Innovating for 21st Century Naval Operations[1]

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November 1997

In this paper I address some of the challenges which the Navy and Marine Corps will face in the 21st century, and how the naval services are shaping their operations to meet them. The principal points made are:

- Dramatic and unprecedented aging trends in the world's population will severely strain public finances, and tend to limit military expenditure as one consequence. This will come soonest and most severely in the industrialized economies -- the U.S. and the nations we count as our closest and most valuable allies -- although other nations also will feel these trends.
- At the same time, populations of people in their most productive years will rise very significantly for decades to come in most of Asia, while remaining level or declining in most of the industrialized world. If Asian nations make good use of their opportunities, they will become a great deal richer and the world's economic "center of gravity" will shift decisively toward Asia, notwithstanding the region's current financial difficulties. Will the U.S. continue to be able to exert a strong stabilizing influence on Asia in these circumstances, as it has over the past century? Will Asian nations develop their own institutions for peaceful cooperation and conflict resolution? Or will Asia become a cockpit of internecine conflict, on an even greater and more destructive scale than was Europe in the first half of this century?
- The world's supplies of petroleum will be largely exhausted before the new century's close, and probably will not last far beyond its halfway mark. The world will turn to other sources of liquid fuels, but the process could result in major economic and political dislocations, depending on the path taken. While petroleum lasts, the Persian Gulf region will become even more critical to the world's economy, and so more critical as a security interest. By some estimates, a supply crisis could come before 2010.
- The climate will change in the 21st century, at least in part due to mankind's activities. It is most likely that the dislocations resulting from this change will not be severe on a global scale, painful though they may be for those most directly affected. But there is some risk of sudden and catastrophic climate change, perhaps a miniature ice age involving significant reductions in temperature and moisture worldwide, coming on

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[1] Presented at a conference on The Role of Naval Forces in 21st Century Operations, sponsored jointly by the International Security Studies Program of the Fletcher School of Law and Diplomacy, Tufts University; the Institute for Foreign Policy Analysis; the Commandant of the Marine Corps; and the Chief of Naval Operations, in Cambridge, Massachusetts, on 20 November 1997.

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swiftly over a period of a decade or less and lasting somewhere between decades or centuries. Responding to such a climatic excursion would involve enormous and unprecedented security challenges for the U.S., in addition to internal economic and social challenges.

- Technological progress, at least over the first half of the 21st century, is likely to focus primarily on processes for manipulation of matter and energy at very small scales. These processes will continue to be applied to computing devices, although the results in terms of increases of computing power are not very predictable beyond about 15 to 20 years in the future. Increasingly, they will also yield new biological products (for industrial as well as medical applications) and materials with wholly new properties. But the direct military impacts of new technologies are likely to be relatively marginal -- revolutions in military affairs may well come in the new century, as a result of new concepts and new problems, but technology will be an aid, not the principal driver.
- The offshore shift in the economic balance, as well as sharply increasing dependence on imported oil, will dictate that the naval services remain rotationally deployed and expeditionary. But the real threats to U.S. interests will lie ashore, not at sea, making power to affect events ashore critical.
- The naval services have taken the initiative in preparing for this future with the Marine Corps Warfighting Lab and the Navy's series of Fleet Battle Experiments. Only the first few experiments have been conducted, but a great deal has been learned concerning potentials and constraints. The focus so far has been on unconventional means to counter conventional threats in littoral regions, but future experimental programs are planned to address wide variety of issues. Results to date show that sea-based forces can gain considerable leverage over stronger forces ashore, and have revealed a number of areas which must be worked on to improve this leverage.
- The fundamental methodology for exploring new concepts is simulation, involving physical, imaginary, and virtual elements. Operational elements are conceptualized and integrated, modeling is used to predict results and select key parameters, simulation is used to explore and measure, and the data form the basis for reconstruction of the action and assessment. The key is close integration of military planners, operations scientists, and technologists in all phases of the conceptualization and simulation process. All need to have broad knowledge of the entire process in addition to their special competencies.
- Promising as this beginning has been, it remains only a beginning. Many important challenges have not yet been addressed.

The World of the 21st Century

There are widespread expectations that the world of the 21st century will be one of breathtaking technological advance, of disruptive gulfs between rich and poor, of soaring economic advance alongside persistent economic stagnation, of passionate crusader beliefs and hatreds, of intense international competition, of excitement and chaos. In short, a world with plenty of material for conflict. But it is also widely prophesied to be a world in which the freedom of action of nation-states will diminish, in which their competition will be largely economic and social rather than military. Thus, this chain of reasoning goes, major wars will become very unlikely, while non-state violence could well grow to epidemic proportions.

Perhaps so -- but then again, perhaps not. Before going on to talk about innovation to meet the naval challenges of the first half of the 21st century, I want to investigate some other aspects of what they might be. Briefly, they include:

Aging Populations and Financial Stringency

There are some things that we know about the 21st century with a great deal more certainty than we know many of the "trends" frequently cited. One thing we can be quite sure of is that the population of the industrialized world will grow significantly older, and that the ratio of people in their prime working years to those in what are today considered retirement years will fall sharply.[3] Absent some very dramatic offsetting changes, this will mean declining proportions of the population in the workforce, increased expenditure for pensions and medical care -- and thus reduced potential for saving, investment, or public expenditure. These effects will be very visible within two decades, and will persist at least through the first half of the century. The demographic problem is actually a bit less severe in the U.S. than in may other places, but the economic difficulties this country will face depend critically on how successful we are in slowing the rate of medical cost growth.[4] One implication is that all the developed countries are going to feel harsh economic pressures, and will be able to increase defense expenditure only at the cost of significant disruption elsewhere in their economies and societies.[5] Indeed, without the emergence of some serious external threats, it seems very likely that in general the industrialized nations will cut their defense budgets over the first half of the 21st century.

It is not only the industrialized nations that will see a rising proportion of elderly to those in the prime working years. Figure 1 plots the number of people aged 65 per 100 people in the 25 to 64 age range for several regions and nations, over the period 1995 to 2050.[6] (I chose the 25 to 64 age band as a reasonable proxy for the group likely to be most productive in any sort of advanced economy -- although some of the economies represented in the chart are not very advanced now and thus tend to depend more on younger and more physically vigorous workers.) As this shows, China's proportion of people 65 and over will climb sharply over the second quarter of the new century, and will converge with that of the U.S. by about 2040. Even India and Southeast Asia will see rising proportions of older people, by mid century reaching levels which are today found only in industrial nations. Because these nations for the most part have no established and politically sanctioned "right" to public support for the aged,

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[3] U. S. Bureau of the Census, International Data Base, 10 October 1997 edition.

[4] U.S. Congressional Budget Office, "Long-Term Budgetary Pressures and Policy Options," March 1997.

[5] Deborah Roseveare, et al, "Ageing Populations, Pension Systems, and Government Budgets: Simulations for 20 OECD Countries," Economics Department Working Papers No. 168, Paris: OECD, 1996.

[6] Data for this and succeeding population charts are from U.S. Bureau of the Census, International Data Base, edition of 10 October 1997. In these figures, I have included Hong Kong and Taiwan with China, and Belarus with Russia. The category of Southeast Asia includes all the nations in the region, including Indonesia -- admittedly a very mixed group.

these trends may not have quite the same impacts on government finances as in the industrialized world, but it is hard to imagine that they will have no impacts, or that these will not act in some ways to constrain government fiscal freedom.[7]

Productivity

The proportion of elderly will rise in part because people are living longer, but also in large measure because in many areas the numbers of those in the 25 to 64 age band will grow only slowly, or actually decline. This is shown in Figure 2. The 25-64 age population is projected to grow modestly in the U.S. -- due largely to continued immigration as well as fairly high birth rates among the less wealthy portions of our population -- but will actually sink a bit in most other industrialized regions, reflecting birth rates which have remained steady or declined over the past quarter century. If this is indeed the part of an industrialized state's population which holds the greatest potential for productivity then it seems that these trends must put limits on the production and wealth of the nations which are today highly industrialized.

China experienced a vast increase in population during the Mao years, notwithstanding the disastrous famine which his policies brought on. But then the regime, fearing the consequences of continued unrestrained population growth, adopted a rather draconian "one-child" policy. As these "sole children" themselves reach reproductive age the growth in population is slowing sharply. Within twenty-five years the Chinese population in the 25 to 64 age band will have peaked, and it will decline rather sharply for several decades thereafter. Thus we can anticipate a sharp deceleration in the growth of China's national product after 2015 or so. With sound policies, however, China may by then have the foundations for strong productivity-led growth in per capita production.

In Southeast Asia and particularly in India (and the rest of South Asia as well) we can foresee a continued rapid rise in population in general, including the 25-64 group. These nations will face challenges in finding the resources to prepare and equip these increasing numbers of people for productive work, notwithstanding their high savings rates.[8]

Figure 3 gives a very rough indication of how productive 25 to 64 year-olds are, on average, in all these nations today. (I have simply divided total national production by the number of people in this age range.) The tremendous advantage of workers in the U.S. over

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[7] There is some dispute about future population trends. Some believe that the most likely scenario is that represented by the UN's low-variant projection, in which rapidly falling fertility results in a significant decline in world population before very long. See Ben J. Wattenberg, "The Population Explosion is Over," *The New York Times Magazine,* Nov 23, 1997, as well as his, "The Population Implosion," *The Wall Street Journal,* October 16, 1997. Others argue that such dramatic declines in fertility are unlikely, making the medium-variant projection (which is very close to that presented in the Census Bureau's International Data Base which I use here) more likely. See G. K. Hellig, *World Population Prospects,* International Institute for Applied Systems Analysis, July 1997. In any event, the effects of these differing assumptions on the data shown in my charts would be slight, as I focus largely on people either already alive or born relatively early in the century. The major impacts on the aged and the workforce will be seen after 2050 -- which is one major reason why I don't attempt to project beyond this date.

[8] See also, "Asia's Population Advantage," *The Economist,* Sep 13, 1997.

those in less developed economies reflects not only superior skills and more favorable social conditions, as well as some important technological advantages, but also more favorable market and natural circumstances. The rate at which these gaps can be closed or offset will determine how rapidly Russia, China, India, the countries of Southeast Asia, and other nations can expand output per worker.

There has been some debate about Asian economic performance. The conventional view has been that the high growth rates achieved by many Asian economies have been driven to a significant extent by productivity growth reflecting "Asian cultural values." This has come under some challenge, however.[9] Naturally, there are differences among Asian economies; a recent examination of China's growth suggests a significant productivity contribution.[10] There are many conceptual, methodological, and empirical obstacles to accurate measurement of productivity trends, which has clouded the debate. As this is written in October-November 1997, much of Asia is going through significant monetary and financial turmoil, which has prompted some to express more pessimism concerning long-term prospects. On the whole, it seems most likely that with prudent policies, Asian economic growth should be strong for decades to come, if not so buoyant as some had supposed.[11]

The U.S. and other highly industrialized nations face limits on growth which differ from those of the developing nations. We've already seen that growth won't come through increases in the productive population (except perhaps to a limited extent in the U.S.). Moreover, the rapid increase in the numbers of the elderly may tend to depress savings rates and divert resources, so limiting amounts available for capital investment. Thus technology-driven productivity growth will be a very prominent factor in determining overall economic growth.

It is very widely believed that we live in an age of great and unprecedented technological advance, in which wonders abound. It is certainly not difficult to find specific examples of truly remarkable technological growth trends, particularly in the fields of computing and communications. A great many people believe quite firmly that this technological advance is leading directly to significant advances in productivity, and there are many well-attested individual examples at the firm or activity level. But broader measurements of productivity are fraught with very complex conceptual, data, and methodological issues, which are probably not susceptible of complete resolution, even in principle. The findings of careful studies of the productivity effects of information technology are mixed, to say the least however.[12]

At the level of the nation as a whole, and of industrialized economies in general, it is clear that productivity grew at very high rates for a quarter of a century following the end of World War II. But the evidence all seems to point to a significant and persistent slowing of productivity in the early 1970s, a slowing from which we have yet to recover. More precisely,

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[9] Paul R. Krugman, "The Myth of Asia's Miracle," *Foreign Affairs,* v.73, n.6 (Nov-Dec 1994): 62-78.

[10] World Bank, *China 2020: Development Challenges in the New Century,* Washington, 1997: 105-108.

[11] "Is it Over?" *The Economist,* Mar 1, 1997. World Bank, Op. Cit.: 17-22.

[12] Erik Brynjolfsson and Shinkyu Yang, "Information Technology and Productivity: A Review of the Literature," *Advances in Computers,* 43 (1996), Academic P.: 179-214. Brynjolfsson has been a notable academic exponent of the productivity benefits of information technology, and is not likely to have overlooked or downplayed any intellectually sound evidence for it.

in the U.S., output per labor hour grew at an average of more than 2.5% per year from 1945 to 1973, and has grown less than 1% per year, on average, ever since. Many explanations have been offered, but most can easily be disproved (although of course this has not affected their popularity very much).[13] Some commentators have attacked the methodological and empirical foundations of the system for measuring productivity, claiming that it systematically underestimates growth of the kinds supposed to have occurred in recent years.[14] At present, however, it is difficult to see how a case can be made for strong economic growth having resulted from recent technological advances, even making the fullest possible allowances for possible under-measurements. It has been suggested that the effects of the information technology revolution simply have not yet worked their way through the economic system, and that we can expect strong growth from them in the future.[15] Perhaps growth in the U.S. and other industrial economies will once again accelerate in the first half of the 21st century -- but for now we can only speculate and hope.

Thus there are uncertainties about economic growth for both developing nations like China and Indonesia and for industrialized nations like the U.S. and Japan -- but of different kinds. For the developing nations the challenge is to bring productivity up to the levels already achieved elsewhere, and they may learn a good deal about how to do this by studying and adapting the experiences of others. In particular, it is clear that well-allocated investment and application of best existing practice in employing the physical and knowledge capital it buys can be expected to yield returns which can be estimated with reasonable certainty in these economies. Moreover, much is known about the kinds of economic institutions that tend to promote better allocations and applications. For the U.S., Japan, and other industrialized nations where productivity in most sectors is already high by world standards, the challenge is largely to invent and apply entirely new ways to produce still more value. If China, Korea, the more advanced of Southeast Asian nations, and some others, consistently pursue wise policies, they have the potential to reach the labor productivity levels of today's most advanced nations within the first half of the 21st century. If productivity in the industrial nations continues to grow very slowly, the nations of Asia, with relatively high labor productivity and very large labor forces, could exceed the U.S. and other present industrial nations in gross production and wealth well before 2050. Such a vast enrichment of Asia would no doubt be a very good thing in most ways, and would surely bring economic benefits to us as well, but it would unquestionably result in a significant realignment of strategic relationships.

Figures 4 and 5 illustrate two different labor-productivity trajectories. In Scenario 1, industrialized economy "I-1" experiences productivity growth of 0.8% per year -- about the rate which the U.S. economy has achieved over the past quarter century. Developing economy "D-1", starting at only 15% of I-1's productivity, manages to achieve 5% yearly productivity

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[13] Paul Kurgman, *The Age of Diminished Expectations,* Third Edn., MIT U.P., 1997 (esp. pp. 11-20). Jeffrey D. Sachs and Felipe Larrain B., *Macroeconomics in the Global Economy,* Prentice Hall, 1993 (esp. pp 554-560).

[14] Leonard Nakamura, "Is the U.S. Economy Really Growing Too Slowly? Maybe We're Measuring Growth Wrong," *Business Review,* Federal Reserve Bank of Philadelphia, March/April 1997.

[15] Paul A. David, "Computer and Dynamo: The Modern Productivity Paradox in a Not-Too-Distant Mirror," *Technology and Productivity: The Challenge for Economic Policy,* OECD, 1991.

growth, bringing it to 115% of I-1's level within half a century. Of course 5% is a very high rate of labor productivity growth.[16] The second scenario, shown in Figure 5, has the industrial economy experiencing 2% annual growth in output per labor-hour, while the developing economy achieves 3.5%. The 2% figure is less than the U.S. achieved over the first three-quarters of this century, but of course a good deal better than our current rate. The figure of 3.5% is representative of the results achieved over extended periods in many "catch-up" economies. Here the developing economy moves from producing 15% as much per labor-hour, relative to the industrial economy, to about 31% as much.

Growth in GNPs

Figure 6 combines the population data of Figure 2 with some speculative but not unreasonable rates of productivity growth to build hypothetical trajectories for the GNPs of some major nations and groups of nations. It assumes that productivity growth rates in the U.S. and other major industrialized nations will improve somewhat from present values, while China and other developing nations will experience steady growth at rates which are less than they have recently been achieving. That is to say, it shows somewhat greater growth for the U.S. and other industrial nations than the trends of the past quarter century might suggest, and rather less for China and other developing nations.

Figure 6 is not intended as a "prediction" of what will happen, but I want to take it as one example of what might very well happen, at least in general terms. That is, we might very well see a world in which:

- The major industrial nations which are our closest allies today will experience growth in individual income, but little in national product -- because the numbers of people in the most productive age ranges will grow little or even decline in these nations.
- The developing nations of East Asia, and perhaps in other regions as well, will grow quite strongly in both individual and national product, and will collectively far outpace the national products of the currently industrialized nations.
- All advanced economies will struggle to adapt to a proportion of old to working-age people that will be much greater than historic norms. This problem will appear sooner and be felt more sharply in Japan and the other advanced industrial economies. It may present somewhat less of a constraint on the public finances of China and other nations that are moving toward industrialized economies.

What of the rest of the world? It would not be surprising to see much or even all of Latin America develop significantly in economic terms, and some regions in Central Asia and elsewhere seem likely to benefit a good deal from oil production. South Asia is also showing signs of economic growth, although high rates of population growth act as a brake. There are some signs of economic progress in the very poor countries of Africa and elsewhere, after two exceptionally bleak decades, but it will be a very long time before the desperate poor will see

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[16] During the "golden age" of productivity gains, 1950 to 1973, a number of developing "catch-up" nations averaged more than 5% annual growth in labor productivity, but very few have been able to sustain 5% over longer periods. See Angus Maddison, *Monitoring the World Economy: 1820-1992,* Paris: OECD, 1995: Appendix J.

any significant amelioration of their miseries. And the numbers of the wretched will continue to climb for several decades at very least.

Oil Shocks?

While continued burning of oil may bring climate problems in the long run, cessation of oil burning would trigger catastrophe in the near term. By current estimates, we have consumed something like one-quarter to one-third of all the petroleum deposits in the world during the course of the 20th century. At current rates of consumption, all the oil so far discovered but not yet consumed, plus all that estimated yet to be discovered, would not last out the next century.[17] But in fact, consumption is rising in order to fuel economic growth. Long before the oil is all gone, a point will be reached at which production can not keep pace with rising consumption -- as early as 2010, by some estimates.[18]

This does not mean that liquid fuel stocks will be gone altogether: there are very substantial supplies of heavy oil, tar sands, shale oil, coal, and natural gas, all of which can be used as sources for liquid fuels -- at a price. Or liquid fuels could be derived from agricultural products. Moreover, it might be possible to employ pure hydrogen as a fuel, if better means of storing it can be developed. It may be that good fortune or good management will result in a smooth rise in the price of petroleum to levels which will encourage the production of fuels from these petroleum substitutes by the time they are needed, thus minimizing economic disruption and distortion. But it seems more likely that there will be some fairly sharp price movements along the way, and that those who find themselves in control of critical and scarce supplies will be tempted to use their monopoly power for economic or political gain.

The U.S., with large reserves of alternative sources and good technological resources, may well resume its long-time position as the world's greatest producer of liquid fuels, once petroleum stocks are significantly depleted, later in the 21st century. But in the meantime, we are bound to join the rest of the industrialized world in becoming progressively more dependent on imported oil, and protection of its supply is bound to be a significant security concern for us and many allies.

Climate Catastrophe?

There are a few more relatively predictable factors. One is climate change. Except among the self-interested and self-deluded, the uncertainties about whether the world's climate will change are over: the evidence is akin that linking smoking to cancer. Nor is there much more doubt that humankind's activities -- especially the burning of hydrocarbons for heating and power generation -- are among the principal driving factors.[19] To do anything about this will

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[17] U.S. Energy Information Administration, *International Energy Outlook 1997*.

[18] Craig Bond Hatfield, "The Oil We Won't Have," *Washington Post,* October 22, 1997: A21. --, "Oil Back on the Global Agenda," *Nature,* v. 387 (8 May 97) p. 121. The specifics of Hatfield's projections are disputed by oil industry representatives, but it is difficult to frame a plausible scenario under which production does not fall short at some time in the first half of the 21st century.

[19] J. D. Mahlman, "Uncertainties in Projections of Human-Caused Climate Warming," *Science,* v.278 (21 Nov 97): 1416-1417.

take virtually universal consensus on measures whose costs will be significant and immediate and whose benefits -- the extent of which is unclear -- will be experienced only by our descendants. But even if strong action were somehow to be taken very quickly, the consequences of anthropogenic climate change would continue to evolve throughout the 21st century and beyond. And even if conditions were somehow to be miraculously restored to those prevailing before humankind's advent, there would still be change in the climate, for research has shown that change is much more "normal" than the stability we have taken for granted. [20]

Not everyone will be affected equally. Indeed, it is thought that some areas will benefit, particularly in the earlier phases. But others will probably be harmed by reduced crop yields, droughts, floods, and other effects. Those who gain are likely to see it as a natural reward for their virtues, while those who lose will be tempted to believe they have been unjustly wronged. If the change is slow, as it is thought most likely to be, adjustment will be gradual enough to make serious tensions from this source seem unlikely.

But it could be worse, possibly a great deal worse. It is now known with considerable certainty from geological evidence that the earth has experienced sudden major perturbations in global or regional climate at various times in the past. These can happen as a result of nonlinear "avalanche" effects, in which a gradual and steady change in one or more parameters (such as average temperature) can trigger a dramatic change in others once a critical threshold has been passed. There are no doubt many such mechanisms we remain happily unaware of, but one in particular has received some recent attention, with disturbing results.

This concerns the North Atlantic Ocean's "heat conveyor," the flow of warm water from the tropics northward, which keeps Europe much more temperate than other regions at similar latitudes. This flow is driven by sinking of cold and salty -- and hence quite dense -- seawater to great depths near the polar icepack, thus drawing the warmer waters from the south to take its place. But this flow could stop if the water at the northern margins of the Atlantic were just a bit warmer or a bit less salty -- as it could become, for instance, if the northern glaciers and icecaps were to start melting, or if rainfall in northerly regions were to intensify. Such a shutdown could come quite suddenly, and it could quickly plunge Europe into Siberia-like conditions.

In fact, the geologic record shows clearly that Europe has gone through abrupt cooling cycles in the past, and there is evidence to link these changes to just such kinds of shifts in ocean circulation. The pattern seems often to have been one of a warming trend interrupted by a sudden sharp cooling. Moreover, in at least some cases, these mini ice ages (lasting a few centuries each, typically) have been global and not confined to Europe -- a fact more difficult to link clearly to the changes in ocean circulation, which do not seem capable of spreading to distant areas fast enough to account for the synchronism apparent in the paleoclimatic records.[21]

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[20] Jonathan Adams, "Sudden (Decade-Timescale) Transitions and Short-Lived Cold and Warm Phases in the Global Climate Record," Oak Ridge National Laboratory, http://www.esd.ornl.gov/ern/qen/transit.html. Mark Maslin, "Sultry Last Interglacial Gets a Sudden Chill," *Earth in Space,* v.9, n.7 (Mar 97): 12-14.

[21] Wallace S. Broecker, "Thermohaline Circulation, The Achilles Heel of Our Climate System: Will Man-Made CO_2 Upset the Current Balance?" *Science,* v.278 (28 Nov 97): 1582-1588. Delia Oppo,

Some calculations suggest that continuation of present trends in CO_2 emissions could trigger an abrupt shutdown of the Atlantic heat conveyor at some point in the 21st century.[22] There are many uncertainties in these models, which could prove quite unduly pessimistic -- or optimistic. Natheless, it is clear that we can not altogether rule out the possibility of a dramatic shift in climate over a large region or even the entire world, with the space of a decade or two at some point over the next century. Even if we knew the timing and extent of such a shift well in advance, there would be no predicting the social and economic consequences. But it seems very likely that it would wreak wide scale havoc.

Is this the business of the naval services? Clearly, if it becomes reasonably certain that humanity's activities are leading humankind to an environmental cataclysm, the sensible response is to avert or reverse the damaging actions, rather than make military preparations for the conflicts that the catastrophe might engender. If a clear chain of causation can be established between anthropogenic CO_2 and a prospective shutdown of the Atlantic thermohaline circulation, there is no doubt that an agreement on decisive action will be forged, for instance, regardless of the political and economic obstacles. But that works only for those catastrophes which can be seen clearly enough and soon enough to admit of alleviation. What about those which are not foreseen? This, it seems to me, is indeed part of what nations like ours maintain armed forces for: to deal with improbable but unavoidable severe contingencies. One reason why public support for military budgets often seems to be higher than that expressed by the policy elites who nominally concern themselves more deeply with such matters may be that the public does not maintain so strong an illusion of omniscience.

A Century of Wealth -- But Also Perhaps of Instability

To sum up, we can probably look forward to a 21st century in which wealth will be created at incredible, unprecedented rates, leading to vast improvements in conditions for large segments of our planet's growing population. We can also anticipate substantial shifts in the distribution of relative economic power among nations and regions, gains in some areas and losses in others from climate change, and the gradual exhaustion of petroleum supplies.

All of these things are reasonably certain: they are based in good scientific evidence rather than the speculative philosophizing that informs much prognostication. We can be much less sure about their impacts on human affairs, which will depend critically on the economic and political choices made by people and their institutions. There is no necessary reason for these things to cause severe political strains, if adjustments are made progressively. But our experience with how people and institutions have responded to comparable changes and

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"Millennial Climate Oscillations," *Science,* v.278 (14 Nov 97): 1244-1246. Gerard Bond, et al, "A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates," *Science,* v.278 (14 Nov 97): 1257-1266. Scott Lehman, "Sudden End of an Interglacial," *Nature,* v.390 (13 Nov 97): 117-119. Jess F. Adkins, et al, "Variability of the North Atlantic Thermohaline Circulation During the Last Interglacial Period," *Nature,* v.390 (13 Nov 97): 154-156.

[22] Stefan Rahmstorf, "Risk of Sea-Change in the Atlantic," *Nature,* v.388 (28 Aug 97): 825-826. Thomas F. Stocker and Andreas Schmittner, "Influence of CO_2 Emission Rates on the Stability of the Thermohaline Circulation," *Nature,* v.388 (28 Aug 97): 862-865.

stresses in the past suggests that there could well be risks to U.S. security objectives, and very possibly some armed conflicts.

Additionally, there are potentials for sudden dislocations, driven perhaps by climatic factors, which could occur too rapidly for any really orderly adjustment.

Technology

I have argued above that the evidence for significant recent productivity benefits from technology is not strong. Yet there is an all-but-universal sense among all of us that technological advance is transforming our work and lives at a remarkable rate, even if the benefits are not measurable in added quantity of output. The form of technological advance that is receiving most attention is the computing revolution, now entering its sixth decade of explosive exponential growth in computing power. By one significant measure, computing power has grown about 35% per year for the past 40 years.[23]

The technical and economic virtuous circle which has fed this growth can not continue at this pace for very much longer, at least not in its present form. The computing revolution will be greatly transformed, if not sharply slowed, within three decades, according to present knowledge.[24] That is, we are now more than halfway through at least this phase of the computing revolution. To a considerable extent, the communications revolution has been an appanage of the computing revolution, and slowing of computing progress will probably slow progress in communications as well.

To a great extent, current advances in other technological areas appear to be products of computer application and/or in the nature of incremental refinements rather than soaring leaps. The principal exception is genetic biotechnology, of which more below.

Because major technological advances are almost always very dependent on scientific information for impetus and guidance, and because it generally takes decades to move from basic research to significant technological application, we can have at least moderate confidence about at least some of the general directions of technological change over the first half of the next century. These include:

- Genetic biotechnology, which may well be in the early stages of a sustained advance which will rival that of computation in importance. Medical applications receive the greatest attention, but industrial and agricultural uses will also be of great importance.[25]
- Molecular computation, in which DNA is used as the computing element. Molecular computers may prove useful for some large, well-structured batch processing problems,

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[23] Alfred E. Brenner, "The Computing Revolution and the Physics Community," *Physics Today,* Oct 96: 24-30.

[24] Gary Stix, "Toward 'Point One'," *Scientific American: The Solid-State Century,* 1997: 74-79.

[25] Desmond S. T. Nicholl, *An Introduction to Genetic Engineering,* Cambridge U. P., 1994.

but seem unlikely to compete with conventional electronic computers for most applications. Crude proof-of-principle demonstrations have been achieved.[26]

- Quantum computation, in which quantum indeterminacy would be exploited for multi-state computation. If such systems could be fully realized, their potential is all but unimaginable -- they would literally allow real-time simulation of absolutely any physical system with perfect accuracy. Whether such performance can be achieved, or even whether *any* useful level of performance can be, is still not certain, although the odds favoring at least limited eventual applications seem to be growing.[27]
- Photovoltaic solar cells, which are growing in efficiency and declining in price as a result of continuing process engineering advances somewhat akin to those in microprocessors for computers. It is beginning to seem likely that solar arrays will become a practical source of bulk electrical power generation, at least in areas where generating costs are now relatively high.[28] In the long run, it may be that photovoltaics will bring down electricity costs at a time when liquid fuel costs are rising, and serve to cut the costs of substitute liquid fuels. The U.S., with its generally high insolation (particularly in the Southwest) could be a major beneficiary.
- So-called "high temperature" superconducting materials, which retain their superconducting properties at the temperature of liquid nitrogen, well above absolute zero. These materials are difficult to work with, but are now starting to show promise for some applications.[29] It is possible that they will eventually markedly improve the efficiency of many electrical and electronic systems.
- Micro electro-mechanical systems (MEMS), in which the photolithographic production technology of microelectronics is employed to create microscopic electro-mechanical devices for sensing or actuation. MEMS sensors are in commercial use and it seems likely that more applications will be found. Actuation systems involve difficult problems and progress has been slower.
- "Nanotechnology," but perhaps not of the sort often suggested. A widely publicized vision has everything from microscopic bearings to your kitchen table assembled an atom at a time by molecular-scale self-replicating machines. There are serious problems with this approach, which no one has any clear idea of how to resolve.[30] However, the basic notion of manipulating the structure of materials and devices at the molecular level is clearly extremely powerful. It is, of course, the fundamental basis for the

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[26] William P. C. Stemmer, "The Evolution of Molecular Computation," *Science,* v. 270, p. 1510 (1 Dec 95).

[27] Timothy P. Spiller, "Quantum Information Processing: Cryptography, Computation, and Teleportation," *Proc. IEEE,* v. 84, n. 12 (Dec 96) 1719-1746. Seth Lloyd, "Quantum-Mechanical Computers," *Scientific American: The Solid-State Century,* 1997: 98-104.

[28] Jack L. Stone, "Photvoltaics: Unlimited Electrical Energy From the Sun," *Physics Today,* Sep 93: 22-29.

[29] "Superconductivity in Electric Power: A Special Report, *IEEE Spectrum,* Jul 97: 18-49.

[30] Gary Stix, "Trends in Nanotechnology: Waiting for Breakthroughs," *Scientific American,* Apr 96: 94-99.

microcomputer, although this is a relatively coarse, crude structure compared to what nature achieves. Efforts to learn from, adapt, and apply techniques from nature could ultimately prove to be productive of materials with remarkable new properties and devices with novel capabilities.[31]

- The much-deferred promise of controlled thermonuclear fusion still glimmers just beyond the horizon. Whether its prospects will command continued development of this expensive technology remains to be seen.[32]

This list is certainly not comprehensive, but is representative. It is notable that most of the items on it concern manipulation of materials at very small scales. These are process technologies, and they tend to have large fixed capital costs but relatively low variable costs of production, thus favoring production in large batches or runs. In this they are like microelectronics, and they are likely to follow the same kind of economic cycle, in which each stage of technological improvement increases fixed research and capital costs, but results in new products which increase the market by more than enough to pay for another cycle of improvements. The question is how great the gain is at each stage, and how rapidly that will push the technological development. [33] In areas where this sort of virtuous cycle operates, defense users can only step back and make use of whatever the market produces, as the costs and benefits sooner or later come to dwarf the sums available for defense purposes. (It is notable, however, that the initial stages in the case of microelectronics were largely paid for by the Department of Defense, at a point at which few commercially viable products had emerged.)

Ships, Aircraft, and Armor

What we do not see here is anything with prospects of very direct effects on the kinds of large vehicle systems which dominate Navy (and defense) acquisition expenditure: ships, aircraft, and armored vehicles. It can be shown from basic physics considerations that to first order, the weight and power of a vehicle capable of carrying a specified payload (or warload) for a certain distance at a defined speed will depend on the following:[34]

- The efficiencies with which the propulsion, lift, and auxiliary systems convert stored energy from fuel into output.
- The power density -- output levels of the propulsion, lift, and auxiliary systems relative to their mass.
- The energy density of the fuel -- energy per unit mass.
- The strength/weight ratio of the vehicle's structure.

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[31] George M. Whitesides, "Self-Assembling Materials," *Scientific American,* Sep 95: 146-149.

[32] Colin Macilwain, "Is Magnetic Fusion Headed for Ignition or Meltdown?" *Nature,* v.388 (10 Jul 97): 115-118. William Sweet, "Nuclear Fusion Advances," *IEEE Spectrum,* Feb 94: 31-36.

[33] G. Dan Hutcheson and Jerry D. Hutcheson, "Technology and Economics in the Semiconductor Industry," *Scientific American: The Solid-State Century,* 1997: 66-73.

[34] George Gerard, "Structural Guidelines for Materials Development: Some Vehicle Performance and Design Generalizations," AIAA-68-331.

- The vehicle's drag or other retarding force relative to its weight.

It is a well-established empirical fact that the cost of vehicles depends very strongly on weight and power, so these are also very important determinants of cost.

Many ways are known for improving all of these factors for most kinds of vehicles, but most of them involve steep cost increases. While some of the technology prospects listed earlier are likely to yield products that will be of value in improving one or more factors, these improvements will be secondary and incremental. It is revealing that, by contrast with fields such as computers and communications, the technology prospects for vehicles are sufficiently limited as to have largely dampened commercial investment, notwithstanding the great economic importance of vehicles for transportation.

The result is that, viewed purely as vehicles (that is, leaving aside the crew, and the weapon and sensor systems they carry) the ships, aircraft, and armored vehicles of 2050, say, are likely to differ only incrementally from their counterparts of 2000 in size, cost, and efficiency. Improvements will be relatively slow, and the Navy (or at least the Department of Defense) will have to pay most of the cost of developing them and putting them into production.

At the level of the whole system, the picture is slightly less bleak. There is some reason to hope for significant reductions in crew sizes through automation and work-saving measures (although the engineering effort to accomplish this will be considerable and there will be some resulting increase in development and acquisition costs) which will allow vehicle sizes and operating expenses to shrink a bit. And some of the systems carried by vehicles will become lighter and more compact as a result of various miniaturization trends -- although there will be offsetting pressures to incorporate more systems or systems of greater capability or power.

In the absence of much technological "magic," incremental improvements in vehicle weight, cost, and capabilities have been attained to a considerable extent through vastly intensified engineering efforts, permitting far deeper exploration of alternatives, optimization of systems, and general refinement than has been possible in the past. The productivity of engineering design and technology work has benefited a great deal from the computing revolution, but the intensified development effort has nonetheless resulted in rising engineering costs. There is no obvious escape from this cycle, making it seem likely that engineering costs will continue to rise.

Unmanned Vehicles

There has long been considerable interest in remotely operated or autonomous unmanned vehicles, and some types of UAVs (unmanned aerial vehicles) have seen limited service over the past forty years or so. There are many proposals for advanced unmanned vehicles of various sorts, and high hopes for them. Unfortunately, there are also some significant obstacles, largely unrecognized or willfully ignored. With no crew to correct or compensate for defects or departures from expected behavior, unmanned vehicles have proven to be highly liable to loss. Most types of UAVs have averaged no more than 10 flights or so between loss or serious damage. This of course results in very high costs per mission, and makes them too costly for any but extraordinary needs, despite relatively low costs per vehicle. The only apparent solution is intensification of engineering and test efforts in developing unmanned vehicles. But there is an all-but-universal expectation that "unmanned" must equal "cheap," resulting in political demands for low development and acquisition costs. Unfortunately, it seems likely that this will continue to stymie effective wide-scale application of unmanned vehicles for some time to come.

Weapons

Weapons are increasingly becoming autonomous guided systems. In this, of course, they benefit from rapid advances in electronics. Not so long ago it was a given that more than half of the cost of any guided weapon would be accounted for by its electronic components, but this is fading even as seeker and control systems become more capable. Moreover, the reduced size of electronic components allows some gains in weapon performance or decreases in size.

There has been enthusiasm recently for advanced explosives and rocket propellants, yielding higher energies per unit of weight or volume. This is chemically possible and prototype systems have been demonstrated at small scale. But the costs of scaling up the processes to production volumes are sure to be immense, and production costs will be high unless significant commercial applications can be found. Moreover, the benefits in terms of weapon size and cost are much less than is often naïvely supposed.

Sensors and Transparent Battlefields

Sensors also have been great beneficiaries of the microelectronics revolution. In many kinds of sensor systems, however, gains from signal processing and integration are running into steeply diminishing returns, as the limits of what is physically possible are approached ever more closely. No major fundamentally new sensors for military purposes have been developed in more than forty years, and there is no reason in physics to expect any to emerge for many decades to come. The prospect is for continued incremental improvement, at reasonably rapid rates, as microelectronics technology continues to improve. Moving to commercial subsystems or components as the system building blocks will bring significant economic benefits, resulting from the lower prices associated with larger volumes, where feasible.

The attractions of the "transparent battlefield," in which sensor networks will tell our forces of everything which is going on over a large area, are clear enough. But in technical terms we are a very long way from being able to realize them. Indeed, it is not clear how far we can get toward this goal, given that every sensor we know about is inherently vulnerable to concealment, deception, jamming, or other countermeasures to hinder its operation. Unless very considerable care is taken in their design and operation, very sophisticated sensors and networks can easily prove to be even more vulnerable than their simpler predecessors.

Cyberwar?

With limited prospects for improvements in cost-effectiveness of traditional categories of naval and military systems, it is of course attractive to look for at least partial substitutes using technology more amenable to advancement. Information technology is a very natural place to begin. This is true not only because of the rapid progress of technology in this area but because many people believe very firmly that we live in an "information age," in which information (most generally in electronic form) has displaced all else in economic, political, and military significance. This gives rise to visions of "Cyberwar" or "infowar," in which attacks on an enemy's information systems will have devastating effects.[35]

As we've already seen, evidence for information technology's criticality to long-term economic well being is not overwhelming. But there's little doubt that disruption of telecommunications, or widespread crippling of computers, would have very unpleasant effects. (Whether it is easier or more effective to achieve this through electronic or physical means is another question, however.) Certainly, the activities of Internet "hackers" should serve to alert us to the need to provide protection for our communications and computing systems which is proportionate to their importance and vulnerability.[36]

But our reasonable disinclination to accept such damage is not necessarily a good guide to gauging its effectiveness as an offensive weapon. In the Gulf War, information systems were a prime strategic target and intensive efforts were devoted to identifying the nodes which were critical to isolating the Iraqi high command.[37] In technical terms, considerable success was achieved, but careful analysis suggests that the strategic results were negligible.[38] The fundamental problem was that communications and information were far less crucial than planners had supposed. Indeed, a remarkable recent study shows a systematic tendency over many decades to seriously overestimate the effects of infrastructure destruction on enemy ability and willingness to fight on.[39]

Technological Revolution?

As we have seen, there are a number of current technological developments that, if they bear fruit, could have major effects on the economy and society. It appears, however, that prospects for major changes in military technology are less clear, at least over the next few decades, because the technologies showing the greatest promise and most likely to make it to the initial step of a self-sustaining virtuous circle of development and production are not well focused on military needs. There may be reasons to expect these trends to continue.

There appears to be a strong overall trend toward less support for basic scientific research and an emphasis on research directed toward meeting identified needs of particular companies and industries. This is coming about through a combination of reduced federal funding for basic research and a redirection of industry-funded research efforts.[40] Moreover, the military

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[35] John Arquilla and David Ronfeldt, eds., *In Athena's Camp: Preparing for Conflict in the Information Age,* RAND, 1997, provides a particularly breathless perspective.

[36] Martin C. Libicki, "Information Warfare: A Brief Guide to Defense Preparedness," *Physics Today,* Sep 97: 40-45.

[37] Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey, Summary Report,* Washington: GPO, 1993.

[38] Robert A. Pape, *Bombing to Win: Air Power and Coercion in War,* Ithaca: Cornell U. P., 1996: 211-253.

[39] Ibid.

[40] Malcolm W. Browne, "Prized Lab Shifts to More Mundane Tasks, *New York Times,* Jun 20, 1995. Gina Kolata, "HIgh-Tech Labs Say Times Justify Narrowing Focus, *New York Times,* Sep 26, 1995. Louis Uchitelle, "Basic Research is Losing Out as Companies Stress Results, *New York Times,* Oct 8, 1996. William

services in general and the Navy in particular are being restrained from shifting more of their R&D funding from basic research to more focused efforts due to concerns about still further eroding basic research. Thus the Navy can look forward to a relatively restricted flow of innovations suited to its needs, except where these happen to coincide with those of industry.

Does this endanger our security? It is unlikely to expose us to risks of technologically superior threats, but it may raise the price of buying needed forces. While there are widely-expressed concerns about U. S. R&D spending relative to that of other economies, our funding for military-related R&D remains at least an order of magnitude ahead of that of any conceivable enemy. There are also those who worry about asymmetric advantages gained by an opponent who targets technology specifically against particular critical weaknesses of our systems or forces. While this clearly remains a possibility to be very watchful of, it is difficult to make a case for systematic vulnerability. Specific scenarios which are offered usually appear to assume that the opponent enjoys far higher R&D productivity than we do (contrary to all historical trends), and that we do not respond with any effort to avoid or counter the threat. If we allow this to happen to any significant extent, we will indeed deserve a drubbing.

Perhaps of greater concern is the possibility that lack of R&D will cause our military forces to fall behind the civil economy in rate of productivity growth, making defense seem increasingly burdensome in economic terms.

Military Revolution?

There has been a great deal of discussion of revolution(s) in military affairs (RMA) in recent years. The term has been variously defined, or more often, discussed without definition.

The *fons et origo* of RMA thought has been the Director of Net Assessment, Dr. Andrew W. Marshall, in the Office of the Secretary of Defense.[41] According to him, "Technology makes possible the revolution, but the revolution itself takes place only when new concepts of operation develop and, in many cases, new military organizations are created." The way we talk about the RMA, he goes on to say, could convey that, "It is already here, already completed. I do not feel that this is the case. Probably we are just at the beginning, in which case the full nature of the changes in the character of warfare has not yet fully emerged. The referent of the phrase 'the military revolution,' is therefore unclear and indeed should remain to some extent undefined for now. It would be better to speak about the **emerging** military revolution, or the **potential** military revolution. What we should be talking about is a hypothesis about major change taking place in the period ahead, the next couple of decades."[42]

Clearly, this emphasis on operational innovation is crucial if major improvements are to be achieved in an era of moderate change in military technology.

B. Scott, "U. S. Coming to Grips with R&D Crisis," *Aviation Week and Space Technology,* Feb 17, 1997. Bart Ziegler, "Gerstner Slashed R&D By $1 Billion: For IBM, It May Be a Good Thing," *Wall Street J.,* Oct 6, 1997.

[41] Thomas E. Ricks, "How Wars Are Fought Will Change Radically, Pentagon Planner Says," *Wall Street J.,* Jul 13, 1994.

[42] Director of Net Assessment, memorandum for the record, subject: "Some Thoughts on Military Revolutions - Second Version," Aug 23, 1993. Emphasis in original.

Innovating for the 21st Century

Prompted in good part, I think, by Dr. Marshall's observations, the Navy and Marine Corps have launched daring and far-sighted efforts to develop, test, refine, and institute a wide range of advanced operational concepts to meet the diverse and unpredictable challenges which lie ahead. The processes are fluid and rapidly evolving, so it is by no means possible to give a definitive account of them, let alone of their outputs, but I will endeavor to provide a sketch.[43]

The two services have separate but closely interlinked processes for concept development. For the Marines, the Marine Corps Combat Development Command (MCCDC) at Quantico, Virginia plays the central role, together with the co-located Marine Corps Warfighting Laboratory (MCWL, formerly the Commandant's Warfighting Laboratory, or CWL). The Navy's process has been somewhat looser, although a more formalized structure is now under consideration. In any case, both services draw conceptual inputs from a broad range of sources.[44]

Generally, in my experience, these concepts evolve through extended interchanges, in response to a variety of influences. They embody a range of views, primarily those of military officers, and derive from ideas concerning technology and socio-political trends as well as the study of military history and experience in recent operations. Any analysis at the conceptual stage is likely to be of a fairly general and philosophical nature, perhaps supplemented by narrow technical calculations regarding some particulars. By the time a concept is committed to paper (or briefing slides) there is usually a core of enthusiasts who believe in it implicitly and are impatient to implement it at once, and a wider circle of those who are interested but not convinced -- as well as people who are skeptical or even flatly opposed. The problem then is one of amassing sufficient evidence to engender a working consensus in favor of implementing, rejecting, or modifying the concept. When the concept has major implications for service capabilities and resources, this is inevitably a complex process.

It is natural in such circumstances to want to "try out" the concept, but this is rarely as straightforward as it sounds. Enthusiasts, already convinced, may favor a colorful "demonstration" intended (and possibly rigged) to advertise what they are sure is so. Hardened skeptics will scoff at the notion of spending precious resources on any dabbling with concepts they already "know" to be vacuous. Others must weigh sufficiency of evidence against cost. This is the point at which analysts generally are brought in.

It is rarely possible to "try out" a military concept in literal terms. Concepts that involve warlike force or very large-scale action are impractical of employment outside of war, and

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[43] Because of the fluidity of the processes, they tend not to be very formally documented. Many of the references in this section will be to Internet World Wide Web sites rather than to specific documents.

[44] See http://138.156.112.14/CDCHome.nsf/?OpenDatabase for MCCDC and http://mcwl-www.cwlmain.org/ for MCWL. Navy sites of interest include http://ndcweb.navy.mil/, http://copernicus.hq.navy.mil/, and http://www.usnwc.edu/nwc/cnws.htm. Several Marine Corps concept papers have been published as inserts to *Marine Corps Gazette,* including "Operational Maneuver from the Sea," (June 1996), "Future Military Operations on Urbanized Terrain," (October 1997), and "Ship-to-Objective Maneuver," (November 1997).

even if experimented with in the context of a conflict almost never yield clear-cut and unambiguous results. Thus test of concepts almost always involves simulation and sampling, to one degree and in one way or another.

In a certain sense, this is like verification of scientific hypotheses, but there are important differences. First, the concepts are generally not presented in readily testable or implementable form. And since those who must be drawn into the consensus are rarely scientifically trained and generally come from diverse professional and cultural backgrounds, the standards of evidence and argument are not clear-cut and may diverge widely from scientific norms. Considerations of expense, time, and impact on other military needs and operations generally prohibit anything like a comprehensive experimentation scheme.[45] Because many of those who must be convinced lack deep knowledge of the relevant technical issues, verisimilitude may take on an exaggerated importance in experiments, even to the point of naïveté, on occasion. In any event, some sort of "live" simulation in the field is generally necessary, regardless of the quality and extent of prior analysis and simulation. Planning, gathering meaningful data, and establishing soundly based conclusions from such field tests involves great difficulties and complexities.

It is in these activities that my organization, the Center for Naval Analyses (CNA) makes its most distinctive contributions to Navy and Marine Corps advanced concepts.[46] CNA, a non-profit institute which has been associated closely with the Navy since 1942 and the Marine Corps since shortly after World War II, is the only research organization with a large pool of scientists who have extensive experience in supporting, observing, and analyzing military operations in the field, in war as well as in peace.[47]

Recently, the Navy has conducted two Fleet Battle Experiments (FBEs), while the Marines have begun a series of Advanced Warfighting Experiments (AWEs). The two are similar in broad principle, and indeed FBE Alfa was conducted in conjunction with the Hunter Warrior AWE in March of 1997.[48] These have by no means settled all of the matters at issue, but they

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[45] "Army, Navy Juggle Experimentation With Need For Force Readiness," *Inside the Pentagon,* v.13, n.48 (Nov 27, 97): 1-2.

[46] While this paper focuses on Navy and Marine Corps aspects, CNA also plays a like role in many joint test and demonstration programs.

[47] As one example, more than two dozen CNA analysts deployed to support naval forces in the Gulf War, and CNA analysts have been on-scene for every major naval crisis or conflict operation since then. For CNA's earlier history see Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis,* Annapolis: U.S. Naval Institute P., 1984.

[48] In addition to the material on the Web sites cited above, see James A. Lasswell, "Assessing Hunter Warrior," *Armed Forces Journal International,* May, 1997; "Equipping the Man," *Marines,* July 1997; "Hunter Warrior Proves Concept But Feeds Both Critics and Champions," *Inside the Navy,* v.10, n.32 (Aug 11, 1997); "Marines Look Anew at Role of Attrition in Maneuver Warfare," *Inside the Pentagon,* v.13, n.32 (Aug 7, 1997); Jon R. Anderson, "Praise and Contempt," *Navy Times,* Aug 18, 1997; Marine Corps Warfighting Laboratory, *Exploiting Hunter Warrior,* August, 1997. Additionally, the Web site of the command which conducts the FBEs, the Third Fleet, contains material relevant to them -- see http://www.comthirdflt.navy.mil/

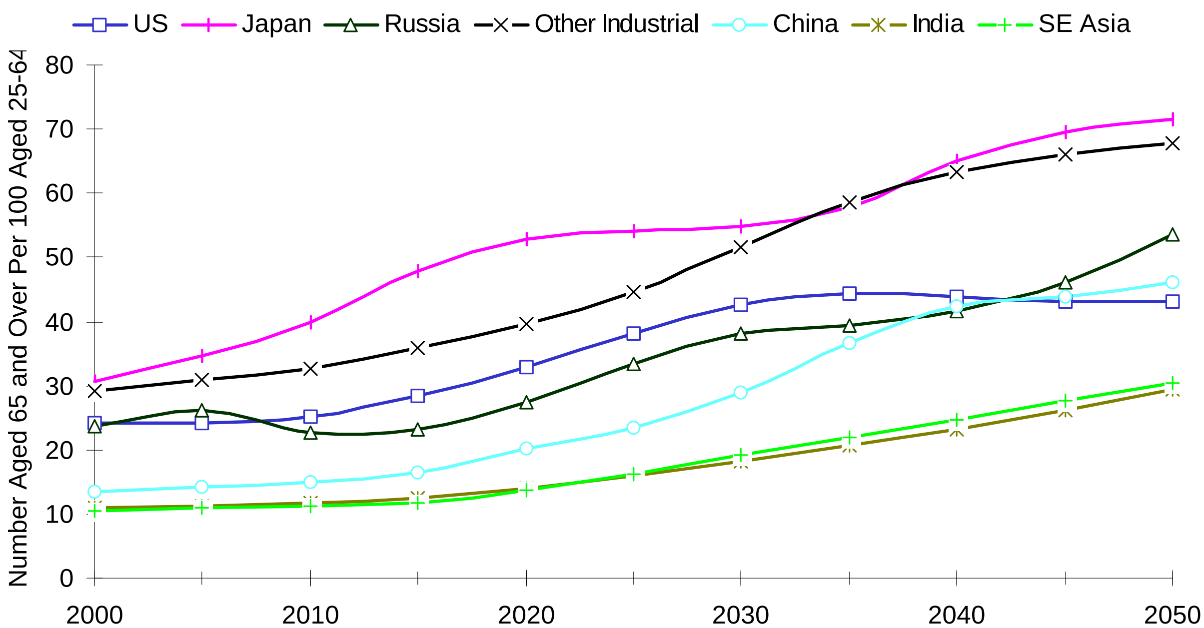
have provided very highly valuable data and insights, and have certainly stimulated a great deal of productive and innovative thought.

To date, the focus in both AWE and FBE efforts has been on operations from the sea against enemies or objectives ashore -- what has come to be called "operational maneuver from the sea" (OMFTS). This is a natural and appropriate emphasis in an era when threats at sea are minimal and the principal U.S. interests lie ashore in littoral regions. It is by no means the sum of the concerns which the naval services must meet, however, and many further issues remain to be addressed.

Particularly important, in my view, is the economic challenge faced by the Marine Corps and Navy as our society looks forward to an era of sharply rising demands on public finances, brought on by the aging of our population. The services will undoubtedly be called upon to make better and more efficient use of both manpower and capital in order to meet expanding needs in times of stringency. The apparatus of innovation that they have been developing will soon need to be turned to this problem if they are to be ready for the 21st century.

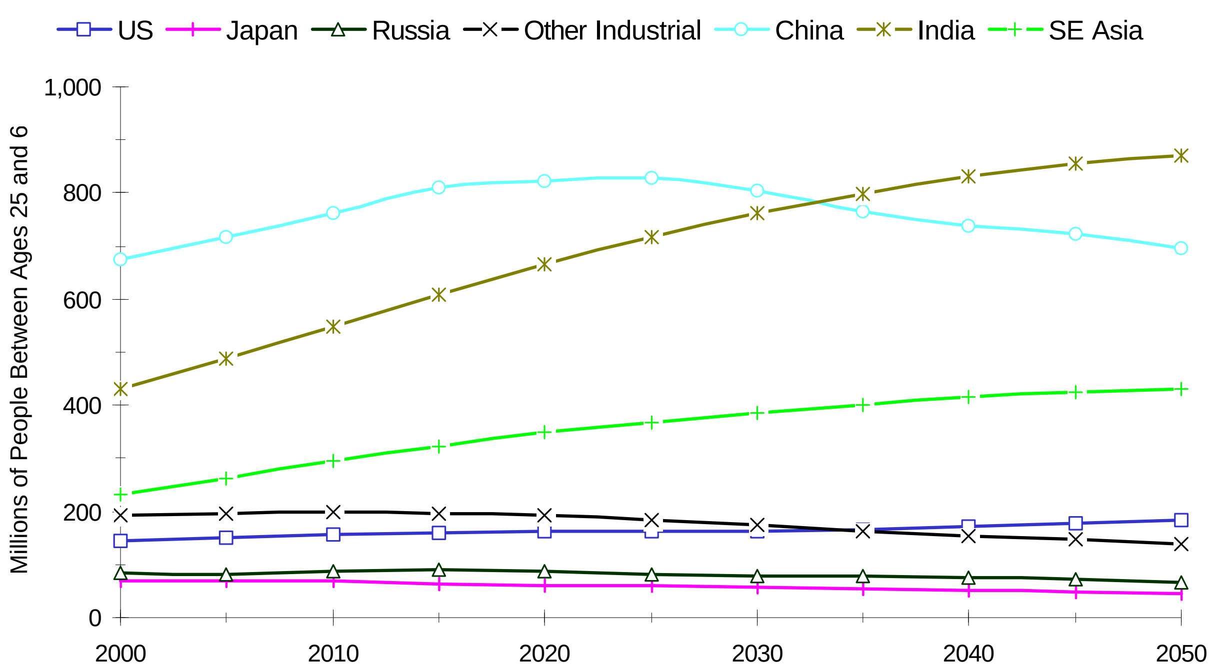
Figure 1: Old-Age to Worker Ratio

Number of People in Age Range 65 and Over Per 100 People in Age Range 25-64



Data Source: U.S. Bureau of the Census, International Data Base, 10 October 1997

Figure 2: Population in 25-64 Age Range



Data Source: U.S. Bureau of the Census, International Data Base, 10 October 1997

Figure 3: An Indicator of Labor Productivity

1995 GNP Per Person in 25-64 Age Range

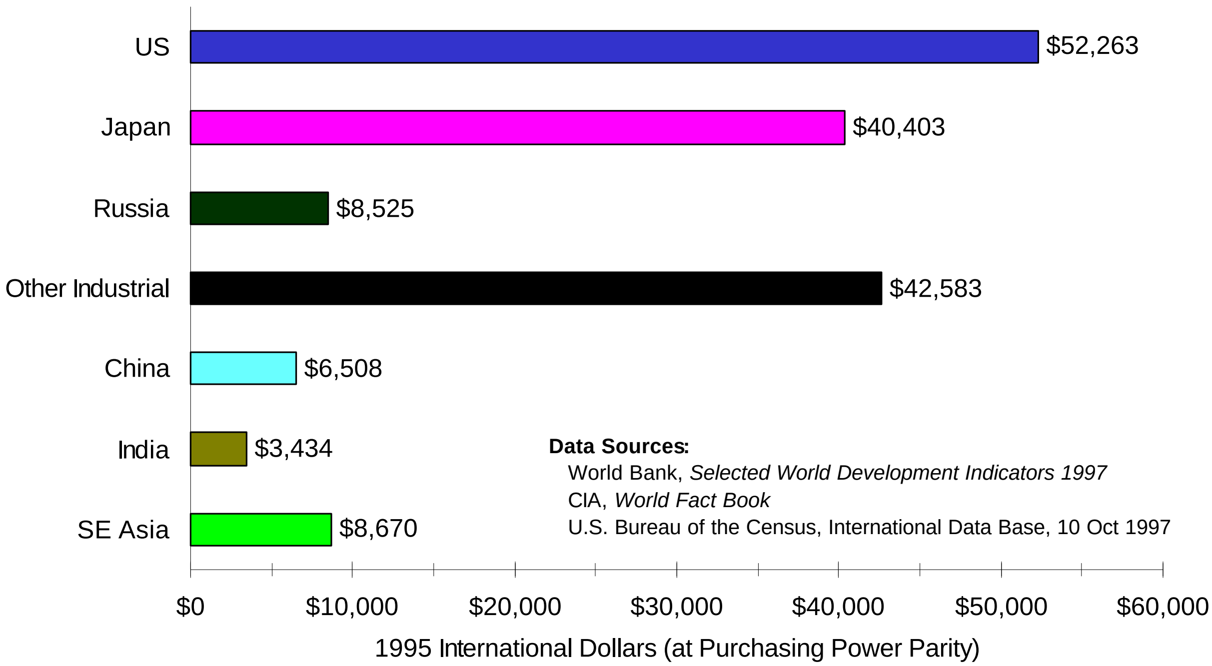


Figure 4: Productivity Scenario 1

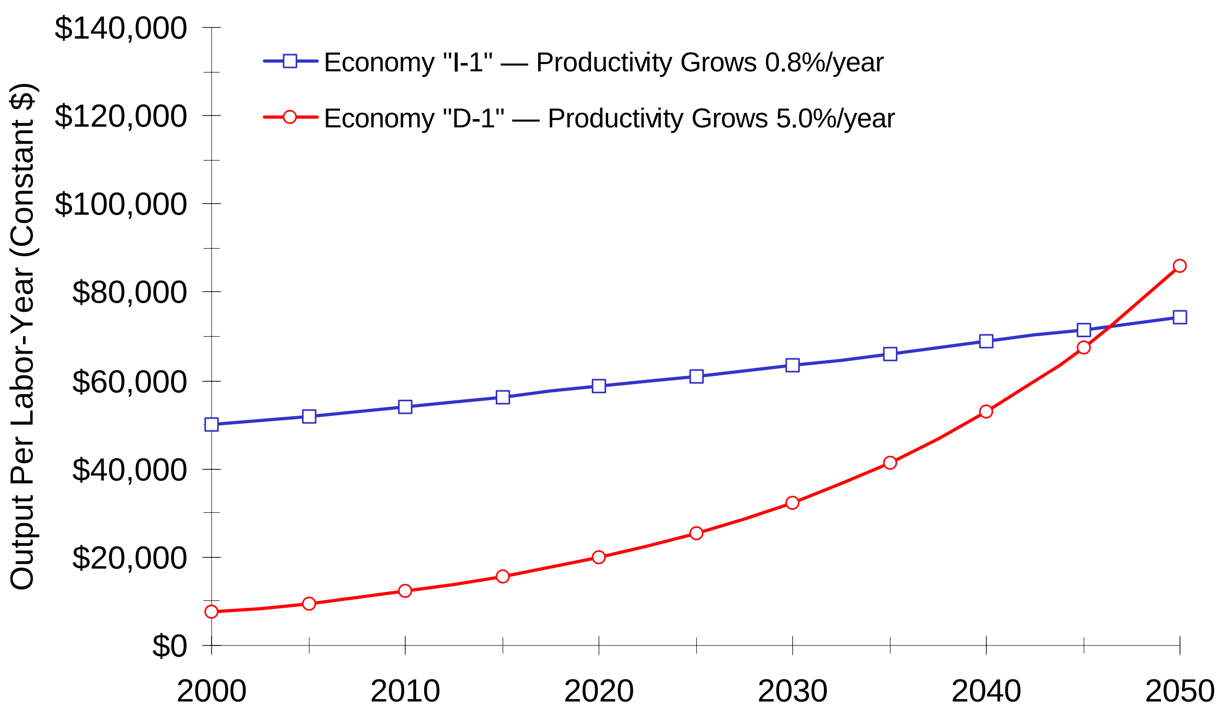


Figure 5: Productivity Scenario 2

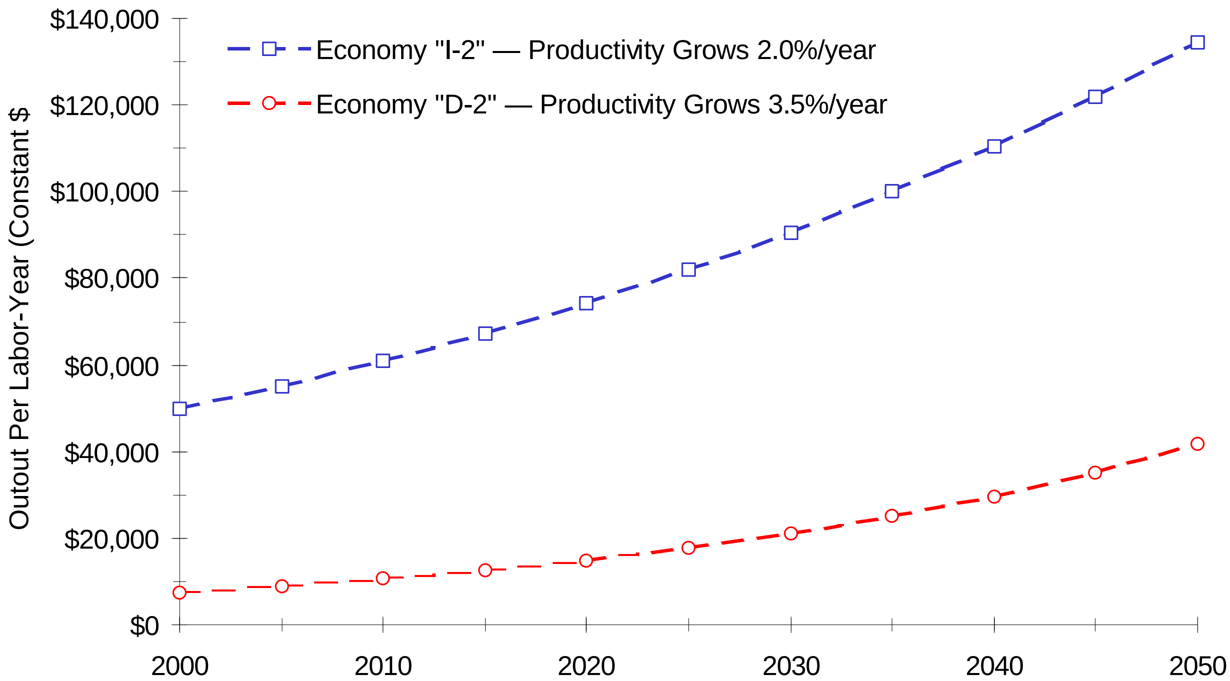
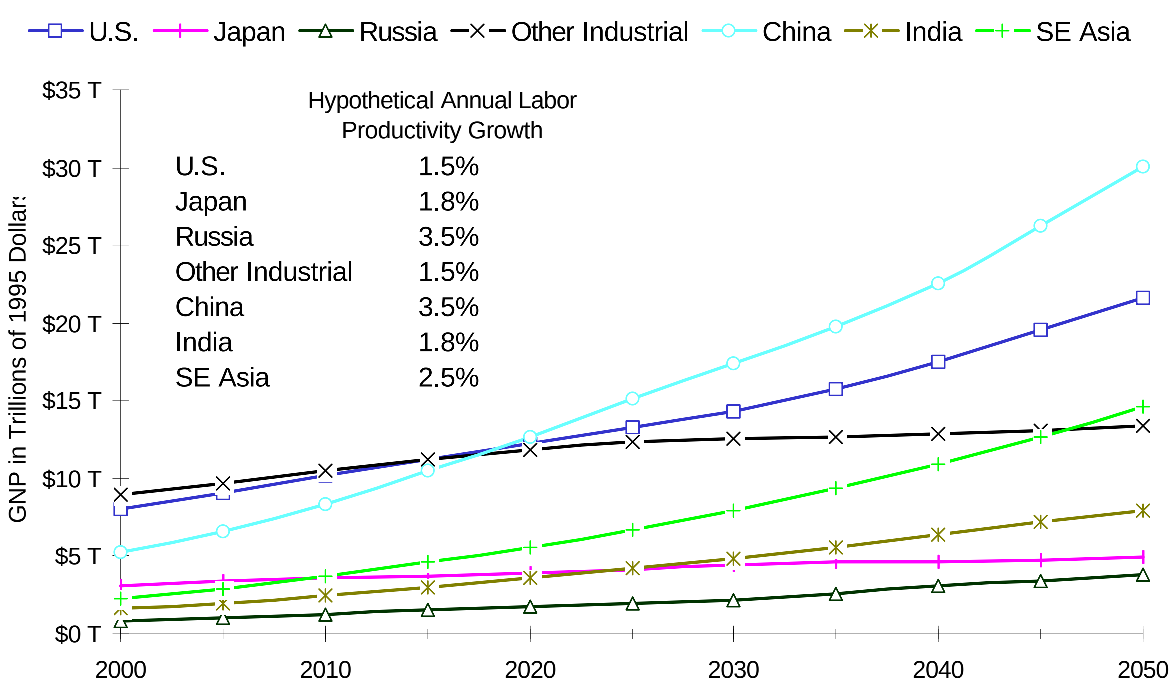


Figure 6: Hypothetical GNP Growth



Sources: Worker population from Figure 2, combined with hypothetical annual growth for labor productivity as stated in legend, starting from base shown in Figure 3.