and recruit the needed systems engineers and project managers; both lacked experience in the in-house development of such skills.

To assess its skills, an organization must make a detailed comparison of the skills in place and the skills required for the whole range of current and future business and technological challenges. This assessment should encompass the skills of engineers and scientists, as well as 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. Also, there are often skills that are too “tacit”—too close to the “art” end of the art/science spectrum—to be included under the technological assets heading.

The assessment of skills proceeds in three steps. First, what *types* of skill does the organization have? What types of degrees do people possess and what disciplines will the organization need in the future? What types of experience do people bring to the task and what types will be needed in the future? This assessment should include the less visible skills, in particular, the shopfloor skills necessary for the deployment of new process technologies. Second, what *level* of skill is available in each of these domains and what level will the organization need in the future? What are the educational and experience levels of current personnel, and what levels will be needed? Types and levels are both difficult to assess, but just as with technological assets, the more difficult step is classifying the relevant types of skills. This step cannot rely on organizational charts or 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, for example, to classify engineers as mechanical and electrical, or as product and process engineers. Third, what is the organization's *skill formation* process? What encouragement is provided for updating skills, phasing out obsolete skills, and bringing in new ones?

Of particular importance is an assessment of the management team's technical and technology management skills. Managers lacking technical skills can be trained in them. It is often helpful to include in the top management team a technologist capable of translating between the business and technical worlds. Technology management skills are difficult to assess. Does the organization have the people capable of providing leadership to its engineers and scientists? Does it have experienced project managers who can undertake complex and advanced projects, who have sound technical judgment and intuition, and who can make the needed tradeoff decisions? Does it have managers on the factory floor who understand how to implement new manufacturing automation? Does it have mechanisms in place to ensure the development of these technology management skills?

These assessments need to be conducted at the aggregate and the work group levels. At the aggregate level, the organization needs to ask questions such as these: Does the organization have the right mix of technical and technology management skills? How effective is the dual ladder (or does the organization need one)? At the work group level, it is important to ensure the correct mix of personalities and roles. Ed Roberts and his associates at MIT have written extensively on the need for a balanced mixture of “critical functions” in innovative organizations.⁹ The lack of one or more of these functions may seriously reduce the probability of successful innovation.

Procedures

- **Electro Corporation** had well-oiled procedures for assessing and selecting new products. Having been in the electronics business for many years, its managers understood the need for a continuous flow of information, and Electro had thus streamlined its process for selecting and launching new products. An engineer with a new idea knew where to go: Several committees evaluated proposed products, operating both within and across product lines. Electro felt confident that this procedure for selecting projects would serve it well in its new business. However, its procedures for controlling projects were less suited to the new situation. Large, complex systems would need more complex control procedures for tracking costs, schedule, and performance.

- **Munitions Corporation**, in contrast, had never needed a sophisticated planning procedure. Theirs was a slow-moving business; the decision process for launching a new product usually lasted several years and involved dozens if not hundreds of reviews by different departments. By the time a decision was made, its rationale and implications were crystal clear to everybody in the company and to its customers. Facing the new era, Munitions managers understood that their old planning and decision-making procedures would need to change.

Both Electro and Munitions had developed project selection procedures that were well tuned for the needs of their respective traditional domains. If Electro's procedures needed refinement, Munitions's procedures were going to need substantial overhaul. Procedures are the "organizational technology"—the routines through which things are accomplished. There are two broad classes of procedures: planning and control. Planning procedures of particular relevance here include technology forecasting, budgeting, project selection, and project management. Control procedures include personnel evaluation, organizational performance criteria, and project control mechanisms. An assessment should encompass all these types of procedures.¹⁰

The key criterion for assessing these procedures is whether they facilitate or impede organizational learning. This is a somewhat unorthodox assessment approach. The most common approach is to focus on whether there is too much or too little proceduralization, assuming that organizations more concerned with efficiency need more procedures and that organizations more concerned with innovation need less, relying on their members' skills and other resources. A focus on learning suggests that the type of procedures is as important a consideration as the degree of proceduralization. Well-designed procedures can focus employees on the right issues and minimize the loss of accumulated learning. The project selection procedure, for example, should be designed to encourage the right mix of creative bottom-up initiative and rigorous review; otherwise it will become a bureaucratic deterrent creating unnecessarily formalistic hurdles and politicized promotion games.

Structure

- **Electro Corporation** was organized into product-based business units, each with its own engineering function. In addition, it had some central

engineering services including software, packaging, analog electronics, and power supplies. It had a strong, centralized manufacturing capability serving all the business units. Each business unit was managed as a separate profit center, with considerable autonomy for product-line managers.

- **Munitions Corporation** was also organized by product line, but not as separate divisions, since there were common technologies and marketing tasks across products. Despite its size, the top management team played the general management role for each product line and often for specific products. This centralized form of management left project and product-line managers with little authority.

Both Electro and Munitions were going to need to adapt their organizational structures somewhat. The basic dilemma in designing organizational structure is between (a) the need to keep together people who are focused on the same types of tasks, 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, the choice of structure depends on the rate of change of the functional knowledge-base (faster change indicating great reliance on the functional dimension), the degree of subsystem interdependence in the projects, and the duration of the project assignments (greater interdependence and duration both indicating greater reliance on the product dimension).¹¹

Many organizations find that they need to attend simultaneously to both dimensions. Formal structures for doing this are called "matrix" structures. Matrix structures encounter many organizational and behavioral barriers, and many managers are therefore reluctant to adopt them.¹² But whether or not matrices are officially recognized in the organization chart, they are often unavoidable; instead of backing away from the matrix form, organizations should make complementary changes in other organizational areas that can buttress its difficulties (e.g., new management skills and procedures, 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.¹³ Indeed, some firms achieve the goals of a matrix structure by combining a functional reporting system with a policy of locating people from different functions working on the same product in the same place. The informal communication created by doing this can counterbalance the formal communication channels of the reporting structure.

The assessment of the structure component is difficult because there is no single, correct organizational design; every design has its strengths and weaknesses, and its ultimate effectiveness depends critically on its fit with the four other elements of the organization. It is useful to remember that structure influences performance through information and incentives. So the two key criteria for assessing structure are: Is the structure facilitating or impeding the needed communication flow, and is it creating useful or counterproductive incentives?

Strategy

- **Electro Corporation's** prior strategy was to maintain its competitive edge by reacting quickly to changes in customer requirements and using the most recent technological developments. This strategy had made Electro a very attractive subcontractor to its customers. Quite different strategic priorities would be needed in the missile systems business.
- **Munitions Corporation** had traditionally thought of itself as specializing in low-cost mass production with particularly high quality and safety standards. Munitions emphasized its products' reliability, long shelflife, and ease of use. In the missile business, however, Munitions would need to differentiate its product on additional performance dimensions. Accuracy, hit-rate, and compatibility with other systems (airborne, naval, and land platforms) would play a major role in any successful strategy in the missile domain.

Both companies would need to adapt not only the content of their strategies but also their strategy processes. But in what sense is strategy part of the technological base? The organizational processes of formulating and implementing strategy and even the substantive content of that strategy are typically embedded rather deep in the organizational fabric of the business. As a result, strategy is often not amenable to rapid change, top management's desires notwithstanding. While some organizations put a premium on strategic flexibility, and while

such flexibility may be particularly valuable in some environments,¹⁴ flexibility is only one criterion among others for assessing the strategic element of the technological base.

We can identify at least two other criteria: fit and form. Strategies for the various subfunctions must fit well with each other and with the overall technology strategy. Many firms have learned over the last few decades how to elaborate explicit business strategies. But so far, despite the burgeoning literature, few firms have elaborated strategies for specific subfunctions (such as engineering or manufacturing) and even fewer have elaborated effective cross-functional strategies in areas such as personnel or technology. If, as we have argued, the technology base includes product, process, and support technologies, then technology strategy must integrate the strategies of the functions such as R&D, manufacturing, information systems, and marketing that contribute most to developing and deploying technology.

In order to ensure an adequate fit, the content of the technology strategy must be reasonably comprehensive (without being so obsessively detailed as to inhibit action). Ten-line strategic statements have the appeal of conciseness; however, to serve effectively as a guide to daily decision making, the technology strategy should be more detailed. 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 about projects and ongoing operations to the overall strategic direction.¹⁵ An effective technology strategy includes a well-defined set of technology management policies.

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

As for the form of technology strategy, the primary question is whether it should be a detailed itinerary or a compass heading. Hayes makes a compelling argument that the itinerary form can be an effective guide only if the environment is stationary and well known.¹⁶ Fewer and fewer industries offer such easy environments. In a dynamic environment characterized by a high degree of uncertainty, flexibility may be very valuable, but the organization still needs to trace substantive lines

of development for itself. In a dynamic environment these lines of development can only be specified as an overall compass heading. This requires that the management team have real insight into the nature of the organization's current and projected capabilities and into those capabilities' 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.¹⁷ The greater the focus and the insight, the longer the effective strategic planning time-horizon will be.

Culture

- **Electro Corporation** had a culture emphasizing technological leadership. Its engineers followed the journals in their fields assiduously, closely tracking all recent technological advances. They traveled frequently and maintained close contacts with colleagues in other firms. Committed to responding rapidly to customers' needs, they spent considerable amounts of time with their customers—debugging new systems and jointly identifying new features and improvements. Electro lacked, however, a systems integration culture and the kind of quality and safety standards needed for missile systems. Its engineers were very good at debugging and refining subsystems, but few of them had the experience to sense the location of problems or improvement opportunities in larger systems, let alone in the role of these systems in the complete battlefield situation.

- **Munitions Corporation's** culture was technologically conservative. Munitions emphasized proven technologies, reliability, and safety. No one in this company was impassioned by new technologies. They were, on the contrary, wary of the dangers of technological change. They appreciated technologies like vintage wine—for their maturity. This culture was obviously too conservative to compete effectively in the faster-paced missile market. The missile market would require them to adopt new technologies before they were fully proven and modularize their design to facilitate rapid upgrades.

Culture is usually the most difficult organizational asset to evaluate, but it was very clear that Munitions's culture would need to change dramatically. In defining culture, Schein's approach is particu-

larly useful.¹⁸ Schein distinguishes three levels of visibility: First there are the visible and tangible artifacts of an organizational culture (e.g., relative pay scales and relative office space); second, underlying these artifacts, are the normative values of the organization; and third, beneath values, are the different assumptions about how the world works. An assessment of the cultural element should explore all three layers.

Two key assessment criteria are particularly useful. First, is the organization sufficiently unitary or is its culture too segmented?¹⁹ A segmented organization—for example, one in which design engineers enjoy a higher status than manufacturing engineers—will have great difficulty ensuring the producibility of its designs and rapid manufacturing ramp-up on new products. Innovative organizations are usually characterized by a unitary culture that encourages different subunits to act as a team.

A second criterion is whether the organization's culture attributes a high enough priority to "learning"—continual innovation and improvement. 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 the company's strategic priorities, and the evaluation and reward procedures—elements that reappear here as cultural artifacts—should reflect those priorities.

External Assets

- **Electro Corporation** had excellent access to the units in the 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. They had no experience in using military test ranges. They didn't even know the people in the firms against whom they would compete. Although these deficiencies didn't seem particularly serious at first, they turned out to pose some of the greatest difficulties.

- **Munitions Corporation's** relationships with the Department of Defense and the test fields were well suited to the missile business. Their close and frequent interaction with weapon systems procurement departments had allowed them to contribute to the definition of new systems. This would greatly facilitate their entry into the missile field, by legitimating them in the eyes of their customer.

An assessment of technological base should include 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 does the organization have to customers' decision makers? And since customers can provide precious new ideas, how well does the organization learn from users?²⁰
- Upstream links to materials and component suppliers, equipment vendors, and potentially relevant sources of scientific and technological knowledge: The organization should assess whether it 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 provide knowledge that fuels the development of the organization's internal technological assets.²¹

Building and maintaining these external links require, 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 these results, a strategy that focuses people's attention on learning from users, and a cultural context that avoids the "not invented here" syndrome.

Apart from the linkages that the firm itself creates, there are less voluntary relations with competitors and the political environment. These relations can, however, make important contributions to the organization's technological base, just as they can severely weaken it. Porter discusses the role of "good competitors" in improving the company's competitive advantage through their potentially positive effects on industry structure, market development, and entry barriers.²² It is therefore important to assess from a technological point of view the quality and configuration of competitors as well as the efficacy of the organization's efforts to influence its competitors. Technical standards constitute one area that often deserves particularly close attention in this regard.

In some industries, regulations strongly affect product innovation (e.g., FDA approval for new drugs) or the organization's internal operations (e.g., EPA or OSHA regulations). Both types of regula-

tion can have a considerable impact on the firm's technical projects and internal assets. The organization should assess the appropriateness of its internal compliance policies and the effectiveness of its 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. Ecological concerns can influence the organization's technology agenda, and an assessment of relations with the relevant social movements is often necessary.²³

Projects

Projects are the means by which the organization's technological, organizational, and external assets are mobilized and transformed. An assessment of these assets generates a "state" view of technical activity—the technology balance-sheet; assessing projects gives a "process" view—the technology profit-and-loss statement. It is therefore critical to assess the organization's project management strengths and weaknesses.

- **Electro Corporation's** project management was well-tuned to the demands and opportunities of a rapidly evolving technology universe: fast decision making, confidence in the integrity of design choices, quick surfacing of conflicts, willingness to assume technical risks. Electro's manufacturing staff was flexible enough to incorporate incomplete new product specifications and frequent changes. However, all of Electro's project experience related to small electronic subsystems. Its project management approach was much less suited to the constraints of larger interdisciplinary projects. Electro's managers and engineers saw the management and technical challenges of these interdisciplinary programs as a nightmare; their old behavior patterns were severely stressed by demands for more elaborate planning and control, higher levels of management authority, and a greater diversity of engineering disciplines and problem-solving styles.

- **Munitions Corporation** 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. In their traditional domain, a strong risk-averse attitude was understandable if not inevitable. Munitions, unlike Electro, had no experience in investing in technologies that might or might not bear fruit that, in turn, might or might not be used in a future project. Everything related to some specific current project. Munitions's projects were subject to an elaborate stage-review process. Transferring a product into production was a lengthy process that involved extensive testing for reliability, safety, and quality. Much of this project management approach would be useful for the new missile business, but Munitions would need to adapt that approach to deal with the newer, more rapidly evolving technologies.

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 according to 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 environment demands.

The internal point of view merits more elaboration. Whether the 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 project's actual stages may be less orderly, but one might still distinguish the following phases: preproject, idea generation, evaluation, selection, implementation, and postproject. Each phase requires assessment.

The preproject phase provides a direct link to the organization's technological assets, since it encompasses the assessment and mapping of technology and products,²⁴ as well as the setting of the "structural context"²⁵ and "strategic context"²⁶ for innovation projects. These preproject activities focus the organization's attention on certain issues and opportunities, and thus play a critical role in shaping the subsequent outcomes. The key factor for effective preproject activities is 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 suggest three key evaluation criteria:²⁷

- **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 development projects are defined so narrowly that project management is split between an R&D manager responsible for the generation phase and an operations manager responsible for implementation. If new products are the organization's life blood, new product development projects should be managed by business managers responsible for the whole cycle.

- **Problem Solving:** Is there sufficient trust and social and technical competence to enable engineers in different disciplines or working on different parts of the project to effectively coordinate their problem-solving efforts? The coordination of product design with process design is a frequent trouble spot. It is still rare for product designers and process designers to work together to negotiate optimal trade-offs (and to discover unforeseen synergy) between performance, cost, and quality criteria. The organizational form of the project as well as the company's procedures and culture often inhibit that collaboration, and when product and process engineers do attempt to collaborate, they often discover that they lack the needed problem-solving skills.

- **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, slows down their resolution, and thus delays the project. One technology manager has told us that 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 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.²⁸

The organization's postproject procedure indicates the extent to which it learns from past projects: Does the organization systematically conduct postproject reviews? Does it collect data that enables it to compare current and past projects? How ob-

jective is the assessment? The key factors for effective postproject 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 truly become a part of the technological base only if management commits the organization to "learning across projects."²⁹

From Assessment to Action

Electro and Munitions's assessments of their respective technological bases led them to quite different strategic plans for their entry into their new business.

- **Electro Corporation** remedied a key technological weakness by acquiring an optical equipment company; other technical deficiencies were remedied by recruiting new people. The firm deliberately retained its procedures and structure—with the addition of a new missile division—but, by default rather than by design, left its strategy concepts and cultures largely unchanged. In order to remedy the lack of Defense Department relationships, Electro established a joint venture with an established weapons systems house for marketing new products and managing the test cycle. This venture initially encountered some opposition from the Defense Department, but the opposition was overcome through an extensive lobbying effort.
- **Munitions Corporation** established several joint ventures and subcontracted some particularly challenging subsystems in order to remedy the weaknesses in its technological assets. The firm also recruited technical people in the electronics, computers, radar, and microwave areas. In order to derive the full benefit of these new skills, Munitions adopted a matrix structure. But the remedies for weaknesses in strategy, process, and culture were more difficult to find; management resolved to use Munitions's relationships with the partners in joint ventures and sub-contractors as learning opportunities—to let some of their entrepreneurial habits rub off on Munitions.

Five years after their move into the missile business, both companies have acquired the key technologies and skills, and have established effective linkages with partners, customers, and suppliers. Both, however, are still struggling with systems integration problems, and they are 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 has impeded the development of the kind of discipline needed for complex systems. The efficiency-oriented culture at Munitions has not changed much despite daily contact with their new partners, and it has proven difficult to establish the behavior patterns needed for high-tech project management.

In this history, Electro and Munitions 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. In contrast, we find that managers often assume that if the technological assets are effectively managed, the others will take care of themselves. However, 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:

- **Skills.** The skill base will have the most direct affect on the organization's goals. Do the personnel have the skills required to effectively select, develop, operate, and maintain the technological assets?
- **Procedures.** Whether or not skills are effectively deployed will depend on prevailing procedures, in particular the procedures for coordinating across different functional departments.
- **Structure.** Whether these procedures—which prescribe certain roles—are effectively implemented or degenerate over time will depend on their congruence with the incentives created by the organizational structure. What specialized departments have been established? To whom do they report?
- **Strategy.** 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 they formulated? How are they translated into resource allocation?
- **Culture.** And underlying these priorities, we often find culture—the values and assumptions that bind the organization and give it continuity over time.

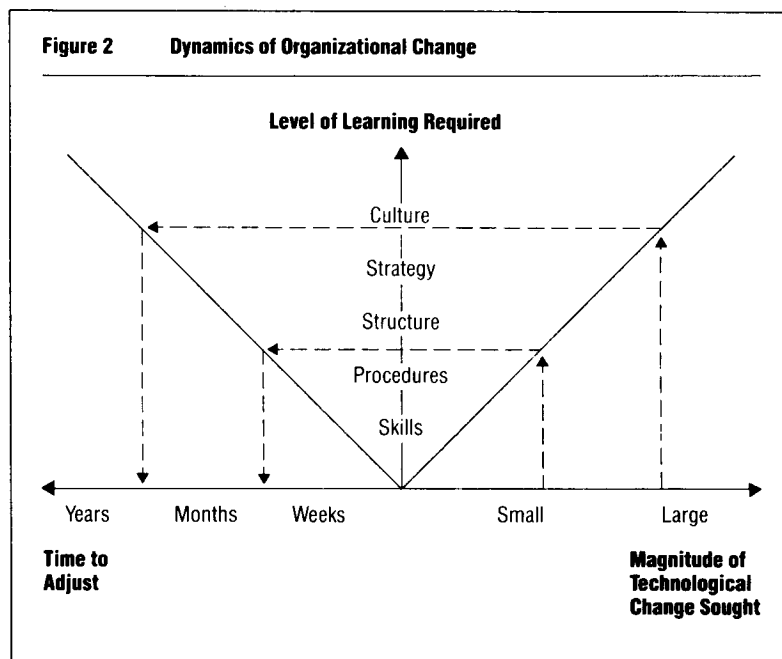
This hierarchical order helps us understand two key characteristics of the dynamics of change in the technology base. First, the greater the magnitude of the change in technological assets that the organization seeks to effect, the higher in the hier-

archy the organization needs to make adaptations.³⁰ Simple technological refinements typically require modest changes in skills and procedures. More substantial technological changes, on the other hand, typically call for organizational changes not only in skills and procedures, but also in structure and strategy. And radical technological changes—such as those undertaken by Electro and Munitions—usually call for changes in all five levels, including culture.

The second key characteristic of change is its rate: 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. Although new organization charts can be drafted overnight, getting the organization to work effectively in the new structure usually takes six months to 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 and Munitions, still struggling to reorient their strategies and cultures to their new technological and business environment after five years of intensive activity, are good examples of the viscosity of the various organizational assets (see Figure 2).

There are, of course, exceptions, but more rapid change in the organizational fabric can be effective only in exceptional circumstances. For example, in the mid-1980s, a large, New York-based financial services firm 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. The firm’s managers could see that the magnitude of change they were seeking would not only necessitate changes in equipment, skills, and procedures, but would also require a major transformation of the organization’s structure, strategy, and culture. So they decided to replace the entire operation’s top management team, nearly half the other managers, and one-third of the employees. The change proved highly effective, but it still took over two years to digest. Even this two-year time span was only possible because the firm was located in Manhattan, where there is a large pool of experienced financial industry operations talent, and because processing commercial paper is a well-established “factory” activity with an exceptionally well-defined technology. And it is 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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