The IT Capability of Nations: A Framework for Analysis

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1. Introduction

A country's information technology capability is the ability of individuals and organizations within that country to develop, diffuse, and apply information technology effectively to address economic, social, military, or technological objectives. Understanding a country's IT capability has been important to analysts, decision-makers, and policy-makers in three distinct, but increasingly inter-related areas of activity. Military and foreign-policy analysts seek to understand the ability of a country to apply information technologies to pursue military and geo-political objectives. Policy-makers in national governments and international organizations seek to understand how information technologies can be used to further the economic and social development of a country. International commercial interests are acutely concerned with the nature of technology markets within countries and their ability to absorb, or at least purchase, a variety of IT-related products and services. Each of these areas is concerned with a country's IT capability, and its current and future capacity for absorbing and utilizing IT.

A complete understanding of a country's IT capability includes understanding not only the state of affairs at a particular point in time, but also the factors that have shaped that capability in the past, and those that will shape capability in the future. What socio-economic and technical factors, conditions, and combinations thereof have contributed to the current level of capability, and which are to play the most important role in affecting the country's future capability? Highlighting critical, or determining factors, can help policy makers identify and prioritize measures that might be taken to improve (or hinder) a country's future IT capability, and its capacity to cultivate, absorb, and apply IT in the future. Although not the principal objective of this study, such an understanding can shed considerable light on the country's ability to compete in increasingly global markets in either the technologies themselves, or in civilian or military applications employing these technologies.

Over the last dozen years, a number of international trends have made conducting assessments of countries' IT capabilities significantly more difficult. First, the variety and volume of information technology available throughout the world have exploded. Technologies that filled a room two decades ago now site on desktops and are sold in millions of units through mass-market consumer electronics outlets. Systems as diverse as mainframe computers, cellular phones, international computer networks, global positioning systems, computer-aided design and simulation software reflect the growing number of types of IT-based products and applications found throughout the world. The global extent and density of computer networks have increased exponentially. The number and geographic scope of sources of the information technologies have expanded dramatically as IT manufacturing and distribution facilities take root in countries that decades ago were considered hopelessly outside of the mainstream of IT activity. The challenges of tracking these developments and their diffusion throughout the international community are considerable.

Second, the number of countries of national security interest to U.S. policymakers is growing. Following the end of the Cold War, the intensity of the national security threat may have decreased, but its variance has increased. National security issues include not only direct military threats to United States property and citizens, but also issues such as the promotion and preservation of regional stability, the growth of democratic governance, the maturation of regional and global markets, the maintenance of international alliances such as the anti-Iraq coalition during the Gulf War, the fight against international organized crime, and so forth. The diffusion of information technologies throughout the world has increased this variance as microprocessor-based technologies play a growing role.

Together, these trends have created a situation in which more analysis is needed about more technologies in more places in the world than ever before. Complicating matters further is the fact that the set of consumers of this analysis is becoming more diverse. It is increasingly likely that individuals who are neither technology nor country specialists–in particular, higher level policy- and decision-makers within governmental and non-governmental or private sector organizations–need to be able to grasp the state of information technologies in a variety of places in the world on short notice, as geo-political events unfold.

The trends enumerated above have created the need for a framework for analysis of information technologies in national and regional contexts that can be applied in a consistent fashion to a wide variety of conditions. Specifically, such a framework should

- be broadly applicable across a wide spectrum of technologies and places
- cater to a wide range of consumers of varying backgrounds who are not necessarily country or technology specialists.
- provide analysis that is neither so detailed that it becomes inaccessible to mid- and upper-level decision or policymakers, nor so simplified (e.g. a single index number) that important insights are lost.
- use a manageable number of variables (e.g. 7±2) that are rich enough to capture a large space of possibilities without necessarily requiring exhaustive and expensive data collection and analysis. These variables should be important enough that they define what a large community of consumers might come to consider a normative set of features to be analyzed.
- be flexible enough that the scope of analysis can be expanded or restricted as needs dictate, from basic analysis of broad categories of technologies (e.g. telecommunications) to focused assessments of a country's ability to apply these technologies to applications of significance (e.g. Command and Control applications).

To our knowledge, a framework that satisfies the above criteria does not yet exist. For years, scholars have studied intensively the nature of technological innovation, technology diffusion, the role of technological innovation in a country's economic and technological development, and a host of related topics. Through case studies, comparative studies, and integrative studies, they have tried to understand a diverse set of issues, including technology transfer, the role of government in technological development, influence of multinational corporations on technology transfer, the "appropriate" role of technology in a given country, technological determinants of an industry's competitiveness, and so forth. Collectively, these underscore the extraordinary complexity of the field and the diversity of factors that play a role. The number of variables examined, both dependent and independent, is extensive; the terminology, diverse. At the same time, most of the literature takes a rather narrow view of the field, concentrating on small numbers of variables, or a very limited number of countries, technologies, or technology-related issues. It is difficult to find frameworks for an analysis that are applicable to a broad collection of countries and technologies and, at the same time, permit an understanding of the richness and diversity of the inter-relationships between technologies and the socio-economic & geo-political environments in which they exist.

This study seeks to develop an analytical framework to evaluate individual countries' technological capabilities, and extend this framework to facilitate an understanding of the factors most strongly influencing the development of that capability, both in the past and the future. It represents an initial effort to develop a framework that satisfies the criteria outlined above.

In this report we first present a model for evaluating a country's IT capability, and then embed this model into a broader framework that addresses the determinants of capability. To illustrate the utility and application of these models, we apply them to two specific country-sectors: the high-performance computing sector in the Soviet Union/Russia and information technologies more broadly in Syria. The latter section further employs the framework to characterizing the threat(s) to U.S. national security of the diffusion of information technologies to that part of the world.

2. Analytical Framework

2.1 A Country's IT Capability

While it is tempting to try to derive a single index to reflect a country's IT capability, such an approach is unlikely to provide the depth of understanding needed for policy- or strategic decision-making. A meaningful representation of a country's IT capability must be based on an evaluation of that country's capability in the individual technologies that constitute this broad category. This is true for at least two reasons. First, countries seldom exhibit uniform capabilities across all technologies. Second, an evaluation of a country's ability to pursue particular applications will in part be based on an evaluation of the technologies needed for that application, not necessarily the broad spectrum of all information technologies. While there are certainly country-based features (e.g. government policy, overall state of the economy, etc.) that impact broad categories of technologies, considerable analytic insight will be lost if too coarse a perspective is taken. For this reason, we will focus our definition of IT Capability, at least initially, on capability with respect to individual technologies.

There are many ways in which a particular technology can be said to "exist" within a particular country. These possibilities range from no presence at all, to examples of imported installations, to instances of domestic involvement in some, but not all, aspects of development and/or production, to the presence of a fully developed, internationally competitive industry producing that technology. Evaluating the state of a country's capability with regard to that technology is significantly more involved than simply identifying the most advanced form of that technology in that country.

2.1.1 Dimensions of Technological Capability

Technological capability is a multidimensional concept. While it is often easy to equate technological capability with the presence of a particular technology, such a uni-dimensional analysis does little to reflect the degree to which the host country is able to employ, distribute, and further evolve that technology to meet its needs, or those of potential markets. The latter ability is a function not only of the technology, but also of the depth and breadth of that country's experience with the technology. These aspects are reflected in the five dimensions of technological capability: proximity of the technology to the technological frontier, depth of development, sophistication of use, pervasiveness, and indigenization. While not completely independent of each other, the dimensions are of a nature that countries may exhibit dramatically different strengths from one dimension to the next for the same technology. It is an identification of these differences that gives a considerable depth to our understand of technological capability, a depth often lost in uni-dimensional analyses.

A country's strength in each dimension may be quantified as shown in Table 1 below.

Proximity to the technological frontier

Level 0: (Non-existent) The technology does not exist in this country and, therefore, is immeasurably far from the technological frontier. An example would be supercomputing in Sudan.

Level 1: (Obsolete) Technology is several generations behind the world-wide state of the art. While it may be functional, it is only marginally so, posing significant maintenance and operational challenges due to the length of time in service and/or changes in the environment of its use to which the technology cannot be adapted. The technology may be viewed as a constraint rather than as an enabler. Examples: Telephone systems employing electro-mechanical telephone switches, 1970s-era mainframe computers no longer supported by vendors.

Level 2: (Non-competitive) The technology represents a previous generation, but may still have useful applications. This level also includes current generation, or near-current, technology that is not internationally competitive, possibly for reasons related to weaknesses in technological features, quality, cost, or level of service. Frequently, the output of protected domestic industries falls into this category. Examples: IBM PC XT, AT, 286, 386; Indian Param High-Performance Computing System, Soviet mainframes.

Level 3: (Competitive) The technology is internationally competitive technology, although not defining the state of the art. Such technology is usually mature, and may have been superseded by more recent models. Such technology is sometimes referred to as the "business state of the art," reflecting the common business practice of adopting technology not when it is first introduced, but after the technology has stabilized and the price/performance ratios have improved. Examples: Intel 486 and Pentium-based computer systems.

Level 4: (Leading) The technology defines the state-of-the-art. It is usually the product of extensive R&D efforts. Those adopting the technology are considered "early adopters" and are willing to endure a significant amount of inconvenience due to the relative immaturity of the technology. Although the technology might require hand-holding from vendor, it is more than "research-in-progress."

Depth of Development

Level 0: (Consuming) No development takes place in the country. Technology, when present, is imported as a finished product.

Level 1: (Assembling) Development consists of simple assembly from kits. Little or no process or product innovation takes place. Development at this level also includes unsophisticated coding or testing of software to detailed specifications provided by customers.

Level 2: (Adapting) Moderately sophisticated development or production is done with significant amount of external assistance, perhaps via licensing agreements. Work may be done to adapt the technology to local conditions. Modest, or sub-state of the art development may be performed in its entirety. An example of the latter would be the development of small or medium-sized software systems without the use of sound methodologies and process management techniques.

Level 3:(Advancing) Domestic firms are actively involved in advancing the relative state of the art in some, although not necessarily all, stages of development. For example, basic research and product design may be done externally, but domestic firms are active in process innovation and other post-design phases. Domestic firms may provide feedback into design phase. Since 'depth of development' is a different dimension from proximity to the technological frontier, it is possible for a country (e.g. the Soviet Union) to have great depth of development, even though the results of that development are not at world standards. What is important for Level 3 is that there be efforts to improve the product, or processes related to its development, even if those products or processes are not considered world-wide state-of-the-art.

Level 4:(Comprehensive) Basic research, applied research, design, and development, process innovation, final production are carried out within the country. Supporting technologies and services also often originate within country. Some stages may be outsourced, but for economic, rather than technical, reasons. In this case the country is *fully capable* of carrying out all stages, but may have economic or political reasons for acquiring the output of a stage of development from another country.

Sophistication of Use

Level 0: (Not) The technology is not used.

Level 1: (Assisted) User community struggles to employ technology in conventional, mainstream applications, and requires significant foreign assistance or outside pressure to do so. Users may desire the technology, but may resist the changes to established practices that are needed to take advantage of the technology. Users do not push the boundaries of the technology's capabilities, nor does the technology significantly change the way they go about their activities. There are virtually no innovative applications. Without outside pressure to use it, the technology will fall into disuse.

Level 2: (Conventional) Usage is limited to conventional, mainstream applications. The user community may change established practices somewhat in response to the technology, or in order to accommodate the technology, but little innovation is done. Few established processes are changed dramatically. Using technology to automate, but not fundamentally alter, existing processes is an example of sophistication of use at this level. Usage does not push the boundaries of the technology's capabilities. This is the first level at which we can say that the technology has "taken hold" in a country.

Level 3: (Innovating) The user community's use of the technology may result in new applications, or significant changes in existing processes and practices although these innovations may not necessarily stretch the boundaries of the technology's capabilities. At this level users may also take advantage of some of the more advanced features of a technology, taking full advantage of its capabilities.

Level 4: (Transforming) The user community is discriminating, and highly demanding. The user community is regularly applying, or seeking to apply the technology in innovative ways that push the capabilities of the technology. Existing processes are regularly transformed to prepare for, or in response to, new technologies. The user community may play a significant role in driving the local state of the art and may have a mutually beneficial and synergistic relationship with developers.

Pervasiveness

Level 0: (Non-existent) Technology does not exist in a viable form in this country

Level 1: (Entrant) Experimental, or isolated examples of the technology exist. This may reflect the first instances of the technology to appear within the country (a growing capability), or a greatly reduced level of activity (a shrinking capability). The supporting infrastructure of goods, services, and complementary industries is very underdeveloped.

Level 2: (Established) The technology is used by a small number of users, but is not considered unique. Experience with the technology is accumulating. The infrastructure of goods and services needed to support broad penetration of the technology throughout the country has begun to emerge.

Level 3: (Common) The technology has been adopted by a significant fraction (although not necessarily majority) of potential users within the country. The infrastructure of supporting and related goods and services has become well established, although is not necessarily extensive..

Level 4: (Pervasive) The technology is pervasive. Its absence is more noteworthy than its presence. The number of first-time adopters of the technology is quite small. The supporting infrastructure of distributors and related goods and services is extensive.

Indigenization

Level 0: (Observing) There is no involvement by nationals. Operation, maintenance, use, adaptation of technology performed by foreign personnel, as is whatever development may be taking place. In short, the technology is present in a particular county in little more than a geographic sense. An example might be a foreign multinational corporation's use of sophisticated analysis tools in an oil field. The only personnel involved with the technology are foreign employees of the corporation.

Level 1: (Operating) National personnel may use and operate the technology, but installation, maintenance and support, and development and adaptation are performed by foreigners.

Level 2: (Supporting) Indigenous personnel are significantly involved in the technology's operation and use and perform many of the routine, day-to-day tasks, including routine maintenance. Foreign personnel largely install technology and are involved in non-routine servicing and upgrading technology.

Level 3: (Managing) Installation, use, operation, maintenance, management, and adaptation of the technology are largely performed by indigenous personnel. However, foreign experts continue to provide key knowledge and services in selected areas.

Level 4:(Mastering) Completely indigenous activity. Indigenous personnel are involved in, and have mastered, all aspects of installation, operation, development, management, use, adaptation & innovation of the technology.

Table 1 Dimensions of technological capability

2.1.2 Diagramming Technological Capability

A country's strength in a particular dimension will generally be the highest level applicable, even if there is considerable unevenness across industries or individual enterprises. This point will be elaborated upon below. The field of high-performance computing provides a illustrative example of how country capabilities vary along these dimensions. For example, the United States is an international leader in this field. Table 2 shows the current capability dimension levels, plus an indication of any significant changes in these levels.

Dimension	Level	Movement	Explanation
Proximity to Technological Frontier	(4) *Leading*		U.S. technology defines the state of the art
Depth of Development	(4) *Driving*		All aspects of development, from basic research to final product are carried out (or can be carried out) in the United States.
Sophistication of Use	(4) *Transforming*		The U.S. HPC user community is the most sophisticated, discriminating, and demanding in

			the world
Pervasiveness	(3) *Common*	+	HPC is still something of a specialized market, although forms of the technology (e.g. the high-end workstation and massively parallel processing market segments) are enjoying growing acceptance in non-traditional commercial markets.
Indigenization	(4) *Mastering*		The U.S. HPC community does not need to rely on foreign assistance in any aspect of HPC development or use.

Table 2 US HPC Capability Levels

The collective impact of all five dimensions can be illustrated by plotting the levels along the radials of a five-pointed star. To diagram all five dimensions, we plot the strength of each dimensions on one arm of a five-pointed star, with level 0 indicating the center. For example, we could represent the HPC capability of the United States as shown in Figure 1. The (+) sign along the Pervasiveness dimension indicates that the level is currently increasing.

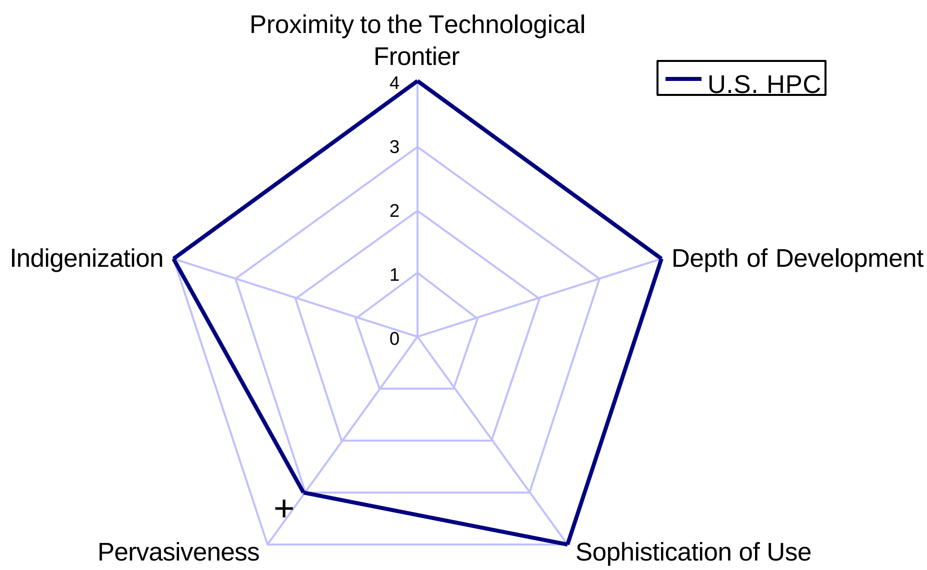

Figure 1 United States capability in HPC

In contrast, high-performance computing in the Soviet Union, circa mid- to late-1980s, exhibited rather different capabilities, as shown in Table 3 (Wolcott, 1993). Figure 2 illustrates

Dimension	Level	Movement	Comments
Proximity to Technological Frontier	(2) *Non-competitive*	—	Even on paper, Soviet HPC systems lagged Western systems. In practice, they suffered extensively from quality problems. In the latter days of the Soviet Union, efforts to sell HPC products on the international markets were unsuccessful. During the final decade of the Soviet Union, the lag behind the technological frontier grew.
Depth of Development	(4) *Driving*		The Soviet HPC industry was autarkic, engaged in all aspects of systems development, from ma-

			terials to components, to software, to finished products.
Sophistication of Use	(4) *Transforming*		The Soviet HPC user community had many skilled practitioners and demanding applications. These users played a significant role in shaping the development of the technologies.
Pervasiveness	(2) *Established*	+	During the mid 1980s, the HPC industry had failed to produce more than a few tens of units of high-end systems, many fewer systems than were needed by industry and academia. Older, common systems like the BESM-6 were no longer in production. The number of systems produced did grow significantly during the late 1980s until the industry collapsed after the dissolution of the Soviet Union. Around 1987 the overall size of the HPC industry was at or above historical levels.
Indigenization	(4) *Mastering*		No foreign assistance was involved in development of the Soviet HPC systems.

Table 3 Soviet HPC Capability

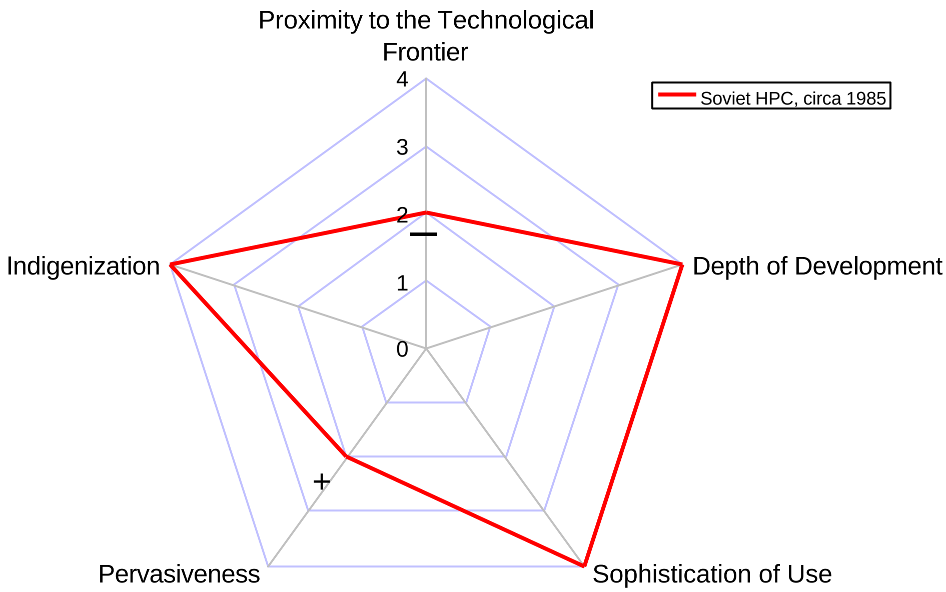

Figure 2 Soviet capability in HPC

Over time, the capability of a country with respect to a particular technology is likely to change. Measuring the dimensions of technological capability gives a snapshot of the capability at a particular point in time, but capability diagrams may be overlaid to illustrate changes in capability over time. Following the break-up of the Soviet Union, the high-performance computing sector was no longer able to exist as a completely self-contained industry. Among other things, linkages between organizations involved in the various stages of development weakened or failed and the discrepancy between domestically manufactured components and those available internationally was too great. A relaxation of policies restricting the use of foreign technologies in HPC made it possible to pursue the development of systems incorporating some foreign components, particularly microprocessors.

By the mid 1990s, HPC capability in the former Soviet Union had changed. Large-scale, government-sponsored development programs that used high-profile HPC systems as drivers of activities at hundreds of supporting industrial enterprises gave way to much smaller-scale projects that relied much more extensively on foreign components and subsystems. Programs producing large, general-purpose systems like the El’brus family developed at the Institute of Precision Mechanics and Computer Technology (ITMVT) in Moscow withered, while efforts like those at the Kvant Scientific Research Institute survived by incorporating Western off-the-shelf component and subassembly technologies into modest multiprocessor configurations. The latter, such as the MVS-100 (Russian Supercomputer, 1996; Massalovitch, 1996) were considerably less reliant on the proper functioning of a fast supporting industry, and had considerably better price-performance ratios. Nevertheless, because they were reliant on a foreign component base, they reflected a decrease along the Depth of Development dimension. Whether or not systems like the MVS-100 are closer to the 1995 technological frontier than the 1985 El'brus was to the 1985 frontier is debatable. However, even the MVS-100 is not internationally competitive. Its attractiveness to domestic Russian customers is in part a function of the fact that it is Russian, an important feature for sensitive military installations. The state of Russian domestic HPC capability in approximately 1995 is shown in Table 4 and Figure 3. These data indicate that overall, Russian HPC capability is no greater, and probably is less, than Soviet capability. While the shift to systems with a much higher usage of foreign components has not improved HPC capability, it has enabled the industry to maintain a level of capability considerably higher than what would have been the case had the industry insisted on continuing to pursue fully indigenous development.

Dimension	Level	Movement	Comments
Proximity to Technological Frontier	(2) *Non-competitive*		Without the use of foreign components, this level would have dropped to (1) obsolete. Because of the rapid movement of the technological frontier in the West, however, the Russian HPC systems of 1995 are no more competitive than the Soviet system were in their day.
Depth of Development	(3) *Advancing*		Development programs continue to develop new generations of systems. These systems continue to rely heavily on foreign components. The research being done by former El'brus engineers for Sun Microsystems also rates at this level.
Sophistication of Use	(4) *Transforming*	—	While many of the traditional users of Soviet HPC are in deep financial straits, those that are in a position to support systems like the MVS-100 continue to pursue sophisticated applications such as aircraft design that shape the development of these systems. However, because of the weakening of financial and material support throughout the scientific and industrial R&D community, the influence of leading users may be weakening. This would also be true if traditional

			users acquire foreign, rather than domestic, systems.
Pervasiveness	(1) *Entrant*	—	There are only on the order of a dozen MVS 100 systems or less. The number of HPC development programs still viable is much less than was the case ten years ago. For the immediate future, the pervasiveness of domestic HPC is not likely to change dramatically either positively or negatively, unless imported HPC technology results in extensive replacement of the few domestic systems that exist.
Indigenization	(4) *Mastering*		The HPC development work which continues within Russia is carried out by Russians, without significant assistance from foreign firms.

Table 4 Russian Indigenous HPC Capability, circa 1995

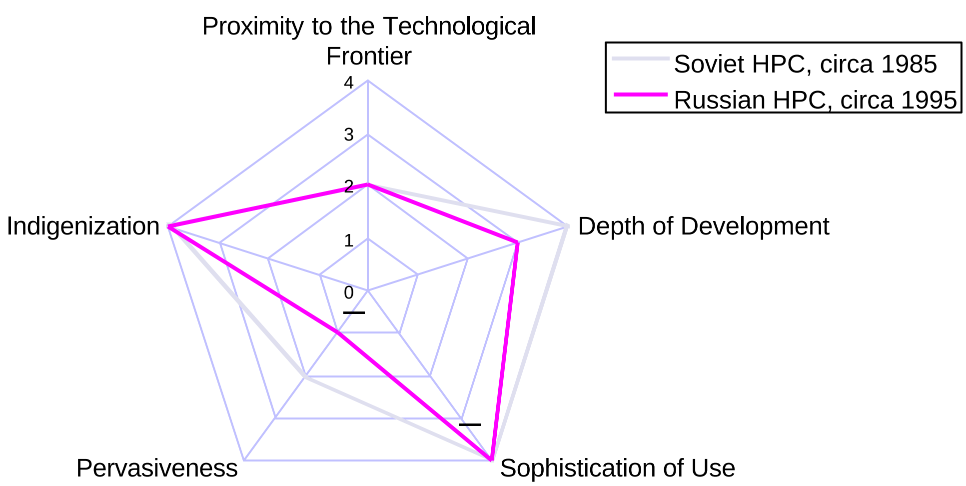

Figure 3 Soviet & Russian capability in HPC

The example of Russian HPC further illustrates that a single technology may exhibit more than one distinctly different form within the same country at the same time, reflecting distinctly different capabilities. Such modalities are important to capture and may be represented on the same capability diagram with two (or more) pentagonal figures. With the end of the Cold War, many of the Soviet/Russian policies regarding the import and distribution of technology have eased, as have export control policies of the former CoCom nations. One consequence has been an increase in the export of HPC systems to Russia. While this transfer of technology is not large, it does represent a very different kind of capability for Russia, as shown in Table 5 and Figure 4.

Dimension	Level	Move-ment	Explanation
Proximity to Technological Frontier	(3) Competitive	+	In recent years, Cray, Convex and other US HPC companies have exported high-performance systems to Russia. These systems have been models that have been available for a few years and/or are limited configurations.

			Nevertheless, they are models in current production at the time of the sale.
Depth of Development	(0) *Consuming*		The technology is imported as a finished product. No modifications are made to the hardware or systems software other than that which is normal as part of system installation and operation.
Sophistication of Use	(3) *Innovating*	+	The technology is used to significantly enhance user abilities to solve certain kinds of problems, such as weather forecasting. Users develop new algorithms and applications to pursue problems in new ways.
Pervasiveness	(1) *Entrant*	+	To date, the number of examples of imported HPC is small, and vendor support is provided as a special case for individual installations rather than as part of an established support infrastructure.
Indigenization	(2) *Supporting*	+	In the past, high-performance installations in Russia would have had an indigenization level of 0 (observing). Operating under strict Security Safeguard Plans, the machines would have been insulated from all indigenous involvement, even though the problems solved would have been of Russian origin. Today, fewer systems are implemented with such safeguards and domestic personnel may handle many routine operations and maintenance tasks.

Table 5 Foreign HPC in Russia

It may be that within a given country a technology is found in two or more distinctly different forms, reflecting different capability levels. HPC in Russia provides an example. On the one hand, indigenous development has resulted in a number of multiprocessor systems incorporating the i860 microprocessor. There are now, however, installations of commercially available systems developed by Cray Research, Inc. The difference in capability represented by these two "modalities" of HPC in Russia can be seen in Figure 4.

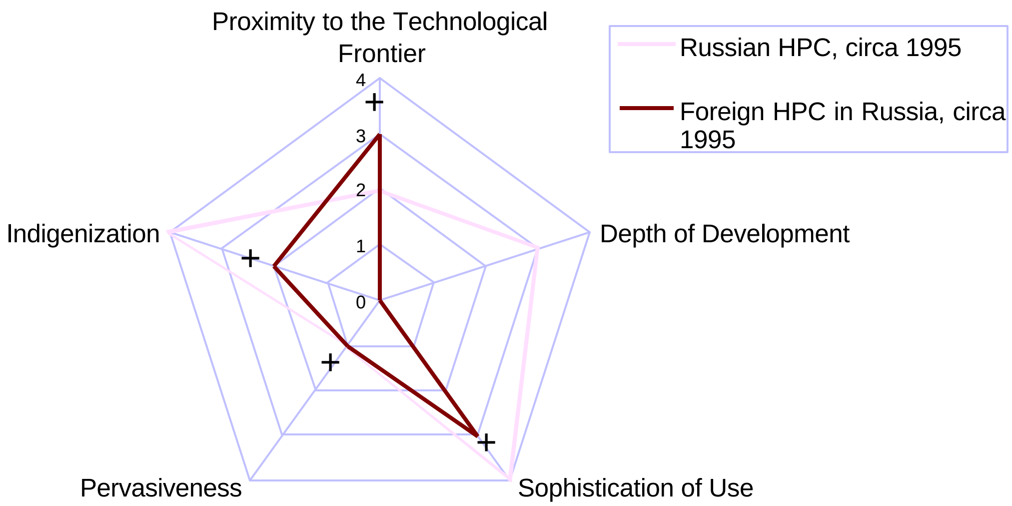

Figure 4 Russian HPC Capability Reflected in Foreign and Domestic Systems

While imported systems bring considerable computing power to their users and may be a boon to downstream applications, the low level of indigenization and the lack of any involvement in development mean that the contribution to Russia's capability in this area is minimal. As such sales increase, the pervasiveness, reflected in the number of installations and the extent of the supporting infrastructure are likely to grow dramatically. The proximity to the technological frontier may rise significantly as well. However, unless Russian engineers become involved with vendors in some form of contractual work, for example, the depth of development will remain low.

2.1.3 The IT Capability Framework: Caveats

In applying the IT Capability Framework, one must keep in mind several important points.

First, one should not reduce a capability diagram down to a single number by, for example, computing the area of the pentagonal figure on individual radar plots. Two capability diagrams with identical area might have very different shapes and, correspondingly, very different implications for a country's overall capability. For example, one country might have weaknesses in the depth of development or indigenization that are offset by high proximity to the technological frontier. Another country might have high indigenization and depth of development, but low proximity to the technological frontier. Equating the IT capability of these two countries would lose much of the valuable insight into the nature of the capability that the radar plots provide.

Second, although the symmetrical nature of the pentagonal radar plot depicting the five dimensions of capability would seem to imply that all dimensions are weighted equally, this may not necessarily be the case. It may be that proximity to the technological frontier has a stronger impact on IT capability than does the level of indigenization. Or perhaps not. The weighting of the five dimensions remains an open question. A great deal more work needs to be done to determine which dimensions have the greatest significance, and under what circumstances.

It is likely that the weighting of the dimensions will be affected by the nature of the application(s) to which the technology is or might be applied. For example, if high-performance computing systems are to be applied to problems of aircraft design, then issues of the proximity to the technological frontier and sophistication of use are perhaps more important than those of depth of development or indigenization. Here, the important characteristic of the technology is the ability to "get the right number," to perform the necessary computation. On the other hand, for HPC in a missile defense system that needs to function in very unique configurations 24 hours a day, the critical characteristic might not be how advanced the technology is, but whether the country has the ability to maintain and adapt the system over time. In other applications, such as large command and control systems, the pervasiveness of a technology may be a particularly important dimension. Such considerations imply that an IT capability radar plot is, by itself, a rather neutral analytic construct. Its significance becomes most apparent when questions about the application of the technology are addressed.

2.2 Determinants of a Country's IT Capabilities

Understanding a country's capability with respect to particular technologies is crucial to understanding how that country might use the technologies to achieve particular objectives. Equally important, however, is an analysis of the factors that influence technological capability and shape its development over time. Such insight can be used to help, or to hinder, capability development. Policy-makers may wish to focus government policy and resources in ways that promote the development of capability in particular areas; foreign adversaries may seek to identify means by which they could hinder the growth of capability. Traditionally, export control policy has been a leading expression of the latter.

The IT capacity of a country refers to the *potential* of a country to develop, absorb, and apply information technologies. The focus of here is on the determinants of capability. We present a framework for understanding a country's IT capacity, and illustrate how the framework can be applied using the examples of Soviet and Russian HPC, and Syrian telecommunications.

2.2.1 A Model of Determinants of Technological Capability

Figure 5 presents a general model that provides a starting point for organizing the many variables that collectively and individually play a role in shaping a country's over-all technological capacity.

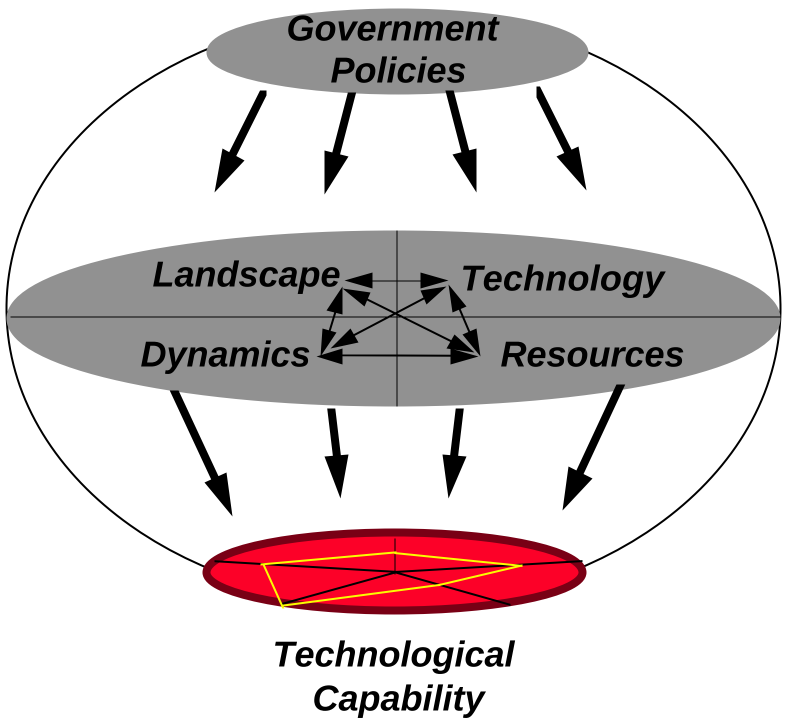

Figure 5 Determinants of technological capability

At the bottom of the figure is the technological capability diagram for a particular technology, as discussed above. The middle layer contains four collections, or dimensions, of variables that researchers have determined impact technological capabilities. These four are:

- *Technology*. This dimension captures the characteristics of the technology for which a technological capability diagram is drawn in the bottom layer. It recognizes that not all technologies are equal when it comes to cultivating a particular capability. For reasons that relate to the nature of the technology itself, it is easier to develop capability in some technologies than others (e.g. PCs vs. HPC systems). Some of variables found in this dimension include: the complexity of the technology to design and to manufacture; the degree to which the technology "stretches" the supporting industries (i.e. how big a step forward is this technology for the existing industry); the extent of the "package" of support functions and services necessary to keep the technology alive once it's installed; the cost of the technology; the degree to which the technology needs to be integrated within other social, organizational, or technical systems (vs. stand-alone) to be useful.
- *Resources*. This dimension refers to the full range of resources necessary for the cultivation of capability: financial, human, technological, material, and informational. Each of these factors can have at least a quantitative and a qualitative aspect. For example, financial resource availability may refer not only to the quantity of financing available, but also to the nature of that financing—whether it is tightly earmarked for certain purposes, or fluid; whether it comes from many small sources, or from a single larger source. As important as the number of individuals available to perform tasks is their

skill levels, or other qualities (e.g. work ethic). Similarly, technological availability refers not only to the presence of the necessary supporting technologies—components, subsystems, tools, technological infrastructure—but also their quality and suitability for a particular purpose. Material resources refers to raw, or semi-processed physical inputs, including energy.

Some concepts may be classified in more than one of the types of resources listed above. For example, 'know-how' may be viewed both as an aspect of technology, as a function of individuals' skill-levels, and as the presence of a certain amount of requisite information.

- *Landscape*. Landscape refers to many variables that describe the relatively static, or slowly changing features of the country that influence, directly or indirectly, its capability with regard to a particular technology. These include the regulatory/legal framework (including legislation on intellectual property rights, if any); the so-called "national innovation system" (Nelson, 1993a), which encompasses the educational system and organizations involved in R&D; natural endowments; historical circumstances that have created local opportunities or burdens for a country; country size; cultural attitudes towards technology; language; economic policy & management system; concentration of power within an industry; the nature of the markets (regulated or liberalized); private vs. state ownership in an industrial sector; political & financial stability, etc.
- *Dynamics*. The dynamics dimension encompasses those factors that are forces for change, or facilitate change within a country. For example, a number of scholars have identified a competitive environment as a particularly strong determinant of technological capability (Mowery and Oxley, 1995; Cusumano and Elenkov, 1994; Lall, 1993; Nelson, 1993b). Other variables include the ease with which capital, information, and labor flow between organizations; the presence of demanding customers; the rate of creation of new organizations; the existence of entrepreneurial spirit and level of risk aversion; the presence of champions with regard to a particular technology.

Each of these four dimensions can impact, and be impacted by, the other three.

Government policies and actions constitute the top layer of the model. These influence technological capability more or less indirectly, by affecting variables found in the middle layer. For example, government may encourage developments in particular technological fields by increasing the R&D funding, or funding procurement of technologies. Policies regarding import restrictions, foreign direct investment, etc. may influence the quality and nature of financial, informational, and technical resources available. Through investment in training and education, the government may indirectly increase the pool of skilled individuals available to work on the development and use of technologies. Governments may influence the dynamic of an industry through regulations regarding the activities of financial institutions, of mobility of the workforce, etc.

There are reciprocal causal relationships that are not shown in Figure 5. In particular, government policy is not formulated in a vacuum, but takes into consideration the state of particular technologies and variables within each of the four dimensions of the middle layer shown above. Such causal relationships are not shown here in order to focus our attention on the determinants of technological capability, rather than the determinants of government policy.

Since the dependent variable is technological capability, the capacity framework is designed to be applied to individual technologies. Intuitively, this is appropriate because countries are likely to exhibit rather different capabilities in some technologies than others, and the set of variables having the most explanatory power may vary from technology to technology.

Nevertheless, the framework may be applied more broadly in three respects. First, there are likely to be shared determinants among significant groups of technologies. Second, the framework has a recursive nature, in which supporting technologies can themselves be analyzed using the framework. This recursive nature lends itself to the discovery and analysis of key “gushpoints” where capabilities in key enabling technologies can quickly enhance the capability of a host of other related technologies, or of “chokepoints”, where a lack of capability has a negative ripple effect on other technologies and applications.

One of the key determinants of the framework is technological availability. Technological availability refers to the presence of supporting technologies necessary to support the development or use of a particular technology. For example, capability in the development of workstations depends on the availability of such technologies as microprocessors, disk drives, printed-circuit board design and manufacturing tools, and so forth. In turn microprocessor development is dependent on the availability of powerful CAD systems, extremely high precision photo-lithography tools, high quality silicon inputs, etc. In principle, capability in each of these technologies could be evaluated using the framework developed here.

The recursive quality of the framework is particularly helpful when the objective is to assess a country’s capability with regard to a particular end-use technology or application. The first stage of the analysis would involve developing a dependency diagram for the application, indicating the technologies on which it depends, the technologies supporting those, and so forth. The second stage would involved applying the capability analysis to each technology to identify those technologies for which capability was particularly weak. The capacity framework could be used to determine the reasons for a particular weakness and perhaps ways in which a key capability could be enhanced.

High-Performance computing in the Soviet Union and Russia provides an example of how the framework may be used to understand the development of capability.

2.2.2 Applying the IT Capacity Framework: Soviet HPC

Although the history of computing in the Soviet Union was nearly as long and rich as that in the United States, the high-performance computing sector of the former was, for most of its existence, not able to match the West in the number, quality, and capability of HPC systems (see Figure 2) (Wolcott, 1993). Although some projects were more successful than others, all struggled within a socio-economic and socio-technological system that, in spite of the high priority placed on such technology, created enormous barriers to development and use. Some of the key determinants of capability are summarized in the following tables.

Table 6 discusses some of the factors inherent in the technology and its use that affected the Soviet Union's ability to cultivate a strong capability. The two technology factors that hindered efforts considerably were the overall complexity of the systems to design and manufacture, and the demands they placed on supporting industries to make non-incremental (and hence, delayed and error prone) advances in their capabilities.

Factor	**Status**	**Explanation**
Complexity	High	Soviet HPC systems were highly complex. This is a quality of HPC throughout the world, but many Soviet systems incorporated "academically interesting" features that increased system complexity and made them difficult to manufacture.
Stress on supporting industries	High	Soviet HPC projects served as drivers of supporting industries. The lengthy development cycles coupled with the perceived need to keep pace with rapid advances in the West meant that transitions from one generation to another were not incremental, but drastic. Each new generation required components and subsystems that were dramatic advances over previous generations. Such non-continuous evolution placed enormous pressure on supporting industries.
Need for "package" of supporting services & products	Moderate-High	HPC systems require extensive "hand-holding" by developers, especially when the technology is new and immature. Few HPC projects matured to the point where the machines could run for long periods of time without developers' involvement. Furthermore, HPC systems are the end result of a very extensive chain of supporting industries that supply everything from ultra pure silicon and water for chip manufacturing to cables, to steel for cabinets, to power supplies.
Level of integration with other systems	Low-moderate	Traditionally, HPC systems have operated for the most part as standalone devices, both technically and socially. Except for systems used for real-time purposes (e.g. early warning systems), HPC units mostly served as number-crunchers that read data off some storage medium and output computational results. Such operation did not require extensive alteration people or organizations' values, work patterns, or social structures.

Table 6 Technology Characteristics of Soviet HPC

In Table 7 we list not an exhaustive set of variables that can be considered part of the "landscape" within which technology development and use takes place, but only those that, in this instance, appear to have the most explanatory power. The variables listed here are important not only for their direct impact on Soviet capability, but also for their impact on other groups of variables, particularly those in the Resources and Dynamics dimensions.

Factor	Status	Explanation
System of economic management	Centralized-directive	The extensive bureaucracy made decision-making considerably more complex and time-consuming. Links between organizations had to be established at or near the point of common administrative superordination. In many cases, this was at the level of Minister or Deputy Minister.
Economic Structure/ Nature of the markets	Monopolistic	By design, the Soviet economic had a low level of redundancy. In HPC, many components and devices were manufactured by a single, or very small number, of plants. This feature had a significant impact on technological availability, for when a component was not available, there were few alternatives to waiting.
Links with upstream and downstream organizations	Variable	In some cases, relationships between research and development facilities and manufacturing facilities were long-term and well established. In other cases, relationships were short-term, tenuous, and contentious. In all cases, relationships were predominantly administratively, rather than economically based.
Organizational structure	Hierarchical and rigid	Although organizational structure is usually an organization-level concept, in the case of the Soviet Union, organizational structures were codified, replicated throughout the country, and difficult to change. In this sense they may be considered a feature of the landscape at the national-level as well. The rigid and hierarchical structures of organizations meant that they had difficulty adapting organizational units to accommodate changing environmental circumstances.

Table 7 The Soviet "Landscape" for HPC

Table 8 illustrates that while the Soviet HPC sector did not lack human or financial resources, a consistent lack of appropriate component and subsystem technologies was one of the major hindrances to HPC development.

Factor	Status	Explanation
Financial resources	Strong	Well-funded, high-profile state programs provided ample levels of financing for HPC. Funding was, however, allocated with significant controls over what funds could be used for what purpose.
Human resources	Strong	Well-trained and highly experienced individuals, the best in the land in many cases, worked on HPC projects. Work in HPC resulted in higher levels of innovation than in other areas of computing.
Technological	Poor	The inadequacy of components and subsystems for HPC was a per-

resources		ennial drag on HPC programs. Development of components and subsystems for HPC was a lengthy and uncertain process. The use of immature component technologies was a major source of delay and aggravation. Many projects, particularly academic, suffered from the reluctance of manufacturing plants to devote capacity to the academic projects.
Material resources	Moderate	Unlike many upstream industries (e.g. semiconductors), organizations designing and building HPC systems were not heavily reliant on material resources. Most inputs to system construction were technological resources. Energy was not a problem in the Soviet Union for most developers.
Information resources	Poor-Moderate	Soviet developers were cut off from direct involvement with their counterparts in the West and did not have access to the informal information-sharing channels that play an important role in technological diffusion in the West. However, they did have considerable, if uneven, access to leading periodicals and, occasionally, systems documentation from Western vendors.

Table 8 Impact of Resources on Soviet HPC

The variables from the Dynamic dimension are shown in Table 9. The variables listed here all point to a very low level of dynamism in the environment for HPC development. They point to weakness in the factors driving change, and diffusing technology and know-how throughout the country.

Factor	Status	Explanation
Competitive Environment	Non-competitive	While HPC development programs may have competed with each other for government funding, they did not compete in the "marketplace". Industrial HPC programs needed a customer to provide development costs, but the funding for development and the resources acquired from sales of systems were completely decoupled; consequently, the goal of development was more to satisfy contract managers than to develop a truly competitive product.
Flow of labor	Poor	Soviet R&D teams were noteworthy for their longevity. Thanks to tradition and government restrictions on the movement of people from one city to another, scientists and engineers rarely moved from one institute to another, and even more rarely from one city to another.
Flow of capital	Poor-moderate	Financing was dictated by the planning apparatus. Private investment was non-existent.

Flow of information	Moderate	HPC projects had relatively low levels of information sharing. There were exceptions when academic groups collaborated with industrial teams to take advantage of the tools and facilities the latter could offer, but the overall trend was for individuals on one project to have very little knowledge of the approaches and insights gained by another.
Presence of demanding customers	Moderate-Good	The leading customers for HPC had quite demanding real-time applications (anti-ballistic systems, radar systems, etc.). These users strongly influenced HPC projects.

Table 9 The Dynamic Determinants of Soviet HPC capability

There is considerable interplay between the factors discussed in the four tables above. For example, a great deal of the persistent delay in many Soviet HPC projects can be attributed to the interplay of 1) the complexity of the systems, 2) the stress placed on supporting industries, 3) the administrative distance between organizations, 4) the monopolistic nature of the economy, and 5) the centralized-directive nature of economic management. These factors together formed a vicious circle in which delays due to systemic factors created the need to jump further ahead on the next generation of development, which placed additional stress on supporting industries, which contributed to delays for lack of alternative sources of components, etc.

Government policies played a strong role in shaping the variables discussed above. The obvious examples are government funding for all Soviet HPC projects and indeed the creation of the centralized-directive system of economic management as a whole. A number of less obvious policies played a role as well, however. Government guidelines for organizational structure, the mobility of individuals, and have already been mentioned. For national security reasons, HPC projects were compelled to rely solely on indigenous technologies. This policy had a dramatic influence on technological availability (assisted, to be sure, by Western export control policies), forcing domestic industries to address all facets of HPC system development. The need pursue developments in so many areas simultaneously sorely taxed the Soviet computing industry.

The preceding discussion could point to the following conclusions regarding the ability to alter Soviet HPC capability. In general, most of the options for bringing about change are available only internally. That is, outside forces can influence change only indirectly, and imperfectly, especially when those within the country are resistant to such change. This is particular true for those variables in the Landscape and Dynamic dimensions. In the case of the Soviet Union:

- Some of the most significant barriers to HPC development were systemic. Changes in this area would require dramatic and fundamental changes to Soviet economic, political, and social systems. Executing such reforms was clearly something that could be done only by the Soviets themselves, and was initiated by Mikhail Gorbachev in 1985.

- Changes in the dynamic—the competitive environment, the flow of information & capital throughout the country, the mobility of the workforce, etc.—would depend to a large extent on changes in government policy. Changes in technology (e.g. communications technology) could play a role in enabling some change.
- One aspect of the dynamic which can be influenced by foreign entities is the competitive environment. In the case of Soviet computing in general, CoCom export controls (and domestic policies) limited the presence of foreign technology in the Soviet market, reducing the competition domestic suppliers had to face.

The variables that are most easily influenced by forces outside of a country are those in the Resources dimension.

- Financial resources. A necessary, but not sufficient factor in HPC development, financial resources can be provided internally by government allocation, externally by foreign investment, or indirectly by changes in the economic structure that permit more flexible domestic investment and inter-organizational arrangements. Both U.S. and Soviet policy restricted the ability of U.S. computer firms to invest in Soviet HPC development efforts.
- Human resources.
- Technological resources. Export control policies are focused here. While the goal of export control policy has been on denying the technological resources to carry out HPC applications of concern, they have also had an indirect effect on the indigenous HPC industry. By not permitting advanced Western computing technology to be exported to the Soviet Union, export control policy helped to limit the level of competition in the domestic market. This reduced the dynamic
- Capital resources
- Information resources

The most significant changes in the Technology dimension might come about not by actually changing the variables, many of which are inherent in a particular technology, but by changing which technologies one focuses on. This is a matter of research or development policy. For example, in the case of Soviet HPC, the following change could have led to improvements although, in the absence of changes in the Landscape dimension would probably not have:

- Instead of using HPC as a driver for supporting industries, adjust development plans to better accommodate the availability of technology from those industries. Although this would have been akin to “giving up the race,” such a shift might have reduced the stress on supporting industries and eased the vicious cycle described earlier.

2.2.3 Applying the IT Capacity Framework: Russian HPC

The environment for Russian HPC changed significantly during the late 1980s and early 1990s. Some of the most significant trends include:

- Decentralization of a great deal of decision-making authority from the centralized ministerial planning structure to individual enterprises and institutes. Individual organizations assumed a great deal more responsibility for their economic activities, and their relationships with customers and suppliers.
- A deepening economic crisis in Russia that brought a sharp decrease in government funding for HPC, and purchases of HPC by traditional customers.
- Greater flexibility in determining organizational structures. Options for subdividing an organization into smaller units with partially independent budgets became possible, and was pursued by many organizations.
- Expanded contacts with foreign organizations & individuals. Russians were given greatly expanded opportunities to travel abroad, new legislation made it easier for foreign organizations to enter into joint ventures or establish subsidiaries in Russia. It became possible for researchers in the field of HPC to enter into contractual agreements with foreign companies. A prominent example of this is the work being done at the Moscow Center for SPARC Technology by former El'brus engineers for Sun Microsystems.
- Decreased barriers to trade. Importing foreign goods and selling them on the domestic markets introduced new goods into Russia, and provided a measure of competition for local produces that had not existed earlier. Access to foreign computer technology, including components and subsystems, or finished products like PCs, workstations, and software improved dramatically.

The overall impact, as shown in Figure 3 and Figure 4 has been a decrease in the Pervasiveness and Depth of Development dimensions of IT Capability reflected in domestic systems, and a growth in the Proximity to the Technological Frontier reflected in foreign systems installed in Russia. The existing HPC development programs decreased dramatically in number, size, and scope of work. Large, comprehensive programs died. The programs that remained relied much more extensively on foreign components and subsystem technologies, relied much less on Russian industry for supporting goods and services.

The changes in capability were influenced by changes in some of the determinants of capability. The following tables show how the determinants changed from circa 1985 to 1995. Table 10 shows that one of the contributors to delay in Soviet projects (and hence, a contributor to the lag in Proximity to the Technological Frontier) has eased in the new environment. Other things being equal, this change would be likely to improve the Russian HPC sector's ability to maintain a position near the technological frontier. As the other tables will show, other things are not equal, however.

Factor	**1985**	**1995**	**Explanation**
Complexity	High	Moderate-High	The "academically interesting" projects for the most part died. The system that continue to be produced are more likely to incorporate "off-the-shelf" technology components and standards that are more easily integrated than the former completely proprietary systems.

Stress on supporting industries	High	Low-Moderate	Because the supporting industries no longer saw it in their interest to develop the leading edge components and subsystems needed for HPC, HPC developers were forced to turn to foreign technologies. Out of necessity, Russian HPC developers have become followers of foreign technological trends, rather than drivers of domestic trends.
Need for "package" of supporting services & products	Moderate-High	Moderate-High	Although we lack conclusive evidence, it is likely that domestic HPC products still require a good deal of "hand-holding" by their developers, although perhaps not the same amount as earlier systems.
Level of integration with other systems	Low-moderate	Low-moderate	The principal role of HPC installations as largely stand-alone systems has not changed significantly, to our knowledge. This could be an area of significant change in the future, however, as HPC becomes a significant component of a host of real-time, or interactive systems in the military *and* commercial sectors including computer-aided design, simulation & training systems, etc.

Table 10 Changes in Soviet/Russian HPC Technology

Table 11 highlights a number of trends that have the potential for making a positive impact on Russia's HPC capability. The common thread through these trends is increased flexibility and autonomy for those participating in HPC development. In spite of their potential, it is not clear, however, that the short-term impact has necessarily been positive. The benefit of greater flexibility in economic arrangements is more likely to be observed in the future when the economy as a whole strengthens, and becomes more diversified in nature.

Factor	1985	1995	Explanation
System of economic management	Centralized-directive	Increasingly market oriented	A great deal of decision-making in economic matters devolved to the level of the enterprise or institute, or even to the sub-enterprise level.
Economic Structure/ Nature of the markets	Monopolistic	Less monopolistic	The Russian market is still very much in the process of developing an economy that has the multiplicity of sources for given products. However, the introduction of greater selections of foreign goods has, in some cases, increased the diversity of sources.
Links with up-	Variable	Variable	Linkages with upstream and downstream organiza-

stream and downstream organizations			tions has improved in that individual organizations have greater flexibility in establishing relationships when they feel it is in their best interests. However, in the case of HPC, organizations tied together under the old administrative structures have not felt both felt it in their interests to maintain the relationship. There have been breaks in the supply chains that, given the monopolistic nature of the economy, have had detrimental effects.
Organizational structure	Hierarchical and rigid	Flexible	Individual organizations have been given much greater freedom to establish the kind of organizational structure they feel most appropriate for their circumstances. This has enabled many organizations to create project-oriented entities that bring together the best individuals for a particular project, regardless of where in the organization they might formerly have worked.

Table 11 Changes in the Russian Landscape for HPC

Table 12 shows the changes in resources impacting Russian HPC capability. Overall, the results are mixed; the changes of the last decade have brought improved access to some resources (e.g. technological, and informational), but drastic reductions in others (e.g. financial). The decline in financing for Russian HPC, whether from government or private sources, has been severe enough to overshadow many of the potential gains in other resources, and other IT capacity dimensions discussed above.

Factor	1985	1995	Explanation
Financial resources	Strong	Weak	The Russian HPC sector has been severely hurt by declines in government funding for R&D, and the near evaporation of systems in production.
Human resources	Strong	Moderate-Strong	With the decline in funding for HPC systems, many engineers have left their institutes to apply their skills in other areas. Many groups have just enough funding to maintain projects, but not move them forward to completion. Some groups, like the former El'brus engineers who are currently working for Sun Microsystems, are improving their skills, at least in the areas in which they are currently active, such as processor design and systems software. There is no indication (yet) that Russians are contracting with foreign organizations to per-

			form portions of systems development, so the level of indigenization remains high.
Technological resources	Poor	Moderate	Although the domestic industry is no longer supply the advanced components used by HPC developers, foreign technologies are much more available than before. This switch from domestic to foreign suppliers is most responsible for the decline in the Depth of Development dimension of capability shown earlier, although it has enabled the Russian HPC sector to remain closer to the technological frontier than would otherwise have been possible.
Material resources	Moderate	Moderate	Although the availability of energy has emerged as a problem in some quarters (more often than not, for failure to pay bills), HPC developers to our knowledge, have adequate material resources.
Information resources	Poor-Moderate	Moderate	Soviet engineers now have much better access to information about HPC-related technologies. First, if money is available, they are able to travel abroad, attend conferences, work at foreign institutions, and visit their counterparts abroad. Second, a great deal more information about trends and technical details is accessible via the Internet, to which Russian engineers increasingly have full access. Third, the growth in collaborative activities with Western companies provides a rich vehicle for information exchange. Nevertheless, for largely geographic reasons, Russian are much less able to participate in informal information flows that are present where there are rich clusters of companies in a give industrial sector (e.g. Silicon Valley). Also, export control restrictions continue to play a role in the types of information companies (e.g. Sun Microsystems) can provide their contractors in Russia.

Table 12 Changes in Resources for HPC in Russia

Table 13 shows the changes in the Dynamic elements affecting HPC capability in Russia. While none these elements is at the same level as in United States, the changes have all been in the direction of introducing greater dynamism into the Russian HPC sector. In the longer term, if the sector is able to survive the increase in competition, the net impact of these changes is likely to bring a great deal more vitality to the sector than currently exists.

Factor	1985	1995	Explanation
Competitive Environment	Non-competitive	More competitive	The environment for Soviet HPC is becoming more competitive on two counts. First, customers have become more discriminating in their selection of technology, at least in part because of their few-found flexibility in deciding how to spend their own resources. Second, foreign workstations now have capabilities that rival that of earlier domestic HPC systems. This source of competition will continue to persist, as the price/performance and availability of such systems improves. There will likely remain market niches, in very sensitive military installations, that remain closed to foreign competitors.
Flow of labor	Poor	Moderate	Russian engineers have much greater flexibility in determining where they will work and live, and organizations are much more able to hire the skills they need.
Flow of capital	Poor	Moderate	While the financial markets are still immature in Russia, they offer options for investment and the flow of capital that are much more flexible than under the Soviet system.
Flow of information	Moderate	Moderate-Good	It is difficult to evaluate the flow of information between development groups in Russia at present. It is likely that the penchant for secrecy between HPC development groups has not eased significantly, since military secrecy has been replaced by corporate confidentiality. It is not clear that worker mobility has reached the point where significant "cross-pollination" of ideas between organizations is taking place. However, as engineers spend time abroad, they likely bring back to their home institutions considerable information acquired from their foreign collaborators.
Presence of demanding customers	Moderate-Good	Moderate	The leading customers for HPC had quite demanding real-time applications (anti-ballistic systems, radar systems, etc.). These users strongly influenced HPC projects. Not all of this core customer based has disappeared, even given the financial straits of the Russian military. Furthermore, alternative customers in the commercial sector may arise, although we have little

	evidence of this to date.

Table 13 Changes in the Dynamic determinants of Russian HPC capability

The preceding tables illustrate some of the most significant factors influencing the development of the HPC sector in the Soviet Union and Russia. For other countries and other technologies, the precise set of variables is likely to be different. The utility of the conceptual framework of Figure 5 is that it provides a means of organizing the factors the analyst has identified in a manner that can be consistently applied across a variety of technologies and countries.

To illustrate some of the diversity the IT capability framework can accommodate, we use it to analyze the state of a broader set of information technologies in a country that is quite different from the Soviet Union and Russia: Syria.

3. Case Study: An Assessment of the Information Technologies in Syria

3.1 Introduction

Since the establishment of the Syrian Arab Republic as an independent country in 1946, the United States has had at best a distrustful and usually a mutually hostile relationship with Syria. Syria is today labeled as a "terrorist country" by the United States and Syrian policies are deemed to constitute, at least in part, a threat to U.S. national security. However, the country has changed significantly since Syria's independence. Coupled with the establishment of Israel two years later, changes throughout the eastern Mediterranean region, development of new modes of combat (e.g., terrorism), and technological progress, the nature of any threats posed by Syria must have changed dramatically.

One of the most notable changes in Syria, and the region as a whole, has been the development of modern—or in the case of Israel, advanced—infrastructures and the proliferation of the information technologies (IT). Since most of the region, again excepting Israel, has little or no IT industry, the proliferation of IT has been the direct result of diffusion of these technologies from more advanced countries.[1] This section will characterize the threat(s) to U.S. national security concerns presented, enabled, or enhanced by IT proliferation and examine what, if any, action might be feasible to reduce or eliminate these threats.

Syrian IT is divided into three general categories—information acquisition, information transmission, and information processing—followed by an assessment of the national security implications of Syrian IT capabilities and associated IT diffusion. The Syrian government's ability to collect, transmit, store/retrieve, process, and understand data and information is devolved into the constituent technolo-

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[1] For the purposes of this section, "advanced countries" refers to the OECD countries, most particularly the countries of Western Europe and, to a lesser extent, Japan.

gies which are then examined individually and from a system perspective. The emphasis is necessarily on public sector organizations, systems, and capabilities; however, elements of the private sector are reported and assessed where pertinent to developing a complete picture of the current and near-term threat. The role of the international community in facilitating Syria's IT capabilities is examined, as well as the degree to which Syria relies today and is expected to rely in the future on foreign sources of equipment and/or expertise.

This assessment is the result of a bottom-up, technology-centric approach in seeking to identify every information technology present in Syria and assess the national security concerns, if any, raised by the presence. An alternative approach would be a top-down, application-centric approach that would identify the threats posed by Syria to U.S. national security, and then seek to identify and quantify the information technology components, if any, of those threats. The former approach would appear to be more empirical at the outset; however, if one had a good understanding of current national security concerns, the latter approach would be more efficient. Also, the former approach attempts to ensure that every aspect of information technology is examined, while the latter approach ensures that every threat is considered.

3.2 National Security Issues

Syria obviously poses no direct national security threat to the United States. Any potential threat must then be understood to take the form of a threat to U.S. national security interests. With the exception of the requirement to ensure the safety of U.S. persons worldwide, these interests change or evolve in conjunction with changes in the international situation or domestic U.S. concerns.

Since the demise of the Soviet Union and the associated Cold War, the United States has been free—forced, some would say—to turn its attention to less critical, but also less clear-cut, threats to a national security more broadly defined than in the past. The current national security strategy is based on the complementary principles of engagement and enlargement. The three cornerstones of this strategy are the enhancement of U.S. national security, promotion of domestic prosperity, and promotion of peace. The first and last of these objectives are germane to this study. Enhancing national security includes the following missions, inter alia: deter and defeat aggression in major regional conflicts, contribute to multilateral peace operations, and support counterterrorism efforts. Within the area of peace promotion, assuring the security of Israel is an explicit mission, as is assuring the free flow of oil "at reasonable prices" (National Security Strategy, 1995, p8-9,30). These latter two explicit missions and the support for counterterrorism define the principal U.S. national security concerns vis-à-vis Syria. Theses concerns, as briefly characterized in the following paragraphs, will be used to assess what, if any, threats are created or increased by IT diffusion to Syria.

3.2.1 Protection of Israel

Syria does not today pose a threat to the survival of Israel, and cannot mount an attack with any chances of gains. However, the two countries remain nominally at war, maintain confrontational military dispositions along either side of the Israeli-occupied Golan Heights, and support proxy combatants in Lebanon. There remains a real possibility of direct military conflict between the two countries, hence a threat to the security of Israel and, by extension, U.S. national security interests.

IT could contribute to the improvement of the combat capabilities of the Syria armed forces, which has been a goal of the al-'Asad regime since its inception, in a bid to achieve "strategic parity" with Israel (Eisenstadt, 1992, p. 26). The most significant potential contribution would be the improvement of command, control, communications, and intelligence (C^3I) capabilities, which could give the Syrian armed forces the capability to launch joint or deep strike operations. The most likely threat enabled by the acquisition of modern C3I means by the Syrian armed forces is the potential for achieving strategic surprise in launching an offensive. Modern IT could be used to improve intelligence collection and, hence, countermeasure development. Of most concern, IT could contribute to development of weapons of mass destruction and long-range delivery systems.

3.2.2 Protection of oil sources

Syria is not a major oil exporter, and disruption of Syrian oil exports would likely not even be noticed by the United States or its Allies. It does not appear, therefore, that IT in Syria has any direct bearing on this concern.

Settlement of the Arab-Israeli conflict, or at least preventing the situation from deteriorating, is key to maintaining good relations with some oil-producing nations (the notable exception being Iran). U.S. interests lie in preventing the occurrence of any incidents that would force the United States to take a stance that would be significantly unpopular with Arab regimes. To the extent that the acquisition of high technology might affect the regional balance or create an unstable situation or crisis, such acquisition might jeopardize the United States' relationship with important oil sources in the Gulf. This is not highly likely, however, and of significantly less concern than any direct threats enabled by IT proliferation.

3.2.3 Prevention of terrorism

Syria's at least passive support for terrorist organizations, and possible collusion with their activities, is the principal threat both to U.S. and Israeli persons and armed forces. Syria could conceivably employ IT to facilitate terrorist operations directly against U.S. interests or within the United States.

IT's principal contributions could be to improve the efficiency and enhance the secrecy of the management/movement of money and/or people, facilitate the production and dissemination of inflammatory propaganda, and enable the conduct of "cyber-terrorism" (defined as hostile attacks against friendly computer systems/networks).

A specific concern relative to information technology is the perceived vulnerability of the United States to "cyber threats." These are defined as "threats of electronic, radio-frequency, or computer-based attacks on the information or communications components that control critical infrastructures," which include "telecommunications, electrical power systems, gas and oil storage and transportation, banking and finance, transportation, water supply systems, emergency services..., and continuity of government"

(Executive Order 13010, 1996) . In addition to the potential for inflicting direct harm on the United States, cyber threats also ameliorate the requirement for a terrorist to operate in proximity to the target.

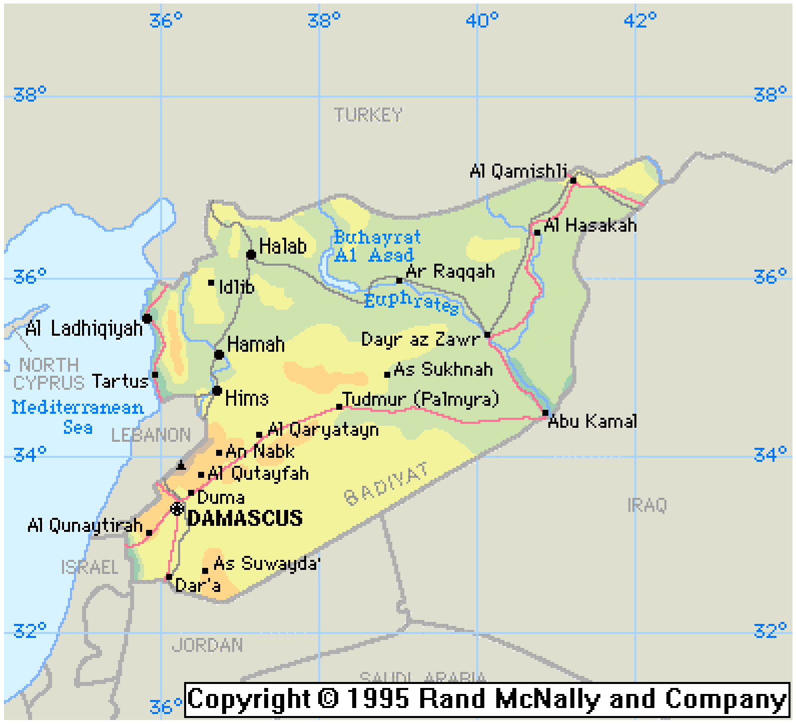

Figure 6 Syrian Arab Republic

3.3 Introduction to Syria

A basic knowledge of the topography, geology, and demography of Syria are useful for understanding the context for the patterns of deployment of certain information technologies, such as microwave radio relay or telephone cables, in Syria.

Syria is statistically one of the most densely populated countries in the Middle East, and its population—approximately 13.8 million, according to the 1994 census—is increasingly urbanized. The average population density is 176 people per square kilometer; however, this figure is misleading, since 80 percent of the population lives in the coastal strip that extends from the Turkish border to Lebanon, in a belt between Aleppo (3612N 03710E) and Homs (3444N 03643E), and in a strip along the western border with Lebanon that includes the capital, Damascus (3330N 03619E). Damascus and its suburbs are home to about 10 percent of the country's people.

Topographically, Syria is an extensive limestone plateau sloping eastward toward Iraq. The western edge is defined by a pair of nearly parallel mountain ranges running north-south that enclose a depression before tapering down to the shores of the Mediterranean. The plateau is punctuated by a series of small mountain ranges, and the Euphrates River in the northern quarter. In the desert and semi-arid regions, temperatures throughout the year range from below 0ºC to 45ºC and above. In the more temperate regions the annual variation in about 5-30ºC. Precipitation averages 300 mm annually, but is concentrated in the coastal region where it averages 76 cm.

In addition to the other challenges to development, the age and uneven development in Syria's more populous areas pose difficulties. For example, both the electrical distribution grid and the local telephone networks in Damascus have grown haphazardly, resulting in a plethora of wires draped throughout, and running every which way beneath, the city. Digging is a special challenge in an 8,000 year old urban environment. The laying of new cables must be carefully planned and old cables—some of whose functions are never discerned—are frequently damaged by the ever-present construction work in the city.

3.4 Information Acquisition

Information acquisition refers to information technology that supports or enables the collection of data or information in order to enter it into transmission and processing systems. This is the beginning of the information processing cycle without which there would be no data in the information technology system. The two principal types of information acquisition IT are sensor systems, devices that gather data, and input devices that act as the interface between a human source of data, information, or knowledge and the IT system.

3.4.1 Sensor Systems

Sensors can be broadly categorized as military or civilian systems, and civilian systems further divided into government, commercial, and scientific and academic. There are no known commercial sensor systems in use in Syria. There are likely some scientific or academic sensor systems, but there is no information available regarding any potential capabilities.

Syria's military sensor systems include radar and electronic surveillance systems. All of Syria's military sensor systems are of Russian origin; none are even of the latest generation available at the time of acquisition, much less state of the art. Prior to the departure of Soviet military personnel coincident with the break-up of the former Soviet Union, virtually all maintenance and repairs on sensor systems were conducted by Soviet technicians. The Syrians are not believed to have the capability to maintain the equipment in peak operating condition without outside assistance. The Scientific Studies and Research Center (SSRC) of the Ministry of Defense has a radar branch, but the extent of its capabilities and the qualifications of its personnel are not known. In keeping with the SSRC's usual practice, the radar branch's engineers were most likely educated in Europe and possess dated academic qualifications and little or no practical experience.

After a partial settlement of Syria's debt to the former Soviet Union in 1994, Russia agreed to resume defense trade with Syria under concessionary terms. At that time, Syria was said to be attempting to acquire up-dated military radar and command and control (C2) systems (Bruce, 1994), but there is no information available that suggests any sales of such equipment were consummated. More recently, Syria was reported to be seeking "advanced" air defense equipment, including radars, from France and

Russia in a deal that was to be financed by Bahrain (Talks on Bahrain, 1996). No details of the proposed transactions are available, and there has been no further reporting of related activity.

The principal government sensor systems are radars used for air traffic control of civil aviation. These radars are all of foreign manufacture. The radar at Damascus international airport (332154N 0362806E), an aging Thomson CSF (France) unit, has been inoperative for at least three years. Its very poor material condition reflects both common Syrian maintenance practices and technical expertise, both of which are far below Western standards. There is no information regarding the radars at Syria's other two international airports, at Qal'at bani Qahtan (351436N 0355654E, serving Latakia) and Aleppo (361024N 0371236E), and the country has no en route radars or other national air traffic management capability. Syria's other air traffic control (ATC) systems comprise various types of navigation aids that do not collect, process, or transmit information.

The Syrian government established the General Organization of Remote Sensing (GORS) in the early 1980s. Although GORS built a new Remote Sensing Institute west of Damascus in the early 1990s, the institute is not known to possess any remote sensors. Researchers, working principally in the areas of geology and agriculture, work with data, generally high-resolution radar and multi-spectral imagery, provided off-line (i.e., in hard copy) by foreign organizations such as Landsat (USA) and Spot Imaging Corporation (France).

The most significant government sensor system is the equipment used by the "intelligence" (i.e., internal security) services for monitoring telephone communications. The Information Branch (Al-Fara' al-Ma'lumat), or Branch 255, of Military Intelligence (Al-Mukhabarat al-'Askariya) maintains a facility at the country's main switching center and international gateway on Al-Nasr Street in downtown Damascus. This facility is for the purpose of monitoring telephone communications. Domestic communications are randomly sampled, although certain high-priority targets may be continuously monitored. All international communications are continuously monitored. Up until 1993, this monitoring was conducted manually, with one intercept operator for each international circuit. It was reported that, since the intercept operators spoke only Arabic, English, and French, conversations conducted in other languages would be disconnected. As part of the new international gateway exchange commissioned in early 1993, Branch 255 was provided with a suite of Kreutler (Germany) "ComGuard" multi-channel communications recorders and digital voice recognition equipment to facilitate automated monitoring of telephone conversations and automatic operator alerts when certain words are spoken. The suite was installed as a turn-key system; local technicians can operate the equipment and perform routine maintenance. Repairs are carried out by Kreutler. Thus, the diffusion of IT had significantly increased the mukhabarat's surveillance capabilities, but there was no technology transfer and the Syrians have failed to develop any indigenous capability to produce, improve, or even repair such equipment.

3.4.2 Human Input Interface

There are no sophisticated technologies present in Syria to automate the input of human knowledge or information into IT systems. Data entry is exclusively via keyboard input. The Syrian Arab News Agency (SANA) initiated a project several years ago to automate the acquisition, input, storage, and retrieval of audio, video, and text from foreign news sources, but has made no progress to date. The project involved the acquisition of a customized turn-key computer system from a foreign vendor. Were this project to be successful, it would enhance Syria's ability to produce and disseminate propaganda, but it would likely have little, if any, direct effect on U.S. national security concerns.

3.4.3 Summary: Information Acquisition

Although insufficient information is available to make a detailed assessment of the state of Syrian information acquisition systems, it is clear from the information available that the Syrian government is entirely reliant upon foreign technology and technical services. The dimensions of Syria's capabilities are summarized in Table 14 and Figure 7.

Dimension	Level	Movement	Explanation
Proximity to Technological Frontier	(1) *Obsolete*	+	Syria's principal sensor systems—military and civilian radars—are obsolete and marginally functional or inoperative. Procurement efforts for new systems are in progress but proceeding slowly.
Depth of Development	(0) *Consuming*		All sensor systems are imported as turn-key installations.
Sophistication of Use	(2) *Conventional*		Military and civilian sensor operators are capable but not innovative.
Pervasiveness	(2) *Established*	+	Sensor technology has been present and used for decades, but is not applied everywhere required, generally due to the cost and difficulty of importing foreign systems and training technicians. Current procurement efforts may increase the number of installations of radars and electronic warfare equipment.
Indigenization	(2) *Supporting*		Indigenous personnel operate the equipment and can carry out some routine maintenance and basic repair functions. Installation is accomplished by foreign technicians, who—along with spare parts—remain key to the systems' functioning.

Table 14 Dimensions of Syrian Sensor Capabilities

The only area of national security concern to the United States is military surveillance, the improvement of which would enhance Syria's military planning and operational capabilities, thereby exacerbating the military threat to Israel.

Figure 7 Syrian Sensor Capabilities

The diffusion of this technology to Syria could be impeded, but probably not stopped altogether, through multilateral export controls implemented by the Wassenaar Arrangement on Export Controls of Conventional Arms and Dual-Use Goods and Technologies (WA), the successor to the Coordinating Committee (CoCom) for Multilateral Export Controls. However, with the exception of nuclear- and missile-related technologies, which are subject to separate international control regimes, the United States is currently the only country which constrains the transfer of IT to Syria. Continued U.S. unilateral controls are unlikely to have any effect on Syrian military sensor capabilities, and the United States is unlikely to gain broad agreement within the WA to implement controls on IT transfers to Syria, especially from Russia and France.

3.5 Information Transmission

Information transmission comprises broadly technology used to move data/information from one place to another. The three major components of information transmission are the media over/through which information travels, the mechanisms that switch the information from one media to another or, more usually, from one to another route within a particular medium, and the format that the information takes—the data handling protocols—within the media and switches. Information transmission thus generally involves the movement of data/information within the information technology system. A special case of information transmission is broadcasting, which involves transmitting information on a point-to-multipoint basis from within to without the IT system.

Starting from a relatively rudimentary base five years ago, Syria has pursued aggressive telecommunications—the principal information transmission sector—infrastructure development. This development, however, is based entirely on imported equipment and technical services. All contracts for sophisticated technology are issued on a turn-key basis; local technicians are used only for basic mechanical installations. Most equipment supply contracts include a technology transfer component in the form of required training. However, either the training received is woefully inadequate or the personnel being trained are incapable of assimilating the knowledge, as the majority of Syrian technicians are not fully qualified for even basic, closely supervised maintenance positions. The few "world class" technical personnel that do exist in Syria stand out distinctly.

3.5.1 Switching

Switching refers to devices that connect transmission media to each other, sensors, or input/output devices, capable of changing those connections and usually maintaining multiple, simultaneous connections. The majority of the switching present in Syria serves the public switched telephone network (PSTN), although a rudimentary data network exists and there are plans to emphasize data networking in near-term development programs.

3.5.1.1 Telephone Switches

Telephone switches were traditionally designed to serve "conventional" telephonic communications, carrying mainly voice traffic or analog data (converted via modems). These were analog switches, from the earliest cross-bar and step-by-step exchanges to relatively recent vintage stored program control (SPC) electronic cross-bar exchanges. With the proliferation of modern digital switches, the distinction between telephone (i.e., voice) and data communications is diminishing.

Commercial and government telephone telecommunications in Syria are under the aegis of the Ministry of Communications and provided by the Syrian Telecommunications Establishment (STE). By law, all public telecommunications are provided exclusively by the STE.

The majority of PSTN exchanges in service today (more than 150 central office exchanges) are state-of-the-art digital exchanges, mostly supplied by Siemens AG (Germany). The first half of this decade saw the Syrian PSTN double in capacity, an expansion project that also involved replacing virtually all of the old mechanical telephone exchanges. Exact figures are not available, but we estimate that approximately 85 percent of the newly-installed lines represented additional capacity, while the rest were used to replace most or all of the remaining analog subscriber lines. The PSTN now has approximately 1,164,400 switching ports, of which an undetermined number serve trunk lines and about 1 million are connected to subscribers. Syria's telecommunications infrastructure today is entirely automatic, and largely digital.

It is worth noting that, despite the magnitude of this expansion project, the total contract and option provided for only 1,500 staff-hours of training for Syrian technicians, or approximately 10 hours per central office exchange. In 1993, the EWSD technicians at the Al-Jalaa exchange could not perform routine daily "housekeeping" functions without the use of detailed instructions provided in English by Siemens and maintained in a three-ring binder. Were a serious fault to develop, the Syrian technicians would immediately call upon Siemens for help. Of further interest, although SS7 provides for the provision of system telemetry in the control channel, the Syrian network relied on telemetry data sent via modem over separate lines. Since they did not use error-correcting modems, data collected at the OMC was held for several days until the corresponding tapes arrived, to enable them to check for errors. Not only did the Syrian technicians lack an item (low-speed error correcting modems) that has been a household commodity in the United States for more than a decade prior, but they had no idea that such a thing existed.[2] It is symptomatic of the lack of Syrian expertise that the local technicians have no understanding of the Siemens proprietary interface between the EWSD SS7 and EMD R-2 signaling systems, accepting at face value the Siemens engineers' reference to the interface as the "magic link" (in English). Problems with this interface were not to be handled by Syrian technicians, but referred to Siemens.

Various government departments also maintain private communications networks. These are principally radio networks, although the Ministry of Defense maintains a nationwide, private switched telephone network. This latter network was procured for the Ministry of Defense by the STE, and some of the network elements serve both the defense ministry's private network and the PSTN. The magnitude and extent of the MoD network is unknown, but estimated to provide at least minimally acceptable voice communications, in terms of line quality and number of lines, to every major military installation. In some instances, it is not possible to differentiate between the PSTN and the MoD switched network, as each runs over the other's lines to some extent.

Syria currently has no capability to manufacture telephone switches, although they had at one time the ability to assemble from basic components central office switches and are currently building a facility to assemble PABXs from kits for rural public switching applications.

3.5.1.2 Summary: Telephone Switches

Table 15 and Figure 8 summarize Syrian capabilities with respect to telephone switching technology. Current Syrian capabilities in the area of conventional telephone switching are minimal. Local technicians can maintain the PSTN in an operable condition in the absence of any major perturbations or malfunctions. Despite the extensive installation of the latest generation of switching equipment, service is less than adequately reliable (although many problems can be traced to the inadequate number of subscriber

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[2] At this time, there were certainly computer professionals who were aware of, and used, error-correcting modems; this specific lack of technical knowledge was demonstrated by the chief engineer of the Al-Jalaa central office, a relatively young man trained for his job in Germany.

lines and trunks), and regional outages are common. Although the theoretical education of some technicians is rather good, few have any practical experience. Most training is conducted on-the-job and is limited to the barest minimum of tasks required for normal operations. In addition to inadequate training, there is inadequate documentation to permit technicians to attempt to learn new procedures or conduct repairs on their own. Most, if not all, central offices have no documentation other than a small, three-ring binder of printed instructions. Any and every deviation from the norm generates a crisis. There is great resistance to changes and up-grades, as the technicians clearly feel just barely capable of handling the system they have. There is no local content whatsoever, although, briefly in the past and in prospect for the near future, there is the potential to at least assemble completed switches from foreign-manufactured components. None of the requisite components or subassemblies are or can be manufactured in Syria. Since there has been no diffusion of the underlying technology, the procurement of the equipment itself is expensive and therefore limited by the availability of funds.

Dimension	Level	Move-ment	Explanation
Proximity to Technological Frontier	(3) *Competitive*		Virtually all telephone switches in Syria today are less than ten years old. At least 90 percent of the switches are of the latest model available today.
Depth of Development	(0) *Consuming*	+	All telephone switches are imported as turn-key installations. A joint venture was recently created to assemble small switches from kits; earlier attempts to do so (i.e., E-10B) were not successful.
Sophistication of Use	(2) *Conventional*		Telephone technicians are marginally capable of routine operations. There is no innovation at all.
Pervasiveness	(3) *Common*		New telephone switches are deployed nationwide.
Indigenization	(2) *Supporting*		Indigenous personnel operate the equipment and can carry out some routine maintenance and basic repair functions. Installation is accomplished by foreign technicians, who—along with spare parts—remain key to the systems' functioning.

Table 15 Dimensions of Syrian Telephone Switching Capabilities

Given that the PSTN and separate but intersecting MoD switched telephone network are used to support both the operations of the Syrian government and the military, and likely comprise a major component or the entirety of the strategic command and control system, any modernization or expansion of the telephone systems in Syria is of potential national security concern to the United States and potentially of real military concern to Israel. However, given the total lack of indigenous production capability, and limited local maintenance and repair skills, the details of the systems being acquired and specific information regarding installations sites and network topology can be obtained, and the threat mitigated mation regarding installations sites and network topology can be obtained, and the threat mitigated or turned into a Syrian weakness through enhanced friendly capabilities to interdict or manipulate the network.

Figure 8 Syrian Telephone Switching Capabilities

Additionally, the total reliance upon foreign suppliers presents the opportunity to control the acquisition of modern telephone switches by Syria. Although unilateral U.S. export controls have prevented the Syrian government from acquiring American telephone switching technology, they have had no effect on the acquisition of a large quantity of leading-edge systems. A significant reduction in donations and concessionary loans from the Persian Gulf in the past two years has had a far greater effect. It has been rumored that this reduction in the availability of project financing was due to U.S. efforts to discourage potential Persian Gulf donors from funding infrastructure projects. If true, they were successful, at least in the short term. If not, they suggest a potential avenue for at least slowing the diffusion of high-technology goods to Syria.

3.5.1.3 Data switches

Data switches are distinguished from telephone switches, for the purposes of this assessment, by the fact that they were designed from the start as microprocessor-controlled digital switches for the purpose of switching data streams. An early example of a data-only switch is the packet switch; current data switches typically handle broadband applications such as asynchronous transfer mode (ATM) or Frame Relay. In advanced countries, the majority of voice communications today are digitally transmitted, and can therefore be interleaved with non-voice communications. This is resulting in a convergence of the two technologies, but today data switches remain well-differentiated from conventional telephone network switches.

In Syria, data communications are relatively new, not well-developed, and poorly utilized. While it would seem reasonable that a relatively modern, commercially active country undergoing rapid economic growth, all conditions which pertain in Syria today, would have a ready market for data communications, several factors have retarded the development of such a market in Syria.

The two most important factors are security and lack of computing sophistication, the latter having been partly caused by the former. Due in part to the nature of the al-'Asad government (a government led by a despised religious minority that took power in a coup d'etat) and in part to the continuing state of war with Israel, security in Syria is very strict, even by the standards of other Arab countries. The several "intelligence" (i.e., internal security) services have duplicative responsibilities. In competing with one another, they provide for pervasive, but not always competent, surveillance and control. Communications are an especially sensitive area, and data communications especially so, since they are not well-understood by the security services.

Syria's first data network, Syriapac, is an X.25 packet-switched network installed in 1992 but not officially commissioned until March 1994 due to the objections of the intelligence services, which feared that the network would be misused by subversive elements and other criminals. When the intelligence services finally allowed the network to be used, the only connections permitted were full-time leased lines from approved facilities. Although nominally a packet-switched public data network (PSPDN), with subscriptions officially open to the public, access to the network is strictly controlled and expensive. (It is possible that the very high fees charged are meant to discourage would-be subscribers, but more likely a result of the STE's abuse of its monopoly. There are conflicting reports as to whether dial-up access to the network is now permitted.)

Syriapac has never been used to its full, albeit limited, capabilities since its commissioning. The STE, which purchased and operates the network, has been criticized for both the high prices it charges and for purchasing outdated technology. It appears to be used principally by academics to connect with central university databases and by government researchers to connect with and mine foreign databases. It has seen limited use for connections to the Internet.

More recently, the STE commissioned a high-speed Digital Data Network (DDN), using an E-1 (2.048 Mbps) trunk on the fiber optic tie-trunk network in Damascus and the fiber optic backbone to Aleppo. However, there are currently no indications of who the intended subscribers to this high-speed data service are. While the lack of data networking capabilities in Syria has been deplored from time to time by Syrian computing professionals, there appears to be virtually no demand for high speed domestic data links. It is most likely that the DDN will be used principally by the government, perhaps principally by the Ministry of Defense, which maintains a nation-wide data network of its own, and by the Ministry of Finance, which is trying to modernize and automate banking operations.

There is currently no Integrated Services Digital Network (ISDN) in Syria. However, the new Siemens EWSD central office exchanges are "ISDN-capable," and the STE has indicated its intention of creating at least an ISDN backbone between major cities. Since the installed SS7 software includes the basic signaling requirements for ISDN, the switches require only the addition of appropriate software to enable the switches' Signal Transfer Point (STP) capabilities, thereby creating ISDN links between switches so up-graded. As with the DDN, it is not clear for what clients or applications an ISDN is required or even moderately useful.

The Computer Development Unit (CDU), or Branch 239, of Military Intelligence maintains a wide-area network (WAN) for the Ministry of Defense, but there is no information regarding the equipment used. The Ministry of Defense's Higher Institute for Applied Science and Technology (HIAST) has a campus-wide local area network (LAN), and has offered dial-up access to its computer center to other government agencies using Case (UK) Data Communications System switches employing a modified HDLC protocol for remote terminal access.

3.5.1.4 Summary: Data Switches

There are currently no high-speed data switches in Syria, although a limited implementation of ISDN is under consideration. There is a limited number of low- and medium-speed data switches that support two networks (one of which is currently under construction) of limited geographic scope and subscriber capacity. There is no evidence that these networks are used by the armed forces, nor is there any reason to believe that the armed forces could today benefit from their use. The research organizations of the Ministry of Defense are heavy users of these networks. However, the networks are used by these organizations principally for access to foreign data sources. The limiting factor is the speed of the international links, which are quite slow, making the speed of the domestic network rather irrelevant.

Table 16 and Figure 9 summarize Syrian capabilities with respect to data switching technology. There is no local content whatsoever and none of the requisite components or subassemblies are or can be manufactured in Syria. Such data networks as exist have been installed and configured by foreign technicians; local technicians have only a limited capability to conduct routine maintenance. It is doubtful that a major fault could be cleared without foreign assistance. It is also doubtful that there are exist in Syria any clients, with the possibility of foreign oil companies, with applications that will fully exploit or noticeably benefit from high-speed data networks.

Given Syria's limited capabilities in this sector, modest plans for the foreseeable future, and the apparent lack of need for this equipment in the armed forces, proliferation of this technology in the near term is unlikely to be threatening to U.S. national security interests. If and when, however, Syrian military command and control is significantly modernized so that it not only can exploit, but requires, high speed data switching, this technology will be critical. This stage is unlikely to be reached in the next ten years.

Dimension	Level	Move-ment	Explanation
Proximity to Technological Frontier	(2) *Non-competitive*	+	Syria's only "public" data network, *Syriapac*, is technologically old but marginally useful. New equipment currently being procured will provide a limited modern networking capability.
Depth of Devel-opment	(0) *Consuming*		Data network equipment is procured on a turn-key basis; installation and network configuration are performed by foreign technicians.
Sophistication of Use	(1) *Assisted*		The existing network is poorly utilized, both due to security restrictions and a lack of knowledge.
Pervasiveness	(1) *Entrant*		There is one small data network of limited scope. Future installations will essentially dupli-cate the existing network.
Indigenization	(1) *Operating*		The data network is used only by local nationals, but its operation is poorly understood.

Table 16 Dimensions of Syrian Data Switching Capabilities

Figure 9 Syrian Data Switching Capabilities

3.5.2 Transmission Media

These are the physical media, connected to switches or terminal devices, that are used to move data from one place to another. These media may serve public telephone networks, public or private radio communications networks, local or wide area computer networks, or a combination. The media, and the equipment that drive the transmitted signals, are one of the two principal determinants (with switches) of the speed that information can be communicated. If the capabilities of the media employed are insufficient to meet the demand, telephone network users experience busy signals and data network users experience slow-downs or disconnections. If the media are sufficient, but the switching is inadequate, similar slow-downs or disconnections may be incurred. Data switches may also form bottlenecks, but this is generally not true for circuit-switched (e.g., conventional telephony) communications.

Information is transmitted via radio communications, either terrestrially or via satellite relay, or via cables, either metallic cables transmitting electrical signals or fiber optical cables using modulated laser. Over the past decade, there has been a transition from analog to digital communications, with concomitant speed and reliability increases, and an increasing use of fiber optic cables. These trends are also evident in Syria, although the transition started later there than in more developed countries. In conjunction with the modernization of its telephone switching systems, the STE has been aggressively replacing old, analog media with digital links via microwave and fiber optic cable, and most of the telephone network's expansion has employed these same media.

3.5.2.1 Radio Communications

The principal forms of domestic radio communications in Syria are microwave radio relay, for both military and civilian applications, and fixed and mobile radio communications for military and other government agencies (e.g., police, fire departments). International radio communications include terrestrial and satellite microwave links, and radio and television broadcasting, which will be covered separately in a later section of this report.

Radio frequencies in the 1,000 MHz-300 GHz range are generically referred to as "microwave," although signals above 18 GHz are commonly referred to as millimeter wave. Terrestrial microwave communications are generally in the 2-12 GHz range. Satellite communications currently in use in Syria are in the C-band,[3] although Ku-band[4] systems are planned.

3.5.2.2 Fixed radio communications

Terrestrial microwave links were used extensively in developing Syria's telecommunications network, due to the nature of the terrain, which is mountainous in the most populated regions and very rocky, making cable-laying difficult. Microwave continues to be used extensively, although both buried and aerial cables are being used more frequently, especially for long-range high-traffic routes (e.g., inter-city main lines). All microwave radio relay more than five years old is analog, operating principally at 2 GHz; there are some newer 6 GHz analog systems in use as well. All new installations are digital links. Trunk lines use 8 Mbps links in the UHF frequency band and main lines use 34 Mbps in the 2-3 GHz range. Since 1994, the STE has started installing a few 140 Mbps links, operating between 6-7 GHz, to complement its fiber optic backbone.

In addition to radio links supporting the PSTN, there are private, fixed radio networks, such as that used by the Al-Furat Petroleum Company to relay communications along its oil pipelines from northeastern Syria to refineries near Homs. Most such networks use conventional UHF multi-channel radios, but some are being up-graded to digital trunked systems.

The Syrian television and radio networks, all owned and operated by the Ministry of Information, also use microwave radio relay to transmit their programming throughout Syria. In many cases, the Directorate General of Radio and Television uses telephone company links, although it also has its own dedicated relays. A typical relay carries one channel of color television and its associated audio channel.

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[3] Up-links are in the 5.85-7.075 GHz range; down-links are in the 3.4-4.2 GHz and 4.5-4.8 GHz ranges.

[4] Up-links are in the 14.0-14.5 GHz range; down-links are in the 10.7-13.25 GHz range.

None of the equipment or components required for fixed radio communications, not even antennas or connectors, is produced in Syria, and there currently are no plans to develop any capabilities in this sector. Simple components are cheap enough to be readily purchased; there is little incentive to manufacture them locally. More complex components are expensive to purchase, but the cost of the quantities purchased by Syria is modest relative to the cost of establishing an indigenous industrial base. Syrian technicians are relatively skilled in operating and maintaining foreign radio communications equipment, but have only a modest capability to perform their own network planning or equipment installation. Basic functions that are described thoroughly in the technical documentation are carried out capably, although routine maintenance is not generally completed as often as recommended.

3.5.2.3 Fixed satellite links

Satellite communications are used extensively for international telephone communications, although there are some limited domestic satellite communications, notably a very small aperture terminal (VSAT) network installed and used by one of the security services.

The main satellite earth station complex for both telephone and television relay is at Sednaya (334111N 0362202E), about 40 km north of Damascus. There is a single 18 m Intelsat Standard-A dish at Sednaya, built by NEC (Japan) and used for relaying telecommunications and television via an Intelsat Indian Ocean Region (IOR) satellite, and several smaller dishes. A new Standard-A antenna was to have been installed by Satellite Transmission Systems (STS), a subsidiary of California Microwave (USA), incorporating digital circuit multiplication equipment (DCME) to provide five Intermediate Data Rate (IDR[5]) channels for telecommunications and television relay to the Atlantic Ocean Region (AOR), but the status of this project is not known. The contract was awarded in 1992, but as of 1994 construction had not yet begun. Interim AOR communications are provided by an antenna mounted on the roof of the STE's Al-Nasr annex via Intelsat 605 at 335.5ºE. This interim link is not believed to provide television relay.

In addition to international satellite communications links based upon equipment provided by foreign companies, foreign companies also directly provide satellite telephone links to Syria. The American companies AT&T, MCI, and Sprint all have earth stations in Syria that carry switched telephone traffic between Syria and the United States, as well as direct-dial access to U.S. dial tone from Syria using special access codes. AT&T's F3 antenna is located at the Al-Nasr Annex and relays communications to the United States via Intelsat 707 (359.0ºE). MCI's F2 dish is atop the Radio and Television building at Omayyad Square (333043N 0361640E), and also uses Intelsat 707. Sprint earth stations are located at an STE central office exchange in the Damascus suburb of Kafr Sousa and in Aleppo, and use an unidentified Russian satellite, most likely the Gorizont at 345.5ºE, to relay telephone communications to Staten Island, NY.

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5 Intermediate Data Rate *or* International Digital Route—Digital satellite communications that operate at a nominal data rate of 128.256 Mbps.

As noted above, the only domestic use of satellite communications is by the security services. The nature and extent of their VSAT network is not known, nor is there any information available regarding the system's employment. The Signal Corps Administration of the Syrian general staff has expressed interest in procuring a VSAT network to interconnect all of the border guard posts, but has not budget and no definite program. If such a network were to be created, it would provide reliable communications between border guard posts, regional headquarters, and the general staff for operational control, administration, and, at some locations (major border crossings), access to the central "watch list" database. However, such an improvement in communications would not be a threat to the United States or any of Syria's neighbors.

None of the equipment required for satellite communications is produced in Syria, nor, given the country's modest requirements in this sector, are there any plans to develop a local industry. As with terrestrial communications, Syrian technicians are well-trained to handle routine operations and maintenance. They apparently have little basic understanding of the capabilities of their equipment, however, resisting change or requests for new services and responding poorly to malfunctions.

The further development of fixed satellite communications in Syria, whether for domestic or international communications, is of little national security concern to the United States.

3.5.2.4 Mobile radio communications

Mobile radio communications fall generally into the categories of terrestrial and satellite; terrestrial mobile radio communications is further divided into cellular and non-cellular technologies. There are today neither mobile satellite nor cellular communications in Syria.

There are currently no plans to introduce mobile satellite communications, and the Syrian government is strongly opposed, on security grounds, to all of the various mobile satellite systems, such as Globalstar and Iridium, that are now under development.

The STE has been planning, since 1992, to tender for a GSM digital cellular telephone network, but progress has been sporadic. Although a tender was announced in late 1993, it was withdrawn almost immediately. A review of the technical specifications revealed an almost total lack of understanding of the technology involved in digital cellular communications. Although rumors of an impending tender appear about twice a year, none has been forthcoming, and, to the extent they have the time and ability, the Syrian technicians responsible for the introduction of GSM (the STE's Transmission Department) have been busy learning about the technology. However, due principally to a lack of funds, virtually all knowledge is self-taught from textbooks, and the technicians still lack the tools, such as site survey equipment and radio propagation modeling software, to adequately develop a network plan.

There are a number of non-cellular mobile radio networks in Syria, including a state-of-the-art trunked radio network recently installed by Rohde & Schwartz (Germany) for the Ministry of Interior to serve the Damascus Fire Brigade. Senior government officials have access to a VHF radio-telephone system, using large hand-held sets similar to World War II-vintage walkie-talkies, in the Damascus area. This system is old and insecure, and communications via this network are unreliable. The police and fire departments use VHF mobile radio networks[6] of various vintages, mostly 1960s era Motorola (USA), 1970s vintage RCA (USA), and some newer Ericsson (Sweden) equipment.

The introduction of trunked mobile radio[7] into Syria represents a significant increase in mobile communications capability and efficiency in spectrum utilization. Although there are no indications that the armed forces have acquired any such equipment, the military would obviously benefit from the introduction of such a modern communications technology, especially if it were coupled with an encryption capability. The introduction of mobile satellite communications, however unlikely in the near term, would be a serious cause for concern.

Syrian military communications equipment and doctrine is generally of Soviet origin, although the Syrians claim to have made some improvements to some equipment, such as the command and control suite for the MiG-23 fighters purchased from the USSR two decades ago. The material condition of this equipment is not known, but is likely to be poor, given Syrian maintenance philosophy, and the lack of maintenance and limited repair capabilities have been exacerbated by the unavailability of repair parts since the demise of the Soviet Union and the termination of arms subsidies for Syria. Following the rapprochement between Syria and Russia last year, some of the first new shipments of Russian military equipment were said to comprise repair parts. A limited number of new fixed microwave radio relay systems were recently delivered, but there is no new information regarding mobile communications equipment.

3.5.2.5 Summary: Radio Communications

Fixed terrestrial and satellite communications systems used for telecommunications and television broadcast relay generally meet Syrian requirements, and are being modernized and expanded. While the majority of installed systems are analog, all equipment installed in the past five years has been digital. Government and military communications systems, on the other hand, are generally older and often obsolete. These are being improved, also, but at a much slower pace than in the telecommunications sector, due principally to budget considerations.[8] There are no private sector/commercial radio communications in Syria.

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[6] In the United States, this type of communications is referred to as "private mobile radio (PMR)." This terminology is avoided because there are no private radio networks, mobile or otherwise, in Syria.

[7] Referred to in the United States as "special mobile radio (SMR)."

[8] While the defense establishment enjoys a relatively large budget, funds are still limited, and communications have historically been of lower priority than weapons. Military communications capabilities are probably at an all-time low at present, due to an inability to purchase from either Western or Russian sources, although both sources have become available once again. Non-military government systems are perhaps in the worst shape, having no powerful constituency. The telephone network is in the best condition and is being improved more quickly than others due to the high priority placed on it by the government (for economic reasons) and the fact that the STE earns much of the

Syria is absolutely dependent upon foreign suppliers for equipment, installation and commissioning, and repair parts for its radio communications systems. Local technicians are competent within narrow limits, and the full capabilities of the equipment are rarely, if ever, exercised, and are most likely unknown. Syrian capabilities in radio transmission are summarized in Table 17 and depicted in Figure 10.

Dimension	Level	Move-ment	Explanation
Proximity to Technological Frontier	(3) *Competitive*		Syria is up-grading and expanding its radio transmission networks with modern digital equipment.
Depth of Devel-opment	(0) *Consuming*		All equipment and spare parts are imported. Some modifications to military equipment is claimed, but the extent is unknown.
Sophistication of Use	(2) *Conventional*		Equipment is employed only for its most basic uses. New applications are not attempted.
Pervasiveness	(3) *Common*		Modern radio equipment is deployed nation-wide.
Indigenization	(2) *Supporting*	+	Syrian technicians are qualified to perform routine operations and maintenance, and some uncomplicated repairs.

Table 17 Dimensions of Syrian Radio Transmission

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by the government (for economic reasons) and the fact that the STE earns much of the money it needs for its own projects. The broadcasting networks also enjoy a high priority, due to their role in proselytizing the populace and maintaining internal stability.

Figure 10 Syrian Radio Communications

Improvements in the telephone transmission network are of little national security concern, except to the extent that they may serve to improve military command and control. Overall, the effect is probably minimal. Improvements in the television relay network are of little concern. Measures taken to up-grade government communications, particularly those systems serving important officials, should be welcomed. In a government characterized by centralization, secrecy, and distrust, confusion is common. Improvements in the flow of information are likely to have a moderating effect on the Syrian decision-making process. Of most concern is the potential for the Syrian armed forces to acquire more modern communications, especially mobile communications, equipment in large quantities. If this were to occur, the concomitant improvement in command and control could increase the threat of a Syrian attack on Israel. It is likely, however, that regardless of the absolute magnitude of improvement in potential capabilities, the improvements actually realized would be small. It is equally likely that this would not be accurately perceived by the Syrian leadership, which might embolden them to take military chances they would otherwise not have deemed reasonable.

Multi-lateral export controls, when they proscribed deliveries to Syria, were moderately effective in preventing Syria from acquiring modern radio communications capabilities. Unilateral American export controls have always have been more stringent than the multi-lateral controls, but have been completely ineffective. The U.S. controls have not always been effective in preventing Syrian acquisition of American equipment, and have had no effect whatsoever on the acquisition of non-U.S. technology. It is interesting to note that some of the most modern equipment acquired by Syria, such as 140 Mbps microwave transceivers, was not developed in the United States and is only manufactured in Europe and Japan. The most significant constraint on Syrian acquisition of radio equipment has been funding. Even Soviet equipment moved out of Syrian reach when the Russians demanded hard currency payments.

3.5.3 Cables

To the extent that improved communications are viewed as a potential threat to U.S. national security interests, this simplest of technologies—the copper wire—may be one of the most threatening, because of its simplicity of use, reliability, and the difficulty it poses to intelligence collectors and those seeking to interdict communications.

The populous western region of Syria is well-wired, mostly with copper cable but more recently with a fiber optic backbone. The principal deterrent to the use of cables in the eastern and southern deserts is geology and, in the mountains regions, topography makes the installation and maintenance of aerial or subterranean cable difficult. However, in the fertile regions, along major highways, and in urban areas, subterranean cable-laying is less difficult and is extensive. Aerial cables are also used along more difficult routes, such as the long, straight road through the hard-packed desert between Homs and Palmyra, and in densely-populated urban areas where digging is difficult or impossible.

The installation of a fiber optic cable backbone was started in 1992 by Siemens and completed in 1995. The backbone runs from the border with Jordan, near Irbid (3233N 03551E), north through Damascus and the main cities of Homs, Hama (3505N 03640E), and Aleppo, to the Turkish border near Gaziantep (3710N 03730E). There is a spur from Homs to Tartous (3455N 03552E), where the domestic cable connects to two international cables.

Syria significantly improved its international connections with the completion of the 250 km Ugarit submarine fiber optic link from Tartous to Pentaskinos (3508N 03359E), Cyprus. This project links Syria into the Southeast Asia-Middle East-Western Europe (SEA-ME-WE) main line. Two pair, one active and one spare, of repeater-less fiber optic cable were installed by Maristel (Italy). The cables, with a total capacity of 8,000 channels, are connected to the Syrian fiber optic backbone near Homs.

An undersea fiber optic telephone cable—Cadmos—between Lebanon and Cyprus was laid by AT&T in 1995 to provide Lebanon with an additional 3,800 international lines. The cable is owned 42 percent by Lebanon, 42 percent by Cyprus, and 16 percent by Syria. Syria has access to these lines via a 140 Mbps microwave link between Beirut (3353N 03530E) and Damascus, installed by Siemens' Italian subsidiary, Siemens Telecomunicazione. The system increased the number of available lines between Syria and Lebanon nations from 220 to 1,920, and also carries four television channels.

Two new international submarine fiber optic cable systems are currently being installed by Alcatel (France). Aletar is a 760 km direct link between Alexandria, Egypt (3112N 02958E), and Tartous, Syria, comprising two fiber pairs. It will operate at 2.5 Gbps with the capacity to carry 23,000 voice circuits. Beyretar is 170 km long and will connect Tartous to Beirut, Tripoli (3425N 03550E), and Al-

Saida (Sidon) (3334N 03523E) in Lebanon. It is also composed of two fiber pairs, but Beyretar will operate at 622 Mbps with a capacity for 7,000 telephone circuits (Aletar-Berytar, 1995).

In addition to the fiber optic backbone and international submarine cables, the STE has installed digital cross-connect equipment and fiber optic tie trunks between all 14 Damascus central offices, and between most of the country's other exchanges.

While the installation of a fiber optic backbone and tie trunks is a significant step forward for Syrian telecommunications, the equipment being installed is far from the state of the art. The domestic lines are being driven at 140 Mbps, principally to make simplify the interfaces with microwave transmission systems. It is likely that another consideration in providing such relatively low transmission speeds was the current lack of a requirement for faster (higher bandwidth) links.

Although Syria has been deploying fiber optic cable since 1992, the overall rate is only a few hundred kilometers per year, all of foreign manufacture. The bulk of the Syrian telecommunications infrastructure remains copper-based, with symmetrical coaxial cables (up to 600 0.5-1.2 mm wire pairs per cable) common for trunks and 0.5-0.9 mm cable is used for local loop and subscriber connections. Copper cable has recently been purchased from Pirelli (Italy) and LG Cable and Machinery Company (Korea), a Lucky-GoldStar subsidiary in partnership with Siemens Korea (Syrian Network Expansion, 1993).

Syria has no capability to produce fiber optic cable or any of the required ancillary equipment or components (e.g., connectors or hanging brackets), nor any apparent plans to develop such a capability. The country also has no indigenous metallic cable industry, but is in the process of planning the construction of a cable factory with technical assistance and machine tools from Iran. However, this factory is intended, at least at the outset, for the production of electrical power cables (Islamic Republic News Agency (IRNA), 1996a; Islamic Republic of Iran Broadcasting Television First Program Network, 1996; Islamic Republic News Agency (IRNA), 1996b). The type of cable to be produced (i.e., aluminum or copper) was not specified, so it is not possible to predict whether this plant will be capable of producing (copper) telecommunications cables in the future.

Installation of local loop cable has not kept pace with the installation of new central office switches, due to both the difficulties inherent in cable installation and the special problems of urban cable installation in ancient cities previously noted. The STE is trying to ameliorate this situation with the purchase and installation of digital subscriber loop (DSL) or "pair gain" modems.[9] Pair gain equipment allows the provisioning of two or more subscriber connections (typically two, four, eight) over a single pair of unshielded, twisted copper wire.

The quality of the pre-1990s copper cable infrastructure is fairly poor, due to age, harsh conditions, and poor maintenance. The new cable installations have been used, however, for the most part to extend the PSTN, rather than replace old copper lines. This has resulted in great variations in line quality, even between buildings on the same city block, much less between older and newer neighborhoods. The result

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[9] Syrian Telecommunications Establishment, Tender announcement 112/5/42 (27 January 1996).

is that much of the current telecommunications network remains incapable of supporting high-speed data communications. This, along with the lack of a customer base noted previously, explains the limited deployment of high-speed systems in Syria to date (i.e., limited to sites along the fiber optic backbone).

It is interesting to note that, due to the potential to "install-and-forget" cables, the STE does not have an accurate understanding of what cables it has installed over the years, their exact routes, or their employment. This is especially true of high-capacity, urban, subterranean cables.

3.5.3.1 Summary: Cables

Metallic cable is not a high-technology component of the information technologies, but is yet a critical infrastructure element. To the extent that telecommunications in general are deemed to be of national security concern, the proliferation of telecommunications cabling exacerbates that threat. Additionally, communications transmitted over cables rather than radio media are not subject to remote interception, although cables can certainly be tapped, given appropriate access. Fiber optic cable exacerbates any threat posed by cable proliferation because a single fiber pair has a capacity equal to far larger (and thus more expensive and difficult to handle) copper cables, and is more resistant to tapping.

However, as with the other components of information technology already addressed, Syria currently has no indigenous production capability, and no plans to develop one, with the possible exception of copper cables, in the near term. Syrian technicians are capable of installing and maintaining (although they don't generally bother) both fiber optic and metallic cables; however, they have no experience in exploiting the advanced capabilities of fiber optic cables. Table 18 and Figure 11 summarize Syrian capabilities in the area of information transmission via cables.

Dimension	**Level**	**Movement**	**Explanation**
Proximity to Technological Frontier	(3) *Competitive*		Syria has installed, and continues to proliferate, modern fiber optic and metallic cable networks, but not of the latest generation.
Depth of Development	(1) *Assembling*		Syrian technicians can install and maintain fiber optic and metallic cables. There is no domestic production of cables or components, however.
Sophistication of Use	(2) *Conventional*		Cable technology, especially fiber optic cable, is not exploited to its fullest capabilities.
Pervasiveness	(4) *Pervasive*		Cables are installed throughout the country, even laid across the surface of the desert in remote areas.
Indigenization	(2) *Supporting*		Syrian technicians install and maintain cables.

Table 18 Dimensions of Syrian Cable Transmission

Figure 11 Syrian Cable Network Capabilities

3.5.3.2 Broadcasting

The radio and television broadcasting sector in Syria is typical of a developing country with an authoritarian government: underdeveloped and state-controlled. The radio and television stations are subordinate to the Directorate General of Radio and Television, itself a department of the Ministry of Information. Programming is strictly controlled both for political content and to maintain a rather puritanical standard of decency.[10]

There is a single channel of television, Syria 1, that is broadcast nationally as much for propagandizing as entertainment. There are two television transmitters in the Damascus region, 16 more nationwide, and 36 low power repeaters.

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[10] The latter is, however, more a function of Syrian society rather than a government attempt to enforce certain values, as in Iran and Saudi Arabia. Most Syrians would, in fact, be offended by the foul language and "adult situations" common on Western television.

The second channel, Syrian TV2, carries mostly foreign programming and sports. It is currently available only in Damascus and by satellite, but will be available soon in other parts of the country as equipment is purchased. The first city outside Damascus to receive TV2 will be Hasakeh (3632N 04044E), in northeastern Syria, which will soon receive a new relay station as a result of a cooperation agreement between the Japanese International Cooperation Agency (JICA) and the Japanese and Syrian governments. [11] The Ministry of Information hopes to build two similar relay stations at Al-Raqqah (3557N 03903E), in north-central Syria, and Dayr al-Zawr (3520N 04005E), in the eastern oil fields. The principal reason for attempting to proliferate TV2 is to woo back Syrian audiences from foreign, especially Turkish, television, which is more entertaining than Syria 1.

Television receive-only (TVRO) equipment has proliferated in Syria over the past two years, despite the fact that it remains officially illegal. The majority of the dishes receive Ku-band television broadcasts from various Eutelsat satellites and, more recently, Arabsat 2A. There are some C-band sets that can receive transmissions from the Arabsat 1 satellites, which carry most of the Arab countries' television broadcasts as well as Syria TV2.

The Syrian government officially plans to "satisfy" the population's apparent desire for foreign programming in a manner currently used in Jordan and being developed in Saudi Arabia: the terrestrial microwave re-broadcasting of downlinked television programming, after having censored it via tape delay. However, these plans have been on-again, off-again for several years, with tenders and contracts for MMDS (multi-point, multi-channel distribution system) "wireless cable" networks alternately announced and canceled.

There are two radio programs broadcast on medium wave (AM), both with essentially nationwide coverage, and three FM stations, all in Damascus. As with television, all programming originates in Damascus. The Ministry of Information also runs the short wave station at 'Adra (3337N 03630E), which broadcasts in Arabic and eight foreign languages, including Hebrew and Turkish, for an international audience. The transmitting stations are all relatively old, but adequate for their purposes.

No radio or television production or broadcasting equipment is produced in Syria, nor are there apparently any plans to develop an indigenous capability in any part of this sector. The favored production equipment is Japanese, while most of the transmitters and associated equipment were purchased from France. Installation, operation, and maintenance, however, is carried out by Syrian technicians, who have done a credible job of keeping the stations operating under difficult conditions.

3.5.3.3 Summary: Broadcasting

Syrian technical capabilities in radio and television broadcasting are adequate for propagandizing the domestic audience and internationally transmitting the government's positions in relatively simple fashion. Even the currently available systems could be used more effectively, however, suggesting that the further diffusion of this type of technology to Syria will do little, if anything, to benefit Syrian broadcasters or

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[11] *ibid.*, p. 10.

viewers and listeners and concomitantly be of little or no threat to other countries. Broadcasting capabilities are summarized below in Table 19 and Figure 12.

Dimension	Level	Move-ment	Explanation
Proximity to Technological Frontier	(2) *Non-competitive*		Most radio and television production and transmission equipment is out-of-date but of relatively recent vintage.
Depth of Devel-opment	(0) *Consuming*		No development or modification of equipment is carried out in Syria.
Sophistication of Use	(2) *Conventional*		There is no innovation; indeed, the media are not exploited to their fullest capabilities.
Pervasiveness	(4) *Pervasive*		Radio and television reach every corner of the country.
Indigenization	(2) *Supporting*		Installation, operation, and routine mainte-nance of broadcasting equipment is performed by Syrian technicians.

Table 19 Dimensions of Syrian Broadcasting Capabilities

Figure 12 Syrian Broadcasting Capabilities

3.5.4 Summary: Transmission Media

The information transmission infrastructure in Syria is improving rapidly in many areas, notably cable and microwave transmission and telephone switching, from a base of poorly maintained, inadequately distributed, largely obsolete equipment. Syrian society is not, however, intellectually equipped to make effective use of the new technology, which Syrian technicians and officials view as merely providing a faster means to accomplish the same tasks. This limited view of the benefits of technology, coupled with the relatively small size of the potential market (the government is the only customer for transmission equipment) and no apparent desire to become self-sufficient in this sector, has created a climate that does not support the development of an indigenous manufacturing industry. Even inexpensive and ubiquitous TVRO dishes are imported from the neighboring country, Lebanon, that has developed a small manufacturing base. The dimensions of Syrian information transmission capabilities are summarized in Table 20 and depicted in Figure 13.

Dimension	Level[12]	Move-ment	Comments
Proximity to Technological Frontier	(3) Competitive	–	Information transmission technology in Syria ranges from dated but adequate to the latest commercially available systems. Up-grading older systems is sporadic, however, resulting in the gradual obsolescence of whole sectors.
Depth of Development	(0) Consuming		Virtually no elements of information transmission technology, not even simple components or cabinets, are produced in Syria.
Sophistication of Use	(2) Conventional		Syrian technicians and operators do not vary from a very narrowly defined routine, even when changing conditions make this routine suboptimal or even dysfunctional.
Pervasiveness	(3) Common	+	All major elements of information transmission technology are common in Syria. The number and their geographic dispersion are increasing.
Indigenization	(2) Supporting		Syrian technicians can operate their equipment and perform simple maintenance. Some equipment is installed by local labor, but complex equipment is purchased on a turn-key basis.

Table 20 Dimensions of Syrian Information Transmission Capabilities

[12] Note that these are not mathematical averages of the levels for the constituent technologies, but a summary judgment taking into account those levels.

Figure 13 Syrian Information Transmission

Syria has no industrial base to support the manufacture of information transmission equipment or any constituent or related components, and has only very modest plans to develop an assembly capability for small telephone switches. Syrian technicians can install some equipment, such as cables and microwave transmission networks, but they have little in the way of fundamental understanding of these tasks, working under strict supervision from detailed check-lists. All information transmission equipment and systems is maintained by local technicians, but generally well below world standards. None of these conditions have changed noticeably since the founding of the republic 50 years ago, and there are no indications that this situation will change significantly in the foreseeable future.

While some aspects of information transmission, such as military applications, have clear national security implications, it is not obvious that the sector as a whole is of concern. As previously noted, improved communications may actually contribute to stability. What is certain, however, is that to whatever extent information transmission technology creates or facilitates threats to U.S. national security, Syria is entirely dependent upon foreign suppliers for this technology. Although much of what Syria purchases is readily available, in comparable quality at lower prices, in other developing countries (e.g., fiber optic and metallic cables from Iran, digital switches made under Siemens license from Egypt, Iran, or Slovenia, microwave equipment from India), the Syrian government has spurned these sources in favor of more expensive but more prestigious products from the West.[13] This dependency can be exploited via two avenues: control of the technology and/or limiting access to financing for high technology purchases. U.S. attempts at the former have a miserable record with respect to Syria. Not only have U.S. export controls, whether unilateral or in the context of a multi-lateral regime, failed to deny or constrain Syria's access to whatever information technology was sought, but they have also been ineffective in denying Syria access to American technology that it particularly desired (although it has made those acquisitions more difficult and expensive in some cases). On the other hand, the availability of financing has been a critical factor in pursuing virtually all information transmission infrastructure projects. While this may be a more efficient control mechanism than others, it is uncertain whether the U.S. has the ability to effectively control Syria's access to financing.[14]

Information Processing

For the purposes of this chapter, we use the term "information processing" to refer to technology that is used to store and/or transform data and information, that is, computers and related equipment and software.[15] This IT sector is relatively poorly developed in Syria. There is little indigenous industry, although commercial software development is an area of increasing interest due to the low entry costs. An effort is being made to develop a uniform system of computer education encompassing grade school through university levels.

3.6 Information Processing

3.6.1 Computer Hardware

The number of micro- or personal computers in Syria has grown rapidly from an estimated 100,000 three years ago, although the current number is not known. Despite high prices resulting principally from high import duties, personal computers (PC) have become a commodity in the Syrian business community, although ownership of computers for the home is still limited to society's upper stratum.

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[13] As in most developing countries, particularly in the Middle East and the former Soviet Union, people have great national and cultural pride coupled with an equally great sense of inferiority. This not only discourages the development of local industry, but makes the industries of all other developing countries equally suspect.

[14] U.S. efforts to limit Syrian and Iranian access to multi-lateral funding sources, such as the International Monetary Fund and World Bank, have largely been ineffective.

[15] "Information Technology" is often used to refer to computers to the exclusion of other information-handling technologies.

There is no computer-related research and development (R&D) in Syria, nor are computers or any components manufactured in Syria. One public company manufactures printed circuit (PC) boards, but these are very basic boards used in cheap consumer electronics. The Ministry of Defense's Scientific Studies and Research Center is said to have the capability to manufacture four-layer PC boards, but they are not manufactured in mass quantities and their intended function is not known (but they are more likely to be related to communications rather than computers). Other basic components, such as integrated circuits (IC), resistors, capacitors, etc., are imported.

Last year, an American company formed a joint venture with a prominent Syrian family to assemble PCs in Aleppo from foreign-manufactured parts. This type of venture capitalizes on the lower duties imposed on components as opposed to assembled systems, as well as the low cost of semi-skilled labor in Syria.[16] The status of the project is not known, however, nor are there any estimates available of the number of machines to be produced. It is probable that there are other, less well-publicized, computer assembly ventures in Syria, but their effect on the market is not apparent.

The number of computer resellers in Damascus has grown rapidly in the past two years, resulting in cheaper prices as vendors cut their margins to gain market share. The most popular PC brand in Syria is Acer (Republic of China) due to its low cost and reasonable quality. With the exception of Apple Macintosh computers, which are popular with government agencies despite their higher prices due to their ease of use, American brand name PCs are almost non-existent in Syria.

There is no main-frame or high-performance computing in Syria, most likely due to both a lack of requirements for such systems and a reluctance to incur the high costs of purchasing and maintaining them. The most powerful computers in Syria are French and American mini-computers, either out-of-date or of limited capabilities. The Ministry of Defense uses Digital Equipment Corporation (DEC, USA) VAX-series mini-computers for its database applications, the Ministry of Finance is in the process of attempting to implement a financial management network also using VAX mini-computers, and the STE's antiquated billing system is based on COBOL software running on a British DEC VAX clone. The Ministry of the Interior uses an IBM (USA) AS400 mini-computer system at the Damascus International Airport for passport control and watch list applications. All of these systems use foreign-developed software packages that have been customized for the local applications.

Last year the STE acquired Groupe Bull (France) mini-computers based on Motorola 680xx-series microprocessors to support the development of a new centralized billing system. The HIAST also uses Bull mini-computers as the multi-tasking hosts in its small computer center.

The dimensions of Syrian capability in hardware are shown in Table 21 and Figure 14.

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16 The former is probably a more important factor than the latter, since Syrian labor costs are certainly higher than those in the Asian countries where most of the computers imported into Syria originate. The fact that the company was established as a "Law Number 10" venture gives them the possibility of importing parts duty-free if the finished products are exported. The fact that the local partners are a prominent Alawite family gives them additional opportunities to circumvent the laws.

Dimension	Level	Move-ment	Explanation
Proximity to Technological Frontier	(2) *Non-competitive*	+	Most computers in Syria are older model PCs; the few mini-computers present are out-dated or special-application machines.
Depth of Devel-opment	(1) *Assembling*		At least one, and probably several, companies have started assembling PCs from kits.
Sophistication of Use	(2) *Conventional*		Computers are used principally for word proc-essing and database applications.
Pervasiveness	(2) *Established*		Computers are prevalent in government and business offices, although private ownership is still relatively rare.
Indigenization	(3) *Managing*		Computer hardware is installed and maintained locally.

Table 21 Dimensions of Syrian Computer Hardware Capabilities

Figure 14 Syrian Computer Hardware Capabilities

3.6.2 Computer Software

Software development is a small but rapidly growing sector in Syria, due principally to its low entry costs. Most software companies start out by customizing large off-the-shelf software packages (e.g., a database management system or accounting software) for clients; some then graduate to creating their own program suites. One company received a contract from the government of another Arab country to create a management system for their national library. The software, developed entirely in Syria, was so well received that a commercial package was assembled. However, no copies have been sold, probably due to the cost and skepticism about the quality of Syrian programming, largely unknown outside Syria.

Syria's most significant contribution in the area of software has been in Arabization. In addition to being one of the development sites for Arabic Apple Macintosh operating systems and software, considerable effort has gone into creating Arabic front end software for database management systems. Besides the general lack of a wide range of common software in Arabic, there is the additional complication of a lack of a single standard, such as ASCII. There are two competing Arabic alphabet standards for computing, and several variants of an Arabic keyboard.

The Syrian Computer Society (SCS) held a seminar and exhibition in Damascus in November 1996, concentrating on the issue of Arabization. The seminar had the following objectives:

- To revive the standardization of Arabization for keyboard layouts, Arabic fonts, database searches and sorts, user interface, and computer terminology.
- To review the state-of-the-art in computer-aided translation.
- To examine dictionaries of computer terms.
- To look at Arabization of various devices and displays.
- To review Arabic and Arabized educational software (Syrian Computer Society, 1996).

One impediment to the growth of a sizable software industry is the lack of adequate copyright laws or enforcement of existing laws. It has long been held that "all software is free" in Syria. It is not uncommon for a vendor to receive an order for dozens of PCs, one copy of MS-DOS (to be installed on all of the PCs), and an original copy of the MD-DOS documentation for each PC. Until this situation changes, there is little incentive to invest time and money in developing a program of which only one copy will ever be sold, no matter how popular and wide-spread it becomes. For the present, bespoke customization of Western software packages remains the most lucrative type of business for software developers. Syrian strength in software in the five capability dimensions is shown in Table 22 and Figure 15.

Dimension	Level	Movement	Explanation
Proximity to Technological Frontier	(3) *Competitive*		Despite the lack of the best hardware, Syria continues to import commercially state-of-the-art software packages. Some local software or modifications is developed for foreign clients.
Depth of Development	(2) *Adapting*		Most software is purchase off-the-shelf and modified to suit local conditions, especially adding Arabic language capabilities.
Sophistication of Use	(2) *Conventional*		There is little innovation in software modification and development. Processes are automated, but not fundamentally changed.
Pervasiveness	(2) *Established*	+	As with computer hardware, a variety of good software packages are to be found in most government offices and businesses. Educational games for small children are popular among the wealthy. The country's four universities have a significant number of micro-computers, and the Ministry of Education is attempting to procure

		PCs for elementary and high schools.
Indigenization	(3) *Managing*	Software is procured in shrink-wrapped packages and modified for local use. Typically, users are proficient at basic functions, but cannot exploit the software to its full capabilities.

Table 22 Dimensions of Syrian Computer Software Capabilities

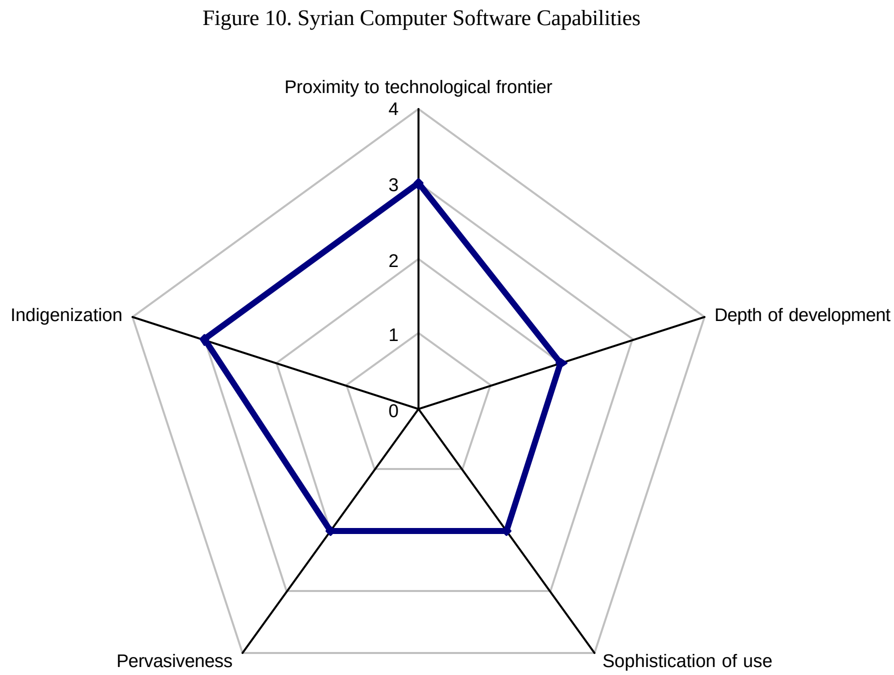

Figure 15 Syrian Computer Software Capabilities

3.6.3 Computing

Computing is still viewed in Syria largely as a way to automate office functions: word processing, accounting, database management, and e-mail. There is no significant research and development in Syria, with the exception of a few, isolated military groups, and no basic research. This situation is due to cultural, political, and economic factors, and is unrelated to the availability of computing resources. It does, however, mean that there are none of the basic factors present in Syria that generate government and industry requirements for large or high-performance computing capabilities.

3.6.3.1 Policy and education

There is a recognition among the "technical elite," most of whom are members of the Syrian Computer Society, that Syria must join the "information revolution" or be left behind, just as it was by the Industrial Revolution (Khiyami, 1994). They have been unsuccessful, however, in convincing the government to articulate and endorse a comprehensive national policy regarding information technology. The Society suggested that a national IT policy would comprise specific policies dealing with computer education, research and development, government and commercial organizations, industry, domestic and international computer networks, and the government's role in IT development and proliferation. No policy has been articulated in any of these areas by the Syrian government. Part of the reason is a lack of a perception of urgency on the part of the responsible government officials. A large part of the reason for the lack of a policy is the lack of personnel in government qualified to make such policy. Unfortunately, the Society itself has not filled this gap by proposing its own set of comprehensive policies, although it has made some impact on the development of computer science courses.

Syrian computer education programs concentrate on the use of PCs and simple programming, most often in Basic and C. Both the computers used and concepts taught are out-dated by American standards (although still common in some parts of Europe, particularly France, where most Syrian computer scientists were trained). The emphasis thus far has been on programming, which is actually required by a relatively small proportion of students. There is no attempt, nor apparently any recognition of a need to attempt, to try teaching non-programmers the skills and mind-set they would need to integrate computers and computing into their chosen fields of endeavor.

3.6.3.2 Networking

There are only a very few computer networks in Syria, none of which belong to Syrian non-governmental organizations (e.g., Syrian businesses). One of the largest and most modern computer networks in Syria belongs to a foreign oil company, which runs DEC Pathworks between VAX mini-computers at various field and office sites.

The Ministry of Defense operates a wide area network (WAN) that it claims was locally developed, using a unique protocol, by the Computer Development Unit of Military Intelligence. This network is reportedly carried by cable and radio, including satellite and high frequency[17] links, nationwide, for the purpose of allowing units access to the Ministry of Defense's central databases (maintained on DEC VAX-series mini-computers).

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[17] High Frequency (HF) or Short Wave, 3-30 MHz, a frequency range not generally suitable for high-speed data transmission.

The four universities and related institutions, such as the Higher Institute for Applied Science and Technology (HIAST),[18] have local area networks covering at least the major academic buildings on each campus. In 1993, the HIAST LAN was an AppleTalk network between Apple Macintosh computers and printers. This was replaced in 1994 with an Ethernet-based network. The technology levels in the universities is believed to be similar.

The European Commission is considering proposals to make two grants of $3.8 million each to the Commercial Bank of Syria and the Central Bank of Syria for the purchase of new computers and networks, and employee training in their use (EC to Finance Upgrade, 1994). The Ministry of Finance, which owns both of these banks, is one of the only agencies of the Syrian government making extensive and reasonably efficient use of computers, although it still has no computer networks. The ministry's first computer systems were installed in 1974 under an assistance agreement with the French government. The current computer systems were installed in 1987. However, the only computer center is at the ministry, and there are no remote terminals. Hence, all bank transactions are recorded on paper, then transported to the ministry for key-punching and processing. The proposed expansion has been in the planning stages for the past two years, and will significantly extend the reach of the ministry's data processing capabilities.

There is a new but antiquated “national” X.25 packet-switched data network, Syriapac, as discussed earlier. This network is used primarily by government researchers to exchange date, log into host computers at the various universities, and connect to the Internet. Internet access is currently possible from Syria, via long-distance telephone calls to Internet Service Providers (ISP) outside Syria, and via Syriapac to EgyptNet, via a SprintLink X.75 satellite connection. The Internet is used by government researchers principally to access foreign sources of technical information. Students and businessmen are interested in having an international e-mail capability, and many Syrian expatriates would like to have “free” telephone connections to Syria via the Internet.

The STE intends to establish a root domain name server (DNS) for the .sy national top-level domain, for which the STE is the domain manager. Unfortunately, the STE has no competence in this area, and thus has embarked on a self-education program while enlisting the aid of HIAST personnel. In addition to lacking the requisite knowledge, the STE’s program is hampered by the usual funding and negotiation difficulties inherent in establishing an international data link.

There are mixed feelings in the West with regard to Internet access by Syrians, particularly SSRC researchers. These are good examples of the difficulty in assessing some of the effects of IT proliferation, especially international communications links. On the one hand, the proliferation of international telephone and data links between Syria and especially the West could be predicted to have a moderating and modernizing effect on Syrian society, as the number of contacts with Westerners increase and be-

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[18] The HIAST is affiliated with the University of Damascus, under whose auspices it grants degrees, but is administratively a unit of the Ministry of Defense’s Scientific Studies and Research Center (SSRC). HIAST personnel are SSRC employees; many are also members of the university’s faculty.

come routine, and as Syrians learn more about life outside their country. An example often cited is the effect of foreign television and especially facsimile contacts on Russia. However, those Syrians who are apt to care what life is like outside Syria are already far more aware of both the advantages and disadvantages of Western culture and life-style than most Russians are even today. On the other hand, it is easy to predict that the Syrian government would bend international contacts to its own ends, using foreign information sources to leap-frog other countries in the development process and military capabilities. Both scenarios are feasible to a degree, and both are probably operative today. There is no doubt that the SSRC is attempting to learn techniques that the West would like to keep away from countries like Syria. However, the Internet does not create the possibility of access to this information, but only speeds and simplifies it. And, there remains the significant question of what the Syrian capabilities might be to exploit any information they obtain. It is not unreasonable to expect, however, that increased contacts between Syria and the West would have a salutary effect on our relations, particularly as Westerners appear to have more to learn about Syria than vice-versa.

3.6.4 Privacy/information security/encryption

Information security is exclusively the realm of the Syrian government, most particularly the military, where security standards and set and enforced by the military "intelligence" organizations. Commercial organizations and private individuals are not permitted to own or use encryption devices, systems, or computer software.

The Syrian military uses encryption equipment purchased from foreign vendors, and also claims to have developed its own digital encryption devices for use on data networks. For Syria, the issue of foreign origin is very much a concern with regards to cryptographic devices. They are viewed as critical to military operations and other national security requirements, but the fact that they are of foreign origin makes the safety of their use suspect. Hence, the issue of technology transfer is very critical, as the Syrians would certainly prefer to meet all their cryptographic requirements with indigenously designed devices or software. While the basic precepts of cryptography are public knowledge, their application in designing systems and software remains difficult. Any proliferation of this technology to Syria would raise significant national security concerns.

Syrian capability in computing is shown in Table 23 and Figure 16.

Dimension	**Level**	**Movement**	**Explanation**
Proximity to Technological Frontier	(2) *Non-competitive*	+	Computing in Syria is limited principally to office automation applications based on Western software packages. Networking is rudimentary.
Depth of Development	(2) *Adapting*		Foreign software packages are customized for local clients, with Arabization a specialty of Syrian software "developers."

Sophistication of Use	(2) *Conventional*	Computing automates but does not fundamentally change existing processes.
Pervasiveness	(2) *Established*	ADP support is common but not ubiquitous in government organizations and businesses.
Indigenization	(3) *Managing*	Computing in support of Syrian organizations is accomplished by local nationals, usually after training by the foreign vendors.

Table 23 Dimensions of Syrian Computing Capabilities

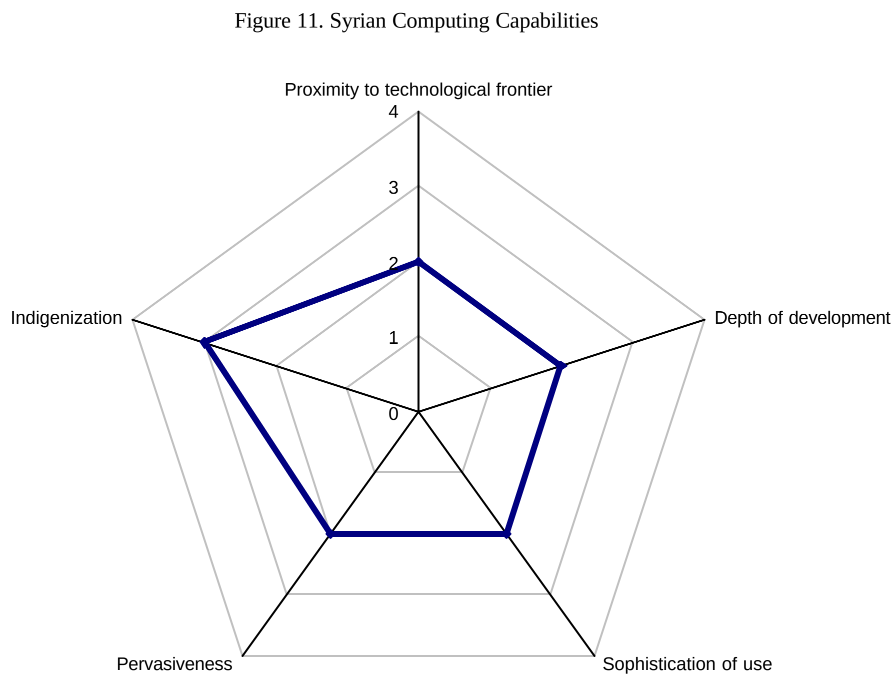

Figure 16 Syrian Computing Capabilities

3.6.5 Summary: Information Processing

Information processing in Syria is more than ten years behind the West, in terms of the quality and quantity of hardware and software available and the sophistication of their use, and Syria is falling further behind. The situation is more the result of cultural, political, and economic factors, than the unavailability of the technology due to Western, particularly U.S., attempts to control its diffusion. Syrian society is exceptionally conservative, and change is effected only very slowly. Although computers and the idea of automation are attractive to Syrians, assimilation of the technology occurs at the usual cautious pace. Rumors and "common knowledge" of the dangers of computers (e.g., foreign computers are bugged by foreign intelligence services to spy on Syria) spread more rapidly than knowledge and skills. The political situation dictates the requirements for a strong central government, centralized management of "strategic" functions and industries (e.g., banana imports and sugar production, both liberalized only this year), and the control of the availability and flow of information, both domestically and internationally. This situation could argue for accelerated computerization, which could strengthen and proliferate government control. However, computerization is change, and change is potentially dangerous, so the government controls the technology (e.g., facsimile machines were legalized in 1993, and modems only this year, although the latter must still be registered with the "secret" police). Finally, lacking a domestic production base, all IT components and systems must be imported, requiring the expenditure of hard currency, of which there is always a shortage. Table 24 and Figure 17 summarize the salient features of the information processing sector of IT.

Dimension	Level[19]	Movement	Comments
Proximity to Technological Frontier	(2) Non-competitive		Computer hardware and software is generally at least one generation behind that commonly available in the West. Additionally, they are seldom used to their fullest capabilities.
Depth of Development	(2) Adapting		Computer software is modified to permit Arabic language processing using common Western (usually English language but sometimes French) software packages, which are also adapted to the clients' requirements.
Sophistication of Use	(2) Conventional		Requirements, however, are simply stated. Computing in Syria neither defines nor modifies processes, but merely automates (often poorly) well-established routines.
Pervasiveness	(2) Established		Computers have not yet become a commodity in Syria, where a "mainframe mentality" persists. Automation of office functions is common both in business and government, however.

19 These are not mathematical averages of the levels for the constituent technologies, but a summary judgment taking into account those levels.

Indigenization	(3) Managing	Except for some ADP support for foreign companies, computing in Syria is conducted by local nationals. Hardware maintenance is not commonly practiced, but most basic repairs are made locally.

Table 24 Dimensions of Syrian Information Processing Capabilities

Figure 12. Syrian Information Processing Capabilities

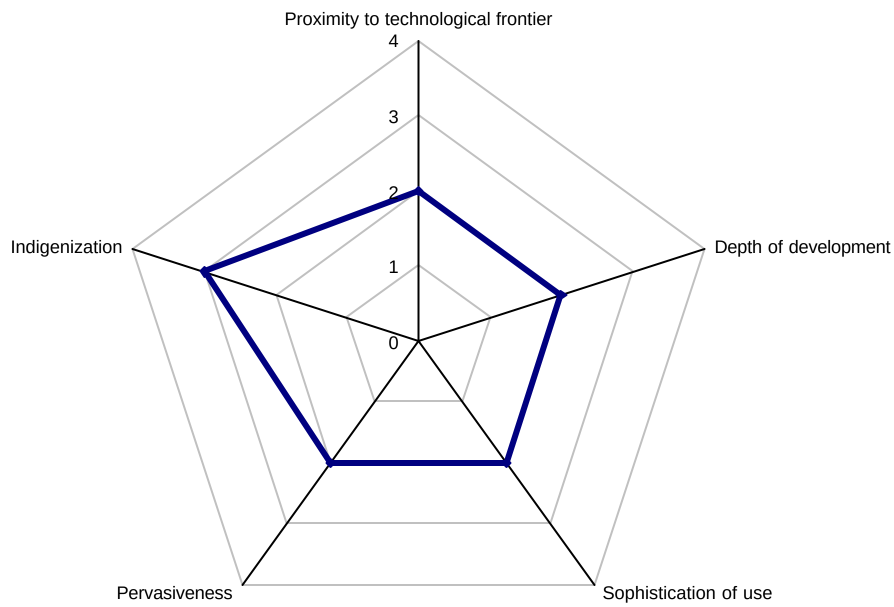

Figure 17 Syrian Information Processing Capabilities

3.7 Determinants of IT Capability

To date, national security concerns raised by Syria have been a factor of weapons proliferation, rather than the diffusion of information technology. Due to the factors previously discussed and the generally poor state of readiness of the Syrian armed forces, this will remain the case for the foreseeable future. Syria is able, within limits, to assimilate and effectively employ sophisticated weaponry, but does not appear to have yet developed a similar capability with respect to high technology information acquisition, transmission, or processing technology. With the exception of military communications systems that could significantly improve the command and control of Syria's armed forces while increasing the security of those communications, the continued diffusion of information technology to Syria is unlikely to create or exacerbate American national security concerns.

This situation exists because of Syria's relatively low level of technological development, despite many trappings of a modern country and the possession of some very modern IT systems. Syria's IT capability is correspondingly low, and shows no signs of significant improvement in the near future.

The principal determinant that has resulted in little high-technology development is government policy. As noted previously, the political situation in Syria has on the one hand acted as a brake on IT development as a potential threat to the regime, and on the other hand has diverted funds that might have been used for development into the defense establishment. Not only does the Syrian government not have a national IT policy, but IT policies, to the extent that the government has had any at all, have been independently developed and enforced by the various "intelligence" services. Computers, facsimile machines, and modems were all restricted items until only very recently. The utility of IT for development was not fully recognized, while the potential threats from its proliferation were greatly exaggerated.

3.7.1 Technology

The current situation and infrastructure in Syria fail to adequately support any of the principal technology determinants of IT technological capability. The introduction of high technology in Syria is relatively recent, and its acquisition and integration have not been pursued in an organized or coherent manner. Between independence and the 1980s, modern telecommunications and computing were virtually unknown in Syria. Technologically, little in the country, with the exception of military hardware, had changed in more than three decades. Computer systems were introduced into some government administrations in the 1970s, but were not well-integrated into those organizations' operations until only recently; they are still used, however, principally for simple office support functions. Acquisition of IT accelerated only in the early 1990s, with the beginning of economic liberalization. The increased business activity and greater turn-over of cash in the domestic economy spurred both commercial and private demand, especially for reliable telephone service. While all sectors of IT have been affected, the results have been uneven, except in the area of conventional (voice) telephony. In the rush to "modernize," the emphasis has been on acquisition. This, and continued uncertainty regarding government policy towards private industry in a country still nominally socialist, have retarded the development of an infrastructure of supporting manufacturing and service industries. For example, purchasing virtually any type or model of micro- or mini-computer in Damascus is trivial; there are a plethora of shops from which to choose. However, installation support, especially for local area networks, and maintenance and repair centers are difficult to find and those few that exist are very limited in their capabilities. Table 25 summarizes the general characteristics of technology in Syria.

Factor	**Status**	**Explanation**
Complexity	Low-Moderate	The majority of the IT systems in Syria are relatively simple, especially in computing. The most complex system is the

	Moderate	telephone network, which employs the most modern switching and transmission technology, albeit operating well below designed capabilities.
Stress on supporting industries	Very Low	There are virtually no supporting industries in Syria. The principal stress is on sources of the funds required to import repair parts and services.
Need for supporting products and services	Low	Most of the IT systems in Syria are sufficiently uncomplicated so as to require little support.
Cost	Moderate-High	Given the abnormal market conditions, even relatively simple computer systems are unusually expensive in Syria. The Syrian government pays a premium price for most IT equipment it imports, whether or not it is purchased on a turn-key (installed by vendor) basis.
Level of integration with other systems	Low	Most IT is purchased on a piece-meal basis, with little regard for how it could be interfaced with other systems to yield greater benefits (or even work at all). The significant exception is the telephone network, which has been developed with reasonable care.

Table 25 Technology Characteristics of Syrian Information Technology

3.7.2 Resources

Just as the technological base is weak, the resources required for robust IT development are scarce. Syria remains entirely dependent upon the outside world for all of its information technology needs, including human resources which—despite the abundance of inexpensive labor and an under-employed labor force—must be trained in foreign institutes. The potential sources of supply vary widely, however, complicating both Syrian development plans and any foreign attempts to constrain Syrian IT acquisition. These factors are discussed below and summarized in Table 26.

Syria has the financial resources to pay for only a small portion of the information technology equipment, services, and training that are required. Programs that are generally internally financially self-supporting are PC acquisition by the Ministry of Education and component purchases by the STE. Even the military is reliant upon foreign financing (formerly Soviet and now Russian) to purchase communications equipment as well as weapons and parts. The principal sources of funding for government IT projects have been the various governments and aid agencies of the Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates), which have been especially generous with respect to funding telephone company projects as well as other infrastructure and industrial programs. The European Community has also funded significant IT projects, such as the replacement and expansion of the HIAST's LAN in 1994 and the major telecommunications expansion project currently being tendered for by the STE. One source of funding for information processing that could become a significant factor in IT development is the commercial sector, which is starting to invest heavily in computers, software, and LAN equipment as both domestic and international commerce continue to grow. Although the proliferation of computers could be quite wide-spread, it is also likely to be shallow, as businesses concentrate on office support and commercial administration applications.

At the technician level, human resources are provided or trained by equipment vendors. Professionals and academics are trained in foreign institutes. For IT, this training usually takes the form of graduate (and sometimes undergraduate) degrees taken in France. Many Syrian electrical engineers are trained in Eastern Europe and Russia, as well. The technological resources are also mostly imported, as previously discussed, and none of the required materials are available in Syria.

Information resources are also poorly developed. On the one hand, the government has pursued a conscious policy of limiting access to information in order to maintain its strong control over the populace. On the other hand, not only has Syria often isolated itself from the West, the principal potential source of information, but has just as often been isolated by the West in response to Syrian involvement in international terrorism. As the base of educated professionals grows, courtesy of Western training, Syrian ability to assimilate foreign technical information will likely improve, probably significantly. Syrian access to off-shore information sources has already improved greatly, but there is no coherent collection, dissemination, or exploitation policy.

Factor	**Status**	**Explanation**
Financial resources	Weak	Most funding for government computer procurement, except for schools, comes from off-shore, as do about half the funds for telecommunications.
Human resources	Weak-Moderate	Syrian primary education is good and the literacy rate is high, but secondary education in IT disciplines is poor, resulting in the requirement for overseas training. The level of expertise thus achieved varies widely (e.g., a Ph.D. from Purdue vs. Leningrad Polytechic).
Technological resources	Weak	The technological base and infrastructure are poor, and thus must be developed in parallel with advance technologies, introducing additional complications and expense and significantly slowing the process.
Material resources	Weak	Few material resources are required; none are available.
Information resources	Weak	Syria has typically been isolated from Western high technology information, access having been constrained by the policies of the Syrian and Western governments, economics (e.g., insufficient funds to pay for subscriptions or database

		access), and inexperience in seeking foreign technical data.

Table 26 Impact of Resources on Syrian Information Technology

3.7.3 Landscape

The "landscape," or background, in which IT exists and upon which IT relies in Syria includes several factors that have contributed significantly to retarding the proliferation and absorption of IT in Syria, as shown in Table 27. These factors are not exhaustive, but are those judged to the most critical, changes to which would have the most impact on future IT development in Syria.

Factor	**Status**	**Explanation**
Nature of government	Imposed minority	The authoritarian minority 'Alawite leadership must retain tight control over any technology that has or appears to have the potential to threaten its continued rule. While certain aspects of IT have the potential to strengthen this control, IT can also be destabilizing. Since modern technology is not well understood in the upper echelons of the government or in the security services, the government has significant restricted IT development.
System of economic management	Partially centralized	The Syria economy is a mix of socialist industrial and social policy and capitalism. While the latter spurs IT development, the former usually results in at least sub-optimal and often outright dysfunctional investment policies. There is virtually no R&D investment in Syria.
International relations	Troubled	The perpetual state of war with Israel, occupation of Lebanon, and periodic trouble with its other neighbors isolates Syria in the Levant. These problems and the government's former support of terrorism have also isolated Syria from the West to varying degrees over the past 15 years. Additionally, the troubled international scene results in the diversion of about 40 percent of the state's already Spartan budget to the defense sector.
Organizational structures	Hyper-bureaucratic	A social milieu that is inherently conservative is exacerbated by extensive over-staffing of bureaucracies, since the socialist state is the employer of last resort. Given the dangers seen to be inherent in easing government controls of IT, this results in a host of officials who can disapprove a proposal who stand in the way of the single official (usually the presi-

		dent himself) who can give the go-ahead.

Table 27 The Syrian Information Technology "Landscape"

3.7.4 Dynamics

The environment for IT development in Syria is not at all dynamic, as shown in Table 28. The one indicator that would normally be taken as very positive, the "very competitive" competitive environment, is a negative factor in Syria, where secrecy is a national pastime surpassed only by tax evasion. A strongly competitive environment in Syria is a negative factor because success in Syria is not based on merit, but on connections derived from family, friends, influence, and/or bribes. Therefore, anyone with a new idea takes great pains to conceal the idea and its implementation from everyone not directly involved in attempting to realize it. This obsessive secrecy greatly hampers the already constrained flow of information, often resulting in duplicative or mutually exclusive efforts. (For example, four different groups, each claiming to be "helping" Syria, registered in 1995 with the InterNIC to become the .sy top-level domain manager for the Internet in Syria. All four groups were Syrian expatriates, none of the made their plans public, and none coordinated their efforts with any organization or government agency in Syria. One of them was successful, but couldn't understand why the Syrian government, which was enraged, was not appreciative of their efforts. The STE is now the .sy domain manager, although they have no expertise in this area and there are no Internet hosts in Syria.)

Factor	**Status**	**Explanation**
Competitive environment	Very competitive	Competition results in secrecy, which further exacerbates poor information flow, since success is not dependent upon merit.
Flow of labor	Poor	There is an over-abundance of labor, resulting in hyper-bureaucratization and under-employment. This in turn results in job stagnation. Among the better educated, those who received government scholarships for their overseas studies owe a pay-back of 10 or more years in a government position.
Flow of capital	Poor	There is a shortage of capital in the public sector, and what capital exists is centrally allocated. There is a shortage of hard currency (required to finance imports) in both the public and private sectors.
Flow of information	Poor	In addition to having constrained access to foreign information sources, internal information dissemination is weak, partly due to government policies, partly because of the penchant for secrecy noted above, and also due to a lack of either an information policy or dissemination infrastruc-

		ture. The newly-established "National Information Center," created to establish central databases of IT information available to all, is viewed with skepticism by a society used to viewing all such initiatives as "empire building."
Presence of demanding customers	Weak	The business community is pressing the development of modern telecommunications services, but there is little general support for IT development in general, and none at all for the development of domestic IT industry, with the exception of software development.

Table 28 The Dynamic Determinants of Syrian Information Technology

3.7.5 Summary

Where the previous example applied the analytic framework developed at the beginning of this report to a specific information technology in one country (i.e., Russian HPC), the chapter has attempted to apply it across a broad spectrum of information technologies in one developing country of national security concern. While optimal for analyzing individual technologies, the framework nevertheless provides a useful and consistent approach for taking a more holistic view of a potential adversary or country of national security concern.

The conclusions that can be drawn about Syrian IT from this application include:

IT in Syria is neither evenly distributed nor well-developed. Furthermore, there is no consistent policy or framework for its development.

There is no indigenous IT industry, with the exception of a nascent software development industry. Everything, including education and training, must be imported.

The reasons for the above, which will continue to be barriers to development in the near term, are largely systemic. Government policy is one of the most significant, and potentially most easily altered, constraints on IT development. It plays upon, rather than attempting to counteract, the natural conservatism of Syrian society. Government policy cannot easily be changed, however, as long as a religious minority retains its power through force.

Given the economic constraints and the fact that IT must be imported, the most significant factor that could potentially be manipulated by other governments is Syrian access to the funds required for development.

The above conclusions beg the question, however, as to whether the global diffusion of IT has had a negative effect on American national security to the extent that the information technologies have diffused into Syria. It appears that the answer is no, and that the further diffusion of more, and more capable, IT will have little if any effect on either the ability of Syria to act in ways seriously detrimental to American national security or on the West's perceptions of Syria's capabilities. While it is possible that

Syrian military capabilities could be enhanced through the assimilation of more modern, efficient, and secure command and control systems, it is questionable whether the Syrian armed forces could make effective use of such equipment, were they to receive it. It is more likely that only Syrian perceptions of its own strength would be enhanced, but this is dangerous in itself, to the extent that it makes Syria either more intransigent in negotiations with Israel or more likely to attempt to launch a surprise attack.

Limited economic liberalization and an easing of constraints on some information technology (e.g., computers, facsimile machines, modems, and international access to data services) have coincided with an attempted Syrian rapprochement, however clumsy, with the West. The result has been a rapidly expanding economy, albeit still within the constraints imposed by an unconvertible currency, limited acceptance by the West of Syria as trading partner, and a greater degree of sympathy for the Syrian view in negotiations with Israel. It is probable that continued and expanded contacts and trade will further encourage the Syrian government to be more open and apparently reasonable, which in turn will accelerate economic growth. A reasonable response from the West then, to Syrian IT acquisition, would be not only to ease constraints on non-military exports to Syria but to facilitate the further development of IT in Syria to the extent possible, while continuing to constrain Syrian military acquisition of both weapons and IT.

4. Conclusions

The IT Capability Framework presented here appears to have some promise of satisfying the criteria for a framework outlined in the introduction. The five dimensions of capability provide a set of variables that are relatively easily grasped, even by non-specialists. At the same time, they have the analytic power to characterize a broad spectrum of different capabilities found throughout the world today.

The use of five levels in each dimension has a number of advantages. First, it should be possible for reasonably well informed analysts to determine the correct level with only moderate effort. The greater the number of levels along each dimension, the greater the amount research necessary to distinguish between levels. Five levels represents a compromise between a scale that is too fine-grained to be reliably applied, and one whose resolution is insufficient to yield useful analytical results.

Second, we expect that our use of only five levels will increase the likelihood that different analysts looking at the same country and same technology will come to the same, or substantially similar, evaluations of capability. This convergence of analysis is likely to increase confidence in the model and the conclusions that result from its use.

Our model of determinants of technological capability also appears to provide a consistent framework within which the numerous variables that play significant roles in specific countries can be examined.

Is the framework applicable in a consistent fashion to a broad spectrum of countries and technologies? Efforts to apply the framework to HPC in the Soviet Union/Russia and to information technologies in Syria give reason to be hopeful. The framework appears to be applicable in a consistent and useful fashion both to individual information technologies, and to more general categories of technologies. It appears to be applicable to technologies as varied as high-performance computing, and networks. Nevertheless, a great deal more research must be done to apply the framework to other countries and other technologies, such as software engineering or large integrated systems.

As employed here, the framework is analytically rather neutral. That is, the framework enables one to capture the salient aspects of a countries capability with regard to a particular technology in a digestible fashion, but does not necessarily answer the question of whether those results are significant in some meaningful sense. The answer to such questions depends on a clear understanding of which national security issues and applications are important, and which dimensions of IT capability are most significant with regard to those applications. For example, low pervasiveness of a technology may be significant for some applications, but not for others.

Finally, a great deal more can be done to improve the presentation of the analysis. In this report, we have used radar plots together with tables of supporting detail. However, there is no technical reason why radar plots, tables of summary data, and underlying raw data cannot be combined into a hypermedia system that would allow a user to “drill down” from final analysis to the underlying detail as their interests and needs dictate.

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