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NATIONAL TECHNOLOGICAL COMPETITIVENESS AND THE REVOLUTION IN MILITARY AFFAIRS

Final Report, Phase I

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National Technological Competitiveness and the Revolution in Military Affairs Phase I Final Report

Introduction

The objective of Phase I of this project is to identify a subset of nations in the Asia Pacific region that demonstrate the following three characteristics. First is a relatively rapidly growing technological capacity. Second is an ability to rapidly absorb and utilize technology. Third is a particular orientation toward using nonstandard models of technology diffusion to acquire technology quickly through arrangements such as joint ventures, foreign direct investment, co production arrangements and outsourcing from multinational corporations. Ultimately, though, the purpose of the project is to identify and to evaluate potential participants in the revolution in military affairs among the rapidly industrializing nations in the Asia Pacific region.

There are several views of the revolution in military affairs (RMA). Some do not find the concept useful. A subset of these critics site the technology of the Gulf War and believe that what we are currently observing is an evolution rather than a revolution. Others believe that the revolution is already upon us. Still others, observing the last 200 years of history, believe that we are in the early developing phases of a revolution in military affairs that will culminate in the first quarter of the next century and change, in a very fundamental way, how warfare is conducted by nations capable of adapting advanced technologies to military purpose. These technologies will be mated to highly adaptive military organizations employing imaginative operational schemes. They cite historical parallels, such as the innovations that occurred in the interwar period, and conclude that presently we are in a period analogous to the 1920s in terms of the contemporary RMA. We accept this latter view and its premises, but would add the following observations.

As is now apparent, and will likely be more so in the first half of the next century, the ability to wage modern war has become a function of economic strength that rests in large measure on the indigenous capacity to create, manufacture, and market technology-based products successfully. This fact will most likely underlie any basis for a revolution in military affairs and serve as the platform from which military innovation of the type to denote peer competition will be launched.

To the extent that national military and economic prowess depend upon similar institutional bases, anticipating a nation's future military capacity requires the ability to anticipate its future technological capacity as well as the social bases of organizational learning. The capacity of a military organization is defined as a diverse set of abilities that permit an organization to perform complex tasks, such as the various skills necessary to project military force over open ocean. Indeed, the idea of a military-technological revolution explicitly reflects the central role that technology plays in the calculus of military power.

Recent analyses of national competitiveness demonstrate the key role that technology and technological change play in developing and maintaining national economic power. Thus technology rests at the nexus of national economic strength and military prowess.

To identify potential participants in the revolution in military affairs (RMA), it follows from the above that one must identify nations that exhibit a set of characteristics that are predictive of technology-based competitiveness. Granted, this alone does not fully accomplish the desired goal since nations may choose to channel their competitive capacities primarily in military directions, or may choose a short-run strategy that builds economic/military strength at the expense of citizens' standard of living. However, most contenders to future competitiveness must pass through a series of development stages.

These include, first, the absorption of new technology from abroad which is frequently manifested as platform manufacturing. Absorption is followed by the adaptation and application of external technology to local conditions of production. Eventually, the nation may progress to the use of locally-developed technology and technical expertise to create products that compete successfully in international markets, or on the battlefield.

Premises Underlying Phase I

Our analysis is premised on several fundamental shifts in the international environment. The first major shift is a fundamental change in the nature of weapons development. The discovery of important new defense technologies has shifted, from development through intensive research directed by the government, then followed by the identification of civilian applications (spin-off), to the development of new technologies largely in and through commercial or civilian research, then followed by the identification of military applications (spin-on).

Technologies developed directly for military application are often no longer cutting edge; the accelerating pace of development in the civilian research and development community has meant that by the time a new military system becomes operational, its component technologies can be obsolete by several generations. This is most apparent in the micro-electronics revolution.

A second factor that will impact the development of militarily competitive nations in the Asia Pacific region is the over capacity of the global arms market. Diffusion of militarily relevant technologies with indigenous weapons production potential has been accelerated. In reaction to the contracting arms market and the increasing costs of weapons development, governments and defense firms have responded by marketing weapons, weapons technologies, and defense production knowledge on a worldwide basis. Due to the current "buyer's market" consumer nations are able to demand the transfer of advanced weapons technology and production knowledge as a condition of purchase from an industrialized supplier.

The third development in the international environment is the growing importance of multinational corporations and economic globalization. In the post Cold War era, research and development by multinational corporations has replaced state sponsored technology development as the most important source of technological innovation. These immense and mobile firms are primarily driven by economic and commercial considerations. Their quest for higher profits can lead to the diffusion of sensitive technologies irrespective of any single nation's national security goals or policies.

Finally, we believe that all but the wealthiest nations will have difficulty sustaining independent defense industries and their research and development complexes. The current consolidation or failure of defense industries and firms in the industrialized world will continue. Industrializing nations will be forced to develop their military technology base through leveraging the civilian economy.

The growing importance of spin-on, the global over capacity of defense industries in the industrialized West and Russia, and the emergence of economic globalization driven by multinational corporations are significant changes in the international environment that will directly affect the development of industrialization in Asia with national security consequences. If economic resources are available to developing nations and if these resources are leveraged properly, the subsequent transformations mean that the growth of advanced civilian technology sectors within a nation can provide a base for development of indigenous high technology industries from which military innovation can be launched.

The Research Process

Our search to identify the subset of nations in the Asia Pacific region that are most likely to achieve the technological capacity to become militarily competitive in the region began with a review of pertinent literature. We located and examined two types of relevant literature: (1) sources that describe the current technological status of nations in the Asia Pacific region in both the civilian and military arenas and (2) sources that describe the likely processes through which the development can occur. From our literature review and preliminary qualitative analysis we determined a set of data sources that would likely be informative and useful. The most obviously relevant data set we sought were several editions of the Militarily Critical Technologies List (MCTL) that is produced by the Department of Defense. The Office of the Under Secretary of Defense for Acquisition and Technology, which produces the MCTL, describes the report as a detailed and structured compendium of the technologies DoD assesses as critical to maintaining superior US military capabilities. The report contains Foreign Technology Assessments (FTAs) which are estimates of foreign capabilities in each of the technology areas.

Our second source was a National Science Foundation study on the Indicators of Technology-Based Competitiveness.[1] This study began in the late 1980s and sought to identify indicators of high technology-based development that would measure the competitiveness of selected countries. The study identifies four composite "input" indicators that are predictive of future competitiveness and three composite "output" indicators that indicate current competitiveness based on world market share of high-technology products, especially electronics. These are referred to as high technology indicators or "HTI". The four composite "input" indicators of competitiveness that are described below are National Orientation, Socioeconomic Infrastructure, Technological Infrastructure, and Productive Capacity.

National Orientation: This input indicator is evidence that a nation is undertaking directed action to achieve technological competitiveness. Evidence of such action can be manifested at the business, government, or cultural levels, or any combination thereof. "Directed" action would be indicated by the existence of:

- an explicit national strategy developed and implemented by government,
- an explicit national strategy resulting from negotiations between business and government,
- an implicit national strategy reflecting individual business actions and, possibly, government support,
- an implicit national strategy reflecting a general consensus in the values and attitudes of the populace about the role of technology in social and economic life.

Socioeconomic Infrastructure: This input indicator evaluates the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation. The existence of such institutions and their effectiveness could be indicated by:

- evidence of effectively functioning capital markets, including mobility of capital; or, in more centrally-planned economies, evidence of flexible, rapid, and appropriate responses to changing investment requirements,
- rates of capital formation, capital investment, and savings,
- levels of direct foreign investment,
- levels of national investment in education.

Technological Infrastructure: Institutions and resources that contribute directly to a nation's capacity to develop, produce, and market new technology comprises this input indicator. Central to the concept are the ideas of economic investment and social support for technology absorption and utilization, which could take the forms of monetary payments, laws and regulations, and existing social institutions. Also included is the physical and human capital currently in place that is capable of developing, producing, and marketing new technology. *Technological infrastructure* includes elements of the socioeconomic infrastructure and productive capacity that are directly and specifically technological in character or purpose. Examples of technological infrastructure might include:

- R&D expenditures by business and government,
- effective protection of intellectual property rights (e.g., a functioning patent system),

- alliances with technology-based multinational corporations via licensing, joint ventures, and direct foreign investment,
- public or private organizations such as trade associations that provide technical support services to industry,
- technological capital stock (R&D plant and equipment, data processing equipment, telecommunications equipment and networks),
- technological knowledge stock (foreign and domestic patents owned, royalty payments, technical books and journals produced),
- technical human resources (scientists and engineers; skilled blue-collar workers, skilled service and support workers; innovative, experienced technical managers, entrepreneurs, and marketing people; technical educators and trainers),
- technical support services (component suppliers; job shops; consulting services).

Productive Capacity: This input indicator measures the physical and human resources devoted to manufacturing products, and the efficiency with which those resources are used. Examples include:

- indicators of manufacturing productivity,
- manufacturing capital equipment (machine tools, robotics),
- proportion of GDP accounted for by manufacturing.

The three composite "output" indicators of HTI competitiveness are described below as Technological Standing, Technological Emphasis, and Rate of Technical Change.

Technological Standing: This measures the current world market share in high technology products, reflecting not only current export market share statistics but also current manufacturing capability. Examples of Technological Standing include:

- indicators of the overall level of technology-intensive production,
- high technology exports,
- electronics exports.

Technological Emphasis: This output indicator measures the extent to which a nation emphasizes high technology products in its export mix. Examples of a nation's technological emphasis include:

- the proportion of high tech exports to total exports,
- the ratio of the difference between electronics exports and imports from year to year, to the sum of electronics exports and imports.

Rate of Technological Change: This is an indicator which captures the speed with which a nation is expanding its export market share in high technology products. Examples include:

- the ratio of the difference between the value of high tech exports and imports over time,
- the ratio of the difference between the value of electronics exports and imports over time.

As noted above, each of these input and output indicators are composites and consist of several sub-variables. Our research and analysis uses many of the NSF study's survey results and additional statistical indexes from sub-variables that constitute each of the composite indicators. The experts surveyed included science counselors and/or economic advisors to embassies and consulates for the United States; editorial boards of international journals in the field of development and technology policy; members of international development organizations and lists of attendees at conferences dealing with technology and development; the personal networks of key individuals in the National Science Foundation's International and Science Resources Studies Divisions; and the personal networks of academics contributing to the field of technology and development. The additional statistical data that comprises components of the aggregate indicators is as follows:

- *National Orientation:* Uses the Frost and Sullivan 5-year investment risk index (in addition to survey data).
- *Socioeconomic Infrastructure:* Uses the percentage of students enrolled in secondary education and the percentage of students enrolled in tertiary education from the *Harbison-Myers Human Skills Index* and UNESCO (in addition to survey data).
- *Technological Infrastructure:* Uses electronic data processing equipment purchases from the *Elsevier Yearbook of World Electronics* and the raw number of scientists and engineers engaged in research and experimental development as defined by the *UN Statistical Yearbook* (in addition to survey data).
- *Productive Capacity:* Uses the *Elsevier Yearbook of World Electronics* (in addition to survey data).
- *Technological Standing:* Uses the value of high tech exports from the United Nations Statistical Office trade statistics and the value of electronic exports from the *Elsevier Yearbook of World Electronics Data* (in addition to survey data).
- *Technological Emphasis:* Uses the ratio of high tech exports to total exports from the UN Statistical Office and the ratio of electronic exports to total exports,

including re-exports, from the *Elsevier Yearbook of World Electronics Data*, but does not use survey data.

- *Rate of Technological Change:* Uses the change in the value of high technology exports over 3 years as reported by the UN Statistical Office and the change in the value of electronic exports for three years from the *Elsevier Yearbook of World Electronics Data* (in addition to survey data).

The third main source used was the 1995 edition of the United States Arms Control and Disarmament Agency's *World Military Expenditures and Arms Transfers* (WMEAT). WMEAT was used to provide aggregate economic and military figures. The data utilized from ACDA's WMEAT included:

- Gross National Product,
- Central Government Expenditures,
- Military Expenditures,
- Arms Imports,
- Arms Exports,
- Total Imports,
- Total Exports.

We used annual data from 1985 to 1995, with all the figures in constant 1995 dollars. Complete data was available for each variable for all the nations targeted in this study. Once our data sources were identified and located, we continued by determining a smaller subset of target countries that warranted further analysis.

In the process of selecting the subset of nations that would be more closely analyzed in Phase 1, we determined that our planned quantitative analysis would not be possible. Originally we hoped to use the MCTL FTAs and the other sources in a discreet time series analysis to test hypothesized relationships between high technology industrial competitiveness, economic development, and the development of militarily critical technologies. However, controlling for missing or inconsistent data in the MCTL FTAs made the investigation extremely challenging. Consistent and expanding measures of each country's technological standing in industries that produce or use technologies central to the manufacture of advanced weapons systems simply are not available. Instead, we were forced to develop heuristic measures, which are discussed later in this report.

We found that the existing data provided by the MCTL FTAs has serious weaknesses and gaps which made it impossible to use in a discreet time series analysis. While the coverage of weapons technologies in the MCTL is quite comprehensive, the MCTL FTAs proved to be extremely inconsistent from edition to edition. Despite its stated purpose, the MCTL is, at best, a spot assessment of the weapons systems technologies of a small, shifting set of nations. The set of nations examined changes within each technical division of the report as well as from edition to edition. The MCTL FTAs data is scaled into four very broad measurements. These are capability in a majority of the technology area critical elements, capability in some critical elements, capability in only a limited set of the critical elements, and no capability or consensus regarding the capability. Consequently, the data are not compatible with a precise statistical analysis. Use of this data was problematic at best, and many nations in the Asia Pacific region are not included in the document.

Despite the deficiencies of the data, the MCTL FTAs proved useful in a more qualitative analysis. Because the data was inconsistent with statistical analysis, we instead used much cruder methods to evaluate the comparative standing of each included nation.

By assigning each measurement category a numerical value (4, 3, 2 and 1, respectively[2]) and by summing the total value for each nation across each of the eighty-four technology sub-sections of the FTAs, we constructed a raw ranking of the technical capabilities across the entire spectrum of militarily critical technologies. While the raw ranking lacks the precision we had hoped to achieve, we believe that the method is sufficient to accurately show the relative standings of the nations. Not surprisingly, the US fared the best in this test, earning 97% of total possible score, and Japan followed with 71%. Somewhat surprisingly, China scored third highest in our subset with 40%, followed by Italy (31%), Taiwan (25%), India (20%) and South Korea (17%).

Through our literature review and the raw ranking produced by summing the MCTL FTAs data, we determined the ten most likely high technology competitors in the Asia Pacific region. These nations constituted our subset for further study in Phase I.

- Japan
- China
- South Korea
- Taiwan
- Singapore
- Malaysia
- Thailand
- India
- Philippines
- Indonesia

In order to ensure that the analysis established the importance of relative position changes, data for the US was used to provide a moving point of reference. In addition, we chose to include Italy as a European point of reference for the study. Because of its position as a late developing western nation that has followed developmental strategies similar to many of the nations in the study subset, it seemed a uniquely valuable point of reference. Once data was collected and our target countries were identified, we began to develop and operationalize a model of military technical capability development.

The Military Developmental Resource Leveraging Network Model

The concept underpinning our Phase I analysis of the development of potential future military competitors in the Asia Pacific region is a hybrid theory based upon a model of technological evolution and the dynamic conceptions of *the displacement of nations as the unchallenged leaders of technological innovation that is fundamental to our theory of technological progress.*

The technological evolution model developed by John Mathews and published in the December 1996 issue of *Journal of Industry Studies* was used as a foil for the development of our model of technological evolution. Mathews advances an explanation of the mechanisms for acquiring and enhancing industrial "technological capability". *We believe, however, that Mathews' conception of technological development as a series of steps to sustainable innovation that once achieved are irreversible is simply incorrect. Mathews also portrays the development of sustainable innovation as a natural, inevitable event. History has shown, however, that attempts at sustainable development often fail. Our model explicitly delineates the conditions necessary for this development, and our* *model includes the possibility that a current high technology innovator can be left behind in a future technological revolution.*

Current trends in the character of arms and arms technology transfer make our model increasingly relevant in the development of military technological capability in the Asia Pacific region. The confluence of the dual elements of expanding market forces driving arms and arms technology transfers and the increasing importance of dual use technologies and commercial-off-the-shelf products in weapons development will likely continue well into the next centruy. Consequently, we believe that our model of the Developmental Resource Leveraging Network is appropriate for the study of future military competitors.

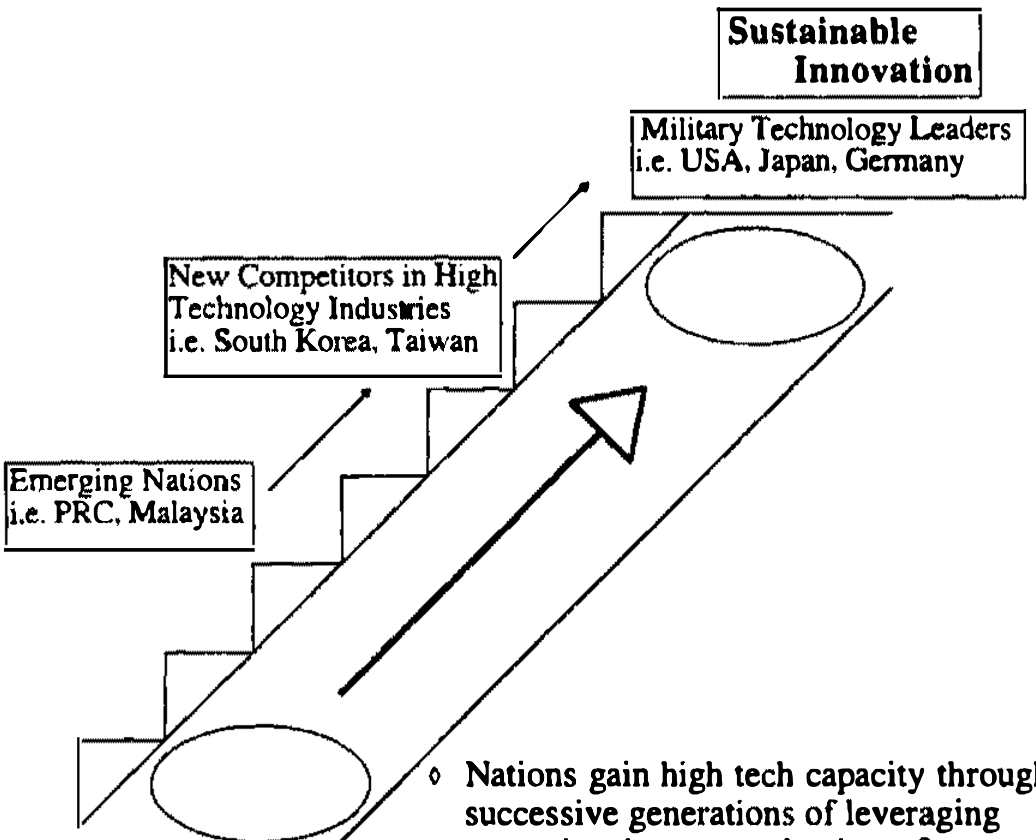
The Military Developmental Resource Leveraging Network (MDRLN), that we developed as hybrid of Mathews' work and our own, is a dynamic depiction of technological progress. Rather than portraying the acquisition of technological capability as a destination to be reached, the MDRLN accurately represents the process as a fluid and advancing structure. Today's cutting-edge technology is tomorrow's industry standard, and technological leaders often find their position of advantage extremely fleeting, much like military competitors. If technological champions fail to constantly innovate, their lead diminishes and may be lost entirely. Thus, we represent military technological capability as a downward moving escalator.

Figure 1 on page 17 is a depiction of the model of development of military technological capability in the Asia Pacific region. Potential competitors step onto the escalator through the incremental build-up of skills and technology. This initial progress can be achieved through conscious public policy consisting of labor-intensive and capital-intensive industrialization strategies that include technology transfer or through the involuntary workings of the civilian market economy and the support of external actors, such as multinational corporations. Once the nation has acquired this base, they pull themselves up the escalator by leveraging market forces through contractual linkages. This is the result of conscious policy choices and strategies. For example, once a base of minimal technological capability has been achieved, if market conditions are amenable, off-set agreements can create a basis of near cutting-edge high-technology production.

Because of the benefits of experience and the slope of the technological learning curve, each successive generation of high-technology brings the nation closer to the cutting-edge of production. Clusters of high-technology industries can form significant reciprocal and symbiotic relationships with benefits to the status of the entire high-technology economy. Once they have advanced to near cutting-edge production, nations utilize their favorable position to profit through contractual linkages that result in production in other technologically ripe nations through foreign direct investment, joint ventures and technology transfer agreements. This in turn leads to the export of technological, organizational, and production expertise to these nations, who then can advance upon the escalator.

Figure 1

Military Developmental Resource Leveraging Network Escalator



- Nations gain high tech capacity through successive generations of leveraging strategies, i.e. co-production of weapons systems
- Military Technology Leaders in effect pull the New Competitors toward sustainable innovation
- The New Competitors and the Technology Leaders begin to invest in Emerging Nations who utilize leveraging strategies to begin their assent toward sustainable innovation in military systems

Adapted from Chart 1-5, Journal of Industry, December 1996, pg. 21

Incremental improvement and sufficient resource allocation eventually leads to the symbiotic conditions necessary to enter the highest level of production, and the need to maintain this position creates incentives to cultivate cutting-edge innovation. If the nation continues to foster continued growth and development, sustainable innovation can occur. If this does not occur, the nation may fall behind the pace of advance and be passed by one of the nations that it was pulling up the escalator. This we term "leadership displacement". Our model emphasizes the interplay of developed and developing nations and the importance of both conscious pursuit of technological capabilities by governments and the workings of market forces. [3]

Two key factors led us to develop this model as the underpinning of our analysis of future militarily competitive states in the Asia Pacific region. The first is the close relationships between many of the business communities in the region due to ethnic and family ties. The second is the deep involvement of militaries in the Asia Pacific region in the civilian economic arena. These two factors create potential opportunities for diffusion of technological capability to militaries througbout the region.

Exploring the Model

As part of our process to locate measures that would serve to adequately operationalize of the important components of the MDRLN model, we conducted a regression analysis of large numbers of variables in order to locate high technology indicator variables that covaried with military measures. Because the MCTL FTAs data is incompatible with a statistical analysis, none of the variables available would be able to comprehensively operationalize growth in military capability development. Therefore, the covariance would not establish a causal relationship between the high tech indicators and military capability development.

However, because we assumed that these nations tend to import only weapons they themselves cannot produce, we believe changes in arms exports (taken in the context of the overall arms transfer environment) operationalizes this concept. We believed that the analysis would identify potential relationships that could help in the identification of a small set of likely competitors. These relationships could then be better explored in Phase II of the project with a more appropriate methodology, case study analysis of a small number of likely competitive nations.

We also used regression analysis to explore hypothesized relationships between economic data and military data. In order to increase the number of cases being observed and to provide a basis for comparison of the Asia Pacific region with the rest of the world, we included a small number of nations from Europe, North America, Oceania and South America in several of the data analysis. The nations included in the analysis, except where exclusions are noted, are the Asia Pacific region's ten nation subset, plus the US, Italy, Spain, the Netherlands, Switzerland, Hungary, Canada, Australia, Brazil, and Argentina--a total of twenty nations. This constituted the vast majority of the nations for whom both ACDA data and NSF HTI data were available. Our regression runs were all bivariate and included runs with variations in the countries included as well as lagged time periods. The R^2 statistic represents, on a scale from 0.0 to 1.0, the degree of correlation between the variables being tested. The more significant correlations approach 1.0. Significant results are listed in **Figure 2.** Implications from this data analysis are explained in the Conclusions section below.

Figure 2

Significant Regression Results

Dependent Variable	Independent Variable	Excluded Nations	R2	Probability	Durbin Watson Statistic*
ME90-95	GNP 90-95	Non-Asian and Japan	.879	.0002	1.55
ME90-95	GNP 90-95	None	.087	.205	1.35
AE90-95	GNP 90-95	Non-Asian	.997	.0001	2.70
AE90-95	GNP 90-95	Japan and U.S.	.884	.0001	2.33
AE90-95	GNP 90-95	None	.840	.0001	2.03
AE90-95	ME90-95	Non-Asian	.859	.0003	1.91
EDP 93-96	GNP 90-93	Non-Asian and Japan	.497	.0338	1.95
EDP 93-96	AE90-95	Non-Asian	.539	.024	1.83

ME-- Military Expenditures GNP-- Gross National Product AE-- Arms Exports
EDP-- Electronic Data Processing Equipment Purchases

* A Durbin Watson Statistic significantly above or below 2.0 can indicate autocorrelation in the sample. This means that the variables are not truly independent of one another. Those values clustered around 2.0 mean that the variables vary independently.

In order to further establish a smaller subset of nations in the Asia Pacific region that are most likely to become militarily competitive, we analyzed the NSF High Technology Indicators study and established that the indicators of Technological Infrastructure, Technological Emphasis, Rate of Technological Change, and the sub-indicators of Technological Mastery (the ability to make effective use of technological knowledge, from a survey question that is a component of Technological Infrastructure) and electronic data processing equipment purchases best operationalized the components of growth in high technology capacity that provides the potential for development of militarily competitive nations in the Asia Pacific region. We then constructed scatterplots that graphed bivariate relationships between conceptually related indicators.

The scatterplots revealed significant clustering of the Asia Pacific region countries in related indicator groups. Clear groupings of nations appeared. To a great degree, these groupings support the relative standings advanced in the economic development literature. In order to observe the movement of the target countries overtime with respect to the high-technology indicators, we also overlaid data from earlier portions of the NSF HTI study on the most recent comparable results.

Figure 3 shows the change in electronic data processing equipment purchases from 1987 to 1996 on the vertical axis and the overall change in the Technological Infrastructure indicator from 1990 to 1996 on the horizontal axis. This figure clearly shows movement in the predicted direction (up and to the right) for our subset of nations with Singapore, South Korea and the PRC showing the greatest improvement.

Figure 3

Change in Electronic Data Processing Equipment Purchases and Technical Infrastructure for Selected Nations 1990-1996

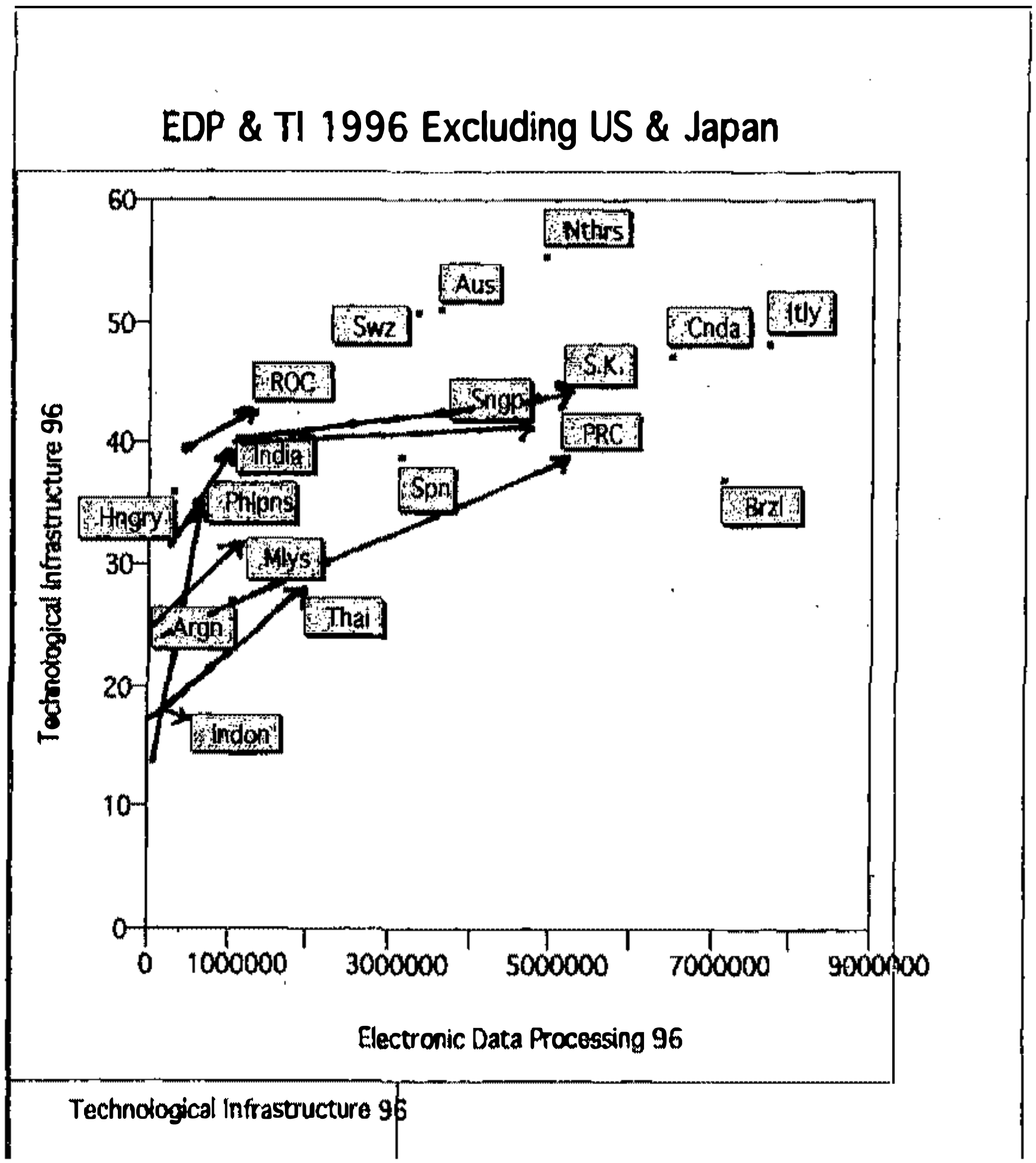


Figure 4 on page 24 shows the change in the Productive Capacity indicator from 1990 to 1996 on the vertical axis and the change in the National Orientation indicator from 1990 to 1996 on the horizontal axis. Again, our subset of nations in the Asia Pacific region show extremely similar patterns of movement. Singapore, Taiwan, India, the Philippines and China show growth in both categories with Singapore, South Korea and Taiwan surpassing several major Western European players such as Switzerland and Italy in their combined scores.

Figure 5 on page 25 shows the change in military expenditures (in constant 1995 dollars) from 1990-1995 on the vertical axis and the change in GNP in constant 1995 dollars on the vertical axis (excluding the US and Japan). Our subset of nations in the Asia Pacific Region shows positive growth in both areas while the countries included for comparison largely exhibit negative movement. Taiwan and the PRC are outliers. The PRC has vastly outperformed the other nations in GNP growth, but more importantly, it is also greatly outspending its neighbors in terms of military expenditures. This is all the more revealing in that the military expenditure figures for the PRC may be underestimated by fifty to one hundred percent. In addition, this rise in military expenditures has come amid reorganization and downsizing of the People's Liberation Army. Modernization in terms of equipment replacement and upgrading tocontemporary technological standards probably amounts for a significant portion of the measured increase, and because of the under reporting of actual Chinese military expenditures, this modernization program is probably much more extensive than the figures reveal.

Figure 4

Change in National Orientation Indicator and Productive Capacity Indicator for Selected Nations 1990-1996

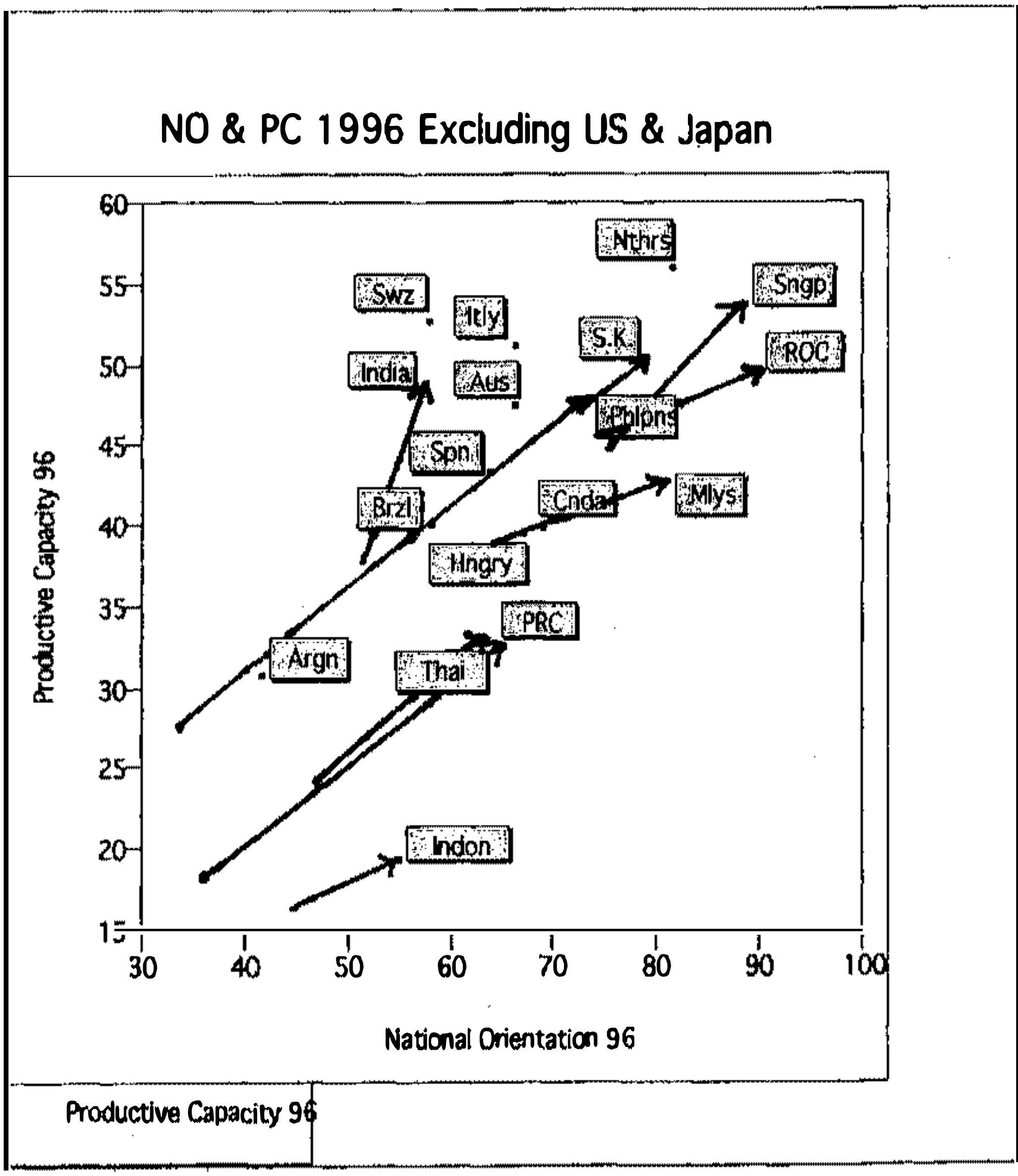
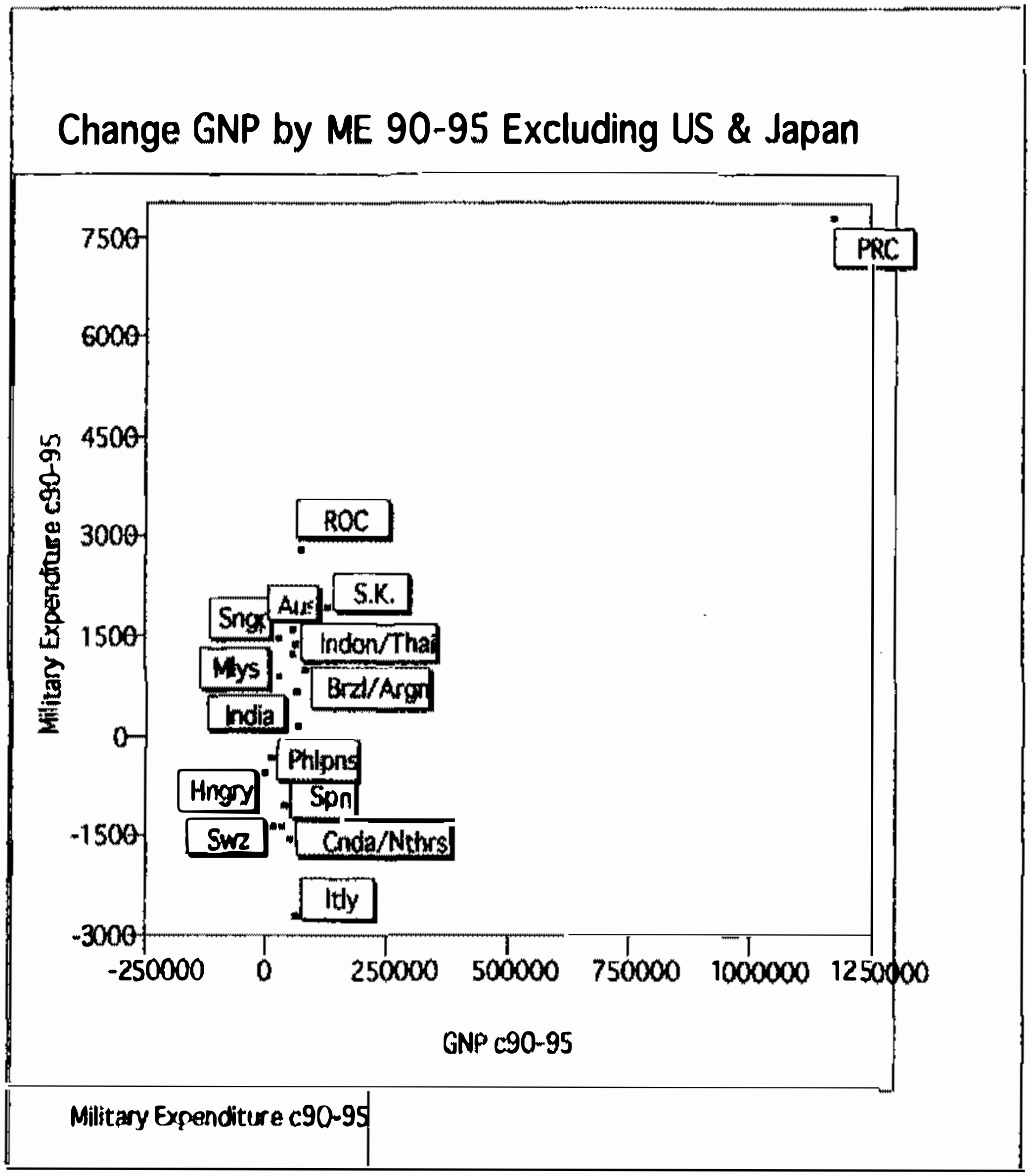


Figure 5

Change in Gross National Product and Military Expenditures for Selected Nations 1990-1995



In order to examine the advancement of each nation between 1990 and 1996, we developed a composite rank ordering based on the indicators and sub-indicators from the NSF study. The indicators and components that we chose best operationalized the potential competitiveness of these nations in the context of a military revolution. In constructing the composite rank ordering, we first rank ordered the nine target nations in the Asia Pacific region based on their position in the scatterplots (Figures 3,4, and 5). We excluded Japan, because this would skew the results. In addition we ranked ordered the Asia Pacific region sample on the change in Technological Standing and the Rate of Technological Change for the years 1990 through 1996. These results are portrayed in **Figure 6**, below. The nations are grouped and shaded as they tended to cluster on the scatterplots.

National Rankings by Multiple Criteria

EDP v. TI 1990-96	NO v. PC 1990-96	ΔGNP v. ΔME 1990-95	ΔTS 1990-96	+ or - Δ	ΔRTC 1990-96	+ or - Δ
CHINA	PHILIPPINES	CHINA	SINGAPORE	+	INDONESIA	+
KOREA	CHINA	TAIWAN	CHINA	+	SINGAPORE	+
SINGAPORE	THAILAND	KOREA	MALAYSIA	+	TAIWAN	+
THAILAND	SINGAPORE	SINGAPORE	PHILIPPINES	+	PHILIPPINES	+
PHILIPPINES	TAIWAN	INDONESIA	THAILAND	+	KOREA	+
MALAYSIA	INDIA	THAILAND	TAIWAN	0	MALAYSIA	0
INDIA	MALAYSIA	MALAYSIA	INDONESIA	0	THAILAND	-
TAIWAN	KOREA	INDIA	INDIA	0	INDIA	-
INDONESIA	INDONESIA	PHILIPPINES	KOREA	-	CHINA	-

Note: Shaded cells indicate clusters of countries that grouped together on the ranking criterion.

EDP = total purchases of electronic data processing equipment
TI = Technological Infrastructure
NO = National Orientation
PC = Productive Capacity
ME = military expenditures
TS = Technological Standing
RTC = Rate of Technological Change
GNP = gross national product

We then summed the rank order from the first three columns of Figure 6. The nation with the greatest positive change scored a 9, the second greatest scored an 8, and so on. This gave us some indication of cumulative ranking within the group. We also recorded whether each nation had a positive change in their Technical Standing and/or a positive change in their Rate of Technological Change. The results are reported in **Figure 7** below. China's cumulative performance far exceeds that of any nation in the sample. In addition, while China's technological standing continues to increase, its rate of technological change has begun to slow. This may indicate a maturation within the Chinese economy. It may also indicate a series of policy decisions prior to a new period of high intensity growth or renewed expansion of the economy and science and technology policy reform.

Cumulative Ranking and Change in Technological Standing and Rate of Technological Change 1990-1996

COUNTRY	TOTAL RANK	+Δ TS	+Δ RTC
CHINA	26	yes	
SINGAPORE	18	yes	yes
THAILAND	18	yes	
KOREA	15		yes
TAIWAN	15		yes
PHILIPPINES	15	yes	yes
MALAYSIA	12	yes	
INDIA	9		
INDONESIA	7		yes

EDP = total purchases of electronic data processing equipment
TI = Technological Infrastructure
NO = National Orientation
PC = Productive Capacity
ME = military expenditures
TS = Technological Standing
RTC = Rate of Technological Change
GNP = gross national product

Conclusions

Our Phase 1 analysis has led to the creation of three propositions.

First, there is a competition taking place in the Asia Pacific region. As Paul Bracken has noted:

> "It is not that Asian states are now maneuvering to attack one another, but that they are in a Post Cold War environment and they have to build capacities to deal with future possibilities whose precise shape is unknown. Openly declaring that they are building a strong military would trigger negative counter reactions. It would disrupt economic progress, and produce counter build-ups."[4]

The first row of statistics in **Figure 2** on page 20 shows that there is a significant correlation between the growth of Asia Pacific region economies and the growth of military expenditures. This finding is even more telling when overall global trends in military expenditures are examined. The second row of **Figure 2** shows that this relationship does not exist for the full twenty nation sample. Outside of Asia, all major regions of the world are experiencing a clear trend of reductions in military expenditure regardless of economic growth. Nations in the Asia Pacific region are clearly diverging from this global trend and militarizing at a rate constrained only by their economic success or failure.

Second, rows three through six of **Figure 2** show that arms exports from this region is strongly correlated with both GNP growth and military expenditures. The larger the nation's economy and the more it spends on defense, the more apt it is to export arms.

While arms exports do not completely serve as a surrogate for increasing military capacities, we believe that these results, in combination with the clear trend toward increasing high technology industrialization in our Asia Pacific region sample, provide support for the hypothesized relationship between high technology capacity development and the growth of militarily competitive nations in the region.

Third, during our analysis of the high technology indicators, we found that electronic data processing equipment purchases (EDP) is significantly correlated with both GNP and arms exports. This suggests that EDP may be an effective measure of these countries physical efforts at improving their competitiveness in military related areas. It appears that a country's potential for successful adaptation to and exploitation of the RMA will be significantly impacted by its ability to promote and utilize high technology industries, particularly those directly related to or dependent upon the advancing information technology and micro-electronics revolution.

While we did locate several interesting relationships between economic and technical indicators and military data through statistical analysis, we believe that it is impossible at this time with these data to confirm many of the interesting relationships only partially revealed. Essentially, these relationships are over determined because of all of the geopolitical and economic "noise" that occurred concurrently in the early 1990's.

In October we briefed Mr. Marshall and received permission to implement Phase II of the project. With Mr. Marshall's guidance, we selected China, Taiwan, Singapore and India for closer qualitative analysis. Using the case study approach, we will examine civilian and military institutional structures, processes, issues and capacities. The central question for Mr. Marshall is: "What kinds of military institutions did those nations have that emerged rapidly as military powers" such as Japan after the turn of the century? To operationalize this question we will examine the ways that the militaries in the target nations demonstrate absorptive capabilities, adaptive capabilities and innovative capabilities, or lack there of.

Among the nations of the Asia Pacific region, only Japan currently can be considered militarily competitive. However, the People's Republic of China appears to be fulfilling the conditions necessary to become militarily competitive within the next fifteen to twenty years. They have seen rapid and consistent increases in the indicators which best represent high technology development, and though the extremely conservative ACDA figures place them behind Japan in military expenditures, their true military expenditures are certainly underestimated by a large amount, and are almost certainly the largest in the region. In addition, they are expanding. These two facts, combined with the heavy involvement of the PLA in high technology commercial ventures throughout Asia and the continued expansion of the Chinese economy, represent the circumstances necessary for advance upon the high technology escalator. While this advance is far from certain, the Chinese government has consistently exhibited a long term commitment to expansion of their high technology capacity.

Taiwan and Singapore have also exhibited long term commitment to expansion of their high technology capacity by allocating sufficient resources to technological infrastructure and allowing firms to operate in a stable, non-intusive environment. However, because of their small size, these nations cannot begin to rival the PRC as likely militarily competitive nations. They are far more likely to become niche competitors. Their most important role in the Asia Pacific region may be as conduits for the transfer of technology and expertise to larger states in the region.

Many of the other nations of the Asia Pacific subset have shown extremely mixed results. While Indonesia and Malaysia have shown flashes of brilliance in the past, their overall performance has been tempered by inconsistency of purpose. Their governments have made great strides in setting up the conditions necessary for high technology development, but as the recent economic crisis has shown, many contradictions continue to exist in those nations.

Probably the most perplexing and disappointing performance has been that of India. India would seem to have most, if not all, of the resources necessary to advance rapidly upon the military high technology escalator. However, it has experienced periods of both rapid growth and rapid decline in some of the most important high technology indicators. Lack of government cohesiveness and consistent decision making has created an extremely unstable environment for high technology growth.

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[1] Roessner, J. David, et al. *Implementation and Further Analysis of Indicators of Technology-based Competitiveness- Final Report.* March 1995. NSF Grant SBE-9219337, supported by the Research on Science and Technology Program and the Science and Engineering Indicators Program. The study produced a variety of materials, including a large data base and three separate period reports, all of which were examined as part of our analysis.

[2] A significant assumption underlying this scoring is that because the nations that will be assessed is not fixed, inclusion in the set warrants a score of 1.

[3] Bracken, Paul *Nonstandard Models of the Diffusion of Military Technologies: An Alternative View-Technical Report.* Joint Management Services for the Director of the Office of the Secretary of Defense, Net Assessment. February 15, 1997.

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Inoue, R., Kohama, H. and Urata, S., editors. *Industrial Policy in East Asia*. Tokyo: JETRO, 1993.

[4] *Asian Military Institutions*, Joint Management Services for the Director of the Office of the Secretary of Defense, Net Assessment. April 1993.