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SCIENCE AND TECHNOLOGY IN THE 1985 ERA

This report is supplemental to a master report, "THE UNITED STATES AND THE WORLD IN THE 1985 ERA," which is a series of projections prepared for the United States Marine Corps by scholars from the Physical and Social Science Faculties of Syracuse University with the assistance of outside consultants and under the auspices of the Syracuse University Research Corporation.

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PREFACE

The Syracuse University Research Corporation has completed a study whose objective was to forecast the state of the United States, and the world, in 1985. As specified at the start: "This study will examine projected national objectives and policies, and international and domestic military, political, economic, and technological factors affecting the United States in the 1985 era. This will provide the basis for a concept of future military combat operations and a forecast of the roles and missions of operational forces."

The study was carried out by two teams: one made up of social scientists, the other of natural scientists and engineers. The latter group (to be referred to as the S-T group) carried out its study by soliciting working papers from selected groups of specialists. In all, 21 such reports were received, reviewed and discussed by the S-T group. They form annexes of the present report.

An overall report on the study has been issued under the title "The United States and the World in the 1985 Era." The present document is a more detailed report on the technological aspects of the study, summaries of which were included in the general report.

Forecasts of basic and theoretical science, other than the material in the annexes, have not been included in this report for two

reasons. First, as pointed out in Chapter 1, the forecasting of basic and theoretical science two decades hence is much less reliable than the forecasting of technology. And second, it was found difficult to make meaningful summaries of the reports in the annex without so much explanatory material that the summaries in effect duplicated those reports.

No attempt has been made here to be exhaustive. Rather, emphasis in this report is placed on those aspects of science and technology which are likely to have the greatest social impact by 1985 and which are expected to have the greatest significance for the Marine Corps.

The report reflects the consensus reached by the S-T group after reading, discussing, and sometimes disagreeing with the working papers. Our statements are phrased as "predictions" or "forecasts" but they should be viewed as statements of likelihood or probability, not all of which are equally likely.

At the outset, a number of assumptions were specified by the Marine Corps. They are:

- (A) A requirement will exist for a military force to support national objectives.
- (B) Nations will continue to take unilateral action to attain specific national objectives despite multilateral commitments.

- (C) Arms control and disarmament agreements will not prevent the initiation of offensive action by any power.
- (D) General war will not occur before 1985.
- (E) Scientific and technological progress will continue at the same or accelerated rate.

For the science and technology part of the study only (D) is pertinent, and this has been accepted as a hypothesis.

It might appear that (E) is a highly significant assumption. Nevertheless, quantitative significance is difficult to attach to the "rate of scientific and technological progress." Actually, this assumption did not play a role in the study of the S-T group. Rather than being an initial assumption or hypothesis, a statement about the rate of scientific and technological progress might more reasonably be a conclusion arising from such a study as the present one. In fact, the conclusion was reached in the overall study that the limitation of trained manpower will curtail the rate of growth of science. (See "The United States and the World in the 1985 Era.") We would recommend that further projective studies of the Marine Corps remove (E) as an initial assumption.

In evaluating the forecasts presented in this report, it should be borne in mind that no classified information was available in the study. The predictions are, therefore, concerned mainly with the

impact on the civilian sector, although some extrapolations are made to military applications. It is possible that there may be developments having a significant impact on society as "fallout" from currently classified activity, which could not, perforce, be included here. Furthermore, we could not predict specific advances which might occur as a consequence of major support from military sources.

The following individuals constituted the Science and Technology Group. All but one are at Syracuse University.

Norman Balabanian, Professor of Electrical Engineering,
Secretary of S-T Group.

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The names of the consultants and specialists appear on the individual reports in the annex.

Chapter 1

INTRODUCTION

At the outset of the study reported here the study group agreed that there existed a wide disparity in the ability to forecast progress, over a period of two decades, in science on the one hand, and technology on the other. Although some advances in science may be predictable (such was the case for the discovery of insulin; its existence was predicted but had to wait upon the development of adequate methods for measuring blood sugar), most often scientific progress is based on the exploitation of unforeseen discoveries. Progress also comes from the insights and brilliant thoughts generated by exceptional men, the Einsteins and the vonNeumanns. A brilliant scientific idea, like that of Watson and Crick concerning the structure of the DNA molecule, can start a chain of research which in a short time may unravel major mysteries of nature.

Neither such discoveries nor the emergence of men with vision are generally predictable. It is possible, nevertheless, to make some limited predictions concerning the effect of work in those fields where there is presently great activity and major effort. The range of such predictions, however, is usually on a time scale of five years or less. In some cases there is an obvious need for a

"breakthrough" in the form of a new technique, or a new theory, or a missing piece of experimental knowledge in some important area where progress has been stymied. The timing and effect of such anticipated breakthroughs have not in the past been predictable. In view of these observations, the report contains very little in the way of detailed or even general forecasts of the status of science in 1985.

In the case of technology the view beyond the horizon is not so murky. To gain an appreciation of the reasons for this difference, it will be necessary to consider briefly the nature of technology. The usual view that technology is the application of scientific principles to the satisfaction of social needs is oversimplified. The reality in the past has not been that society first identifies a need, then turns to an engineer who seeks the appropriate scientific principles to apply for the satisfaction of this need. Very seldom in the past has technological progress been based on a knowing and conscious application of scientific principles. Sometimes, as in the invention of the steam engine by Newcomen and Watt, the pertinent scientific principles were quite unknown. At other times, as in the invention of the airplane by the Wrights, even though the scientific principles were known to some, they were not known to the innovators.

But the realities of the past are not a true mirror of the future. The physical world accessible to the ordinary senses of man is limited.

No special knowledge, but only ingenuity and imagination, was needed for the invention and design of many common devices. But most obvious physical effects have now been exploited. As time goes by, simple, intuitive ideas cannot be relied upon to design and successfully implement useful devices.

Technological problems of 1985 will comprise a whole spectrum vis-a-vis the utilization of scientific principles. At one extreme, problems which are thought of as technological are really administrative, managerial or organizational. This is typified by the cargo "containerization" problem. The problem is to design standard packages or containers which can be loaded on trucks, railroad cars, airplanes, and ships interchangeably, and easily handled by automatic machinery at the terminals. Although there is some engineering involved, the major problem lies in negotiations at national and international levels on standardization and customs procedures.

At the other extreme there is the problem of controlled fusion energy. This is greatly dependent on scientific knowledge. The scientific principles involved are extremely complex and are not even well defined yet. Technological progress in this case must wait upon the discovery of appropriate scientific principles.

Most engineering problems lie between these two extremes. In this region the distinction between science and engineering becomes blurred. An individual engaged in the solution of an engineering problem may find that certain scientific information he needs is not available. He is likely to postpone the solution of the engineering problem to find the required scientific information first. This type of engineer is a far cry from his counterpart of even 25 years ago.

But even beyond the degree of application of scientific principles lie a number of other factors upon which major advances in technology depend. Whether or not a particular technology will be developed or a particular product will be made available to society, even assuming the scientific feasibility, is a function of (1) social acceptance or resistance, (2) the availability of the amount of capital required, (3) the vested interest in competing products, and (4) the degree of conservative thinking of industrial management.

The generation of far-sighted and brilliant ideas may not, as in science, lead to major advances because the fruition of these ideas depends on social, political, economic and organizational forces. A few examples will illustrate these remarks:

a) It is proposed to build a long tube like wind tunnel, running the length of the Megalopolis from Boston to Washington,

within which stubby-winged planes would carry passengers. The transportation would be convenient (not dependent on weather), safe (the plane would always be within a few feet of the ground) and economically competitive. Technically this idea has great merit, but the economic and organizational problems are enormous and public acceptance is not assured.

b) Then there is the idea of building a dam across the Straits of Gibraltar. It is known that there is more water pouring into the Mediterranean from rivers than the water that evaporates from its surface. If there were a dam, the level of the Mediterranean would be raised. It is said that in a relatively short time (decades) the water would become fresh. With the water flowing over the dam, electricity could be generated to pump water into the Sahara for irrigational and industrial use. This also is a brilliant technical idea, but the political, social, economic and organizational problems are overwhelming.

c) On a smaller scale, social acceptance of nuclear power plants in high population density urban areas is retarding the installation of such technologically feasible plants. Likewise nuclear-powered cargo submarines are technologically sound and economically viable. But it is difficult to overcome public reluctance to accept nuclear vessels (including nuclear surface ships) in the harbors of our cities.

These considerations lead to the conclusion that technological progress which has a major social impact may not be preconditioned on new scientific discoveries but on scientific knowledge now available. In this respect, it is instructive to consider some aspects of modern society and their dependence on science and technology.

Mass production and automation

Use of steel and other "new" metals, and concrete

Use of electricity

Use of oil and natural gas

Use of synthetic materials

Broadcasting (radio and television)

Motion pictures

Telephone

Photography

Electronics for communication, control and navigation

High speed printing and color printing

The automobile

The railroad

The airplane

The modern ocean liner

Vastly improved methods of agricultural production by breeding and selection, fertilization, mechanization, etc.

Prolongation of life, immunization, antibiotics, vitamins.

Refrigeration and deepfreezing

Airconditioning

Home labor-saving devices

Food processing, canned foods, food mixes and other prepared foods, frozen foods, dehydrated foods.

Waste treatment and clean water supply.

In almost all cases, the exploitation of scientific knowledge to the extent that a perceptible impact is registered on society has lagged

the initial discovery of the pertinent scientific principles by more than a quarter century. The shortest lags have occurred in those cases in which the technological advance was not fighting to displace a competing system, as in the case of electronics for communication, and radio and TV broadcasting.

On the basis of the preceding discussion it can safely be assumed that the major technological advances that will occur by 1985, and whose impact will be important by then, will for the most part be based on scientific knowledge presently available. This is not to say that there will be no unpredictable advance.

Chapter 2

SELECTED TECHNOLOGIES IN 1985

Perhaps of greatest interest and potential value to the Marine Corps is the predicted state of development of certain selected technologies by the year 1985. In this section of the report our predictions relating to these selected technologies are given.

2-1 Transportation

Current modes of transportation will remain dominant in 1985-- private automobiles, trucks and busses, aircraft, railroads, and surface vessels. The major deterrent to rapid changes in transportation systems is the slow rate of write-off of capital equipment in comparison with its technical obsolescence. Economic, sociological, legal, and administrative regulatory factors are of primary importance in determining what developments will or will not occur in the transportation industries, and not the development of new technology, which continues to remain ahead of large scale implementation.

There is no foreseeable force that will replace or curtail in the next 20 years the 90 per cent of inter-city passenger traffic carried by private automobiles. Futuristic ideas of highway engineering or automatic piloting of individual automobiles, while technically feasible, will not be in wide use by 1985 because of the huge investment

required. Improvements will have been made in traffic control. Better-designed roadway interchange and computer-controlled signals and traffic flow will be the primary mode of improvement. Basic automobile design will be about the same as it is today, because of its general adequacy and the large investment in existing manufacturing facilities.

Gas turbine cars will not find wide use except perhaps in heavy-duty vehicles, because of their marginal advantage and high cost. The necessity of cooling and slowing down the exhaust gas will destroy the basic simplicity of the turbine. At a cost comparable to that of present day cars, electric automobiles, powered by batteries or fuel cells, will be used for intra-urban traffic--partly because of their quiet and trouble-free performance and lower maintenance costs, but mostly because of their minimal effect upon air pollution. Truck traffic will continue to expand, particularly through "containerization," the realignment of the corporate structures of common carriers, and modifications of rate structures. "Containerization" will make possible quick and economical cargo transfer between trucks, airplanes, railroads, and ships or barges.

Passenger traffic will continue to decline on the railroads, except for short-run 50-300 mile trips in congested areas. The use of existing rights of way, but with new equipment and technology, will

enable rail transportation to reach an average speed of more than 100 miles per hour, achieved by lighter-weight metals, lower centers of gravity, roadbed realignments and automatic controls. Greater public investment in railroads will long since have occurred and as a result rail transportation will be substantially improved. Under these conditions, there will be little incentive for futuristic types of rail service such as monorails, Levi-cars, flight tubes or the Westinghouse motor-in-roads. Nuclear locomotives will not be feasible because of shielding requirements, high cost and the disastrous nature of accidents. The use of pipelines for gas, oil and water will increase, as well as the transportation of coal by pipeline.

Airlines will be the dominant common carrier for long-distance passenger traffic. Supersonic aircraft with speeds up to Mach 3 will be in general use by 1985 for trans-continental and inter-continental flight. VTOL and STOL aircraft will be in use for short and intermediate routes linking more cities. Private airplanes, including air automobiles, while increasing in number, will not be an important means of personal travel because, even with mass production, the costs of craft suitable for large scale public use will be prohibitive. More cargo will be shipped by air, and jet cargo planes will tend to generate their own traffic rather than take it away from other carriers. Nuclear airplanes will not have come into practical use.

Space and orbital vehicles will not be used for transportation of cargo or persons on earth in 1985.

Surface vessels will predominate in transoceanic cargo service. More nuclear powered cargo ships including submarines will be available; they will be attractive for very long routes, such as trans-Pacific trips. Because of the absence of wave drag, submerged vessels can attain much higher speeds, without excessive power requirements, than surface vessels can.

The transportation of people over water will continue to be principally by surface vessels of conventional design but with greater speed, comfort and safety. This mode of oceanic travel will be preferred mostly for recreational reasons. Transoceanic hydrofoil vessels do not appear to be feasible. While it will be feasible to use nuclear powered ships for passenger service, it will not be psychologically accepted.

The military use of submarines as weapons systems and as troop and cargo carriers will increase. The hydrofoil vessel may be valuable as a substitute for PT-boats and high speed landing craft in certain military operations.

2-2 Communications

In looking back over the last two decades, it is observed that very few advances having major significance for communications had their initial development during this period.

Radar and microwave techniques were introduced near the beginning of this period and their development was tremendously accelerated by the exigencies of World War II. Besides these, only the development of semiconductor amplifiers within this period of time had a major impact on communications technology.

On this basis it can be assumed that the state of communications technology can reasonably be predicted from a knowledge of devices and techniques now in experimental or developmental stages. Potential "breakthrough" areas now suspected are (1) microminiaturization techniques which can lead to widespread use of designs or procedures currently limited by size and weight; and (2) the laser. The potential for using laser-generated beams as carriers in broadband communications systems exists, but this is dependent on developing means for modulation, which are not yet available. It is not likely, however, that either of these innovations, even if it occurred, would have a significance comparable with the introduction of radio or television.

No striking changes in mass radio and TV broadcasting is forecast. There will be a great increase in color television attendant on a largely reduced cost. Use of satellites in broadcasting will long since have become commonplace by 1985, and high quality international programs will be possible.

Long distance telephone rates will be reduced drastically by 1985 leading to greatly expanded use. The use of electronic switching will make telephone service more versatile: private dialing of a few (up to 30) most often called numbers, automatic transfer of calls to another designated number, and add-on conference calls. Direct dialing throughout most of the world will probably be available. Video telephone circuits will be used by business and by individual users who can afford the cost.

The expanded use of computers for many activities--business, financial, travel planning, etc.--will create a demand for communications systems to interconnect widely separated data-processing facilities. By 1985 there will be an enormous increase of communications from machine to machine without an intervening human being. (See next section.)

The preceding discussion has specifically excluded consideration of military communications. In the first place, most information on military communications is of a classified nature. Furthermore, the extent of development of any specific technique will depend on decisions of the military which it would be impossible to predict here.

Nevertheless, it is clear that the military communications problem is fundamentally different from non-military (non-combat) communications. In the latter, clear channels may be allocated to each user by mutual agreement. Under such favorable conditions, extremely high information rates per channel are possible and system performance is limited only by

the cost and complexity that will be tolerated in the terminal equipment. In combat communications, on the other hand, communications capacity will be limited by the environment. Under such circumstances, communication techniques must be developed which permit almost individualized coding. One such system is random access multiplexing (or spread-spectrum communication).

2-3 Computers and Automation

Although the subjects of this section could be treated under two separate headings, they are considered together here because the joining of automated machines with computing equipment multiplies the social impact produced.

Major factors that influence the application of computers to problems of industry, finance, science, etc., are speed and cost. In most applications cost is the dominant factor; in these cases speed is desired only because speedier computations can reduce the cost. In some applications, however, speed is the dominant factor almost irrespective of cost.

The principal limitation on speed is the computer memory access time. The introduction of the magnetic core memory a decade ago brought a major reduction in speed and cost. Although major development effort is being expended currently (and has been for some years) on alternative memory systems, such as superconductors and thin magnetic film, it does

not appear likely that these systems will be successful in replacing the core memory. Thus, although improvements in core memory systems will be made, a significant (order of magnitude) reduction in memory access time is not likely.

On the other hand, speed of computing circuits is likely to increase significantly. This will permit the implementation of serial rather than parallel logic with an attendant improvement in size, reliability and cost.

Thus, it is predicted that cost and size of computers will be reduced. The reductions will be a result of increasing use of miniaturized components and high speed computing elements (as distance from memory) and automated design procedures. It is estimated that 90 per cent of the tasks in carrying out a design can be performed by automatic machinery without the intervention of humans. This degree of automation in design can lead to an order of magnitude reduction in cost.

In the utilization of computers, it is predicted that major changes will occur in the use of peripheral equipment, of which analog-to-digital and digital-to-analog input-output converters is an example. Use of such equipment will permit rapid completion of tests and experiments in physical science, social science and engineering. A related use is in simulation, both of large scale physical systems and even of human behavior. The latter is possible because complex models of human behavior are now

available from social scientists. (Such simulation is even now being used, though with tongue-in-cheek, for voting predictions.) A major increase in the use of computers for simulation is predicted in research in natural science, engineering and social science.

It is predicted that the use of computers which can interchange information with other remotely located computers over communication links will increase tremendously. The implications for industrial operations are staggering. An example of a possibility here is the process of letting bids on a job. If this is all done between computers, the time involved can be reduced from months to hours.

In assessing the degree to which automatic machinery and processes, with or without computer control of operations, will displace humans from productive activity, it is necessary to distinguish between traditional industries, such as steel or mining, with already established procedures and a labor force, and newly emerging industries, such as plastics or semiconductors. In the former case, technological improvement and automation of processes lead inevitably to the displacement of human workers. In the latter, the automation, without which large scale production at low cost may not be possible, is itself a factor in the emergence of the industry, and thus in the creation of jobs.

It is predicted that the automation of industries and offices which is already under way will continue, with dramatic effects on American life by 1985. Large numbers of factory and office jobs will be eliminated. Although new categories of jobs will be created in the manufacture, installation and maintenance of the automated equipment, the total of these jobs will be considerably smaller in number than the jobs eliminated. As mentioned above, however, newly developing industries will help in the creation of additional jobs.

Another category in which many jobs will be eliminated is that of intermediate level supervisory and management personnel. Managers of complex, decentralized organizations, aided by rapid communication between geographically separated computers, will be able to obtain detailed and accurate information regarding the state of any aspect of the organizations they control. As a result, the managers in a headquarters office will be able to exert a more direct influence on the operation of the system and will be able to assess rapidly the effects of their decision. This will eliminate the need for large numbers of "middle managers."

2-4 Electric Power

Installed electric power capacity in the United States will have increased more than threefold to 700 million kw by 1985. The great bulk of this capacity will continue to be derived from steam driven turbo-generators using coal and oil as fuel, with the use of coal gradually increasing.

Nuclear fission plants will increase only gradually and by 1985 will probably account for less than 10 per cent of the power generated. To achieve even this rate will require a 100-fold increase in nuclear generating capacity which, in turn, will require a tremendous capital investment. Furthermore, the economic advantage of fission power is only marginal. (It is instructive to note that the Consolidated Edison Co. has just withdrawn its application to build a one million kw nuclear power plant to have been completed by 1970 in favor of buying Canadian hydro-electric power at a rate about 20 per cent cheaper.)

It is improbable that fusion power will be a factor by 1985. In the first place, a number of unsolved scientific and technical problems in thermonuclear fusion exist to which serious attention is not now being devoted. But even if all these hurdles were overcome, the required capital investment and development costs alone would preclude significant development by 1985. Another inhibiting factor is the lack of urgency to achieve nuclear fusion power. Two factors which are not now foreseen might reverse the above prediction: (1) if urgency to develop fusion power were introduced, with an attendant heavy government investment, and (2) if spectacular advances in theoretical and nuclear physics led to understanding of nuclear processes other than the thermonuclear process.

It is projected that power transmission lines will increase tremendously in number, in length and in voltage, linking larger central stations in a North American power grid to obtain higher load factors and greater reliability.

Other proposed sources of power are not expected to be significant by 1985. Direct conversion of solar energy may find some low-level use in energy-poor areas of the world, but it is too inefficient for large scale use. Magnetohydrodynamic generation will be barely beyond the prototype stage in 1985, since some of the technical problems will have been solved but a few years earlier. As for thermionic converters, materials needed to withstand the high temperatures required are unavailable now. Even if such materials are developed, they will probably be used in the blades of steam turbines which could then be operated at higher temperatures, thus achieving higher efficiency more cheaply.

As additional power sources, fuel cells and storage batteries will be improved and will come into increasing use, especially in mobile applications. They will compete with each other as power sources for electric automobiles, whose use will increase in urban areas. (See Section 2-1)

2-5 Space Technology

It is estimated that between 1 and 1-1/4 per cent of the Gross National Product will continue to be expended between now and 1985 on a space program which is likely to continue to expand. Natural resources are not

likely to be strained because the space program does not involve a large amount of hardware. The only critical materials that we can foresee are fissionable material (for nuclear rocket engines cannot be recovered for reprocessing) and a few potential reactor materials such as tungsten. The greatest limitation to be expected on the space program will arise from the lack of trained scientists and engineers. It is estimated that a likely national space program will require 500 thousand scientific and engineering personnel by 1985. (See Annex)

The most likely projects to follow the Apollo lunar mission, which is expected to culminate in a lunar landing around 1970, are a manned space station, a lunar base, and manned interplanetary flight culminating in a landing on Mars by 1975-1980. Probes to Jupiter (1975) and to Saturn (1985) will be technologically feasible but it is unlikely that a probe will be sent outside of the solar system by 1985.

There will be operational satellite systems for commercial and military communication and for weather observation well before 1985. A further desirable development from military, commercial, and scientific standpoints (and therefore a very likely development) is the invention of a relatively cheap and re-usable manned patrol vehicle for near-earth space, which might serve for surveillance, especially of space objects, for repair and modification of established satellite systems, and for retrieval of scientific data and instruments.

There will have been dramatic improvements in the size, the reliability and the specific cost of space vehicles throughout the period. Boosters will exist capable of putting one thousand tons into earth orbit.

Chapter 3

NATURAL RESOURCES

What of the resources which will be available in 1985 to feed the increased population of the United States and the world, to provide fibers for clothing and raw materials for manufacturing? What advances will be made in developing new materials and fibers? This chapter attempts to answer these questions.

3-1. Minerals and Fuels

Much of the world's supply of metallic ores comes from the older complexes of crystalline rocks which everywhere on the continents underlie the younger sedimentary rock strata. These older rock complexes, called the basement, are exposed at the surface in a relatively small part of the earth's surface. By 1985, new and improved geophysical exploration tools coupled with significant advances in the technology and economics of deep drilling will permit successful exploration of buried basement terranes for new sources of metallic ores. The economic and technological feasibility of the deep drilling required for basement exploration is an expected "spin-off" from the present research attempts to drill a hole (Mohole) to the Mohorovicic discontinuity and from future research. These developments will enhance the status of mineral commodity resources nationally and throughout much of the world, and may be expected to cause some major

shifts in the geographic and political distribution of the sources of required mineral commodities.

By 1985 substantial advances in mining technology will have been made which will permit economic exploitation of relatively low-grade ores on a large scale. Important improvements expected by 1985 include remote-control mining methods, biochemical concentration of low-grade iron, silver, copper and manganese ores, solution mining, principally of salines and in situ mining, smelting and refining of underground ores.

In the 1985 era adequate supplies of required mineral commodities will be available to the United States provided that no adverse shifts in political alignments take place. If such adverse shifts occur, the United States will experience short periods (5 years +) of readjustment while mineral-based industries change over to the use of substitute commodities, or new domestic supplies are developed. Increased emphasis on national planning and management of the United States economy by 1985 may further minimize imbalances in supplies of mineral commodities. Low grade and substitute commodities, for example, will be developed with the aid of subsidies, tariff protection and tax benefits.

In 1985 the principal energy source in the world will continue to be the fossil fuels. (These comprise petroleum, natural gas, coal and lignite, oil shale and tar sands.) The peak of world petroleum and

natural gas production will probably be reached in about 40 years and that of coal within 200 years. However, the peak production of petroleum in the United States will occur in less than 20 years. Liquid hydrocarbons in 1985 will be in sufficient supply in the United States and in the rest of the world to meet the projected energy needs for industrial, heating and automotive purposes. Most liquid hydrocarbons will continue to be supplied from petroleum, but increasing amounts (especially in North America) will be derived from tar sands and perhaps oil shale. Regardless of the raw materials used, refinery products in 1985 will be essentially of the nature presently produced. The heavy capital investment in production, refining and transportation facilities will militate against large-scale changeover to other forms of energy in those activities now largely dependent upon liquid and gas hydrocarbons for primary energy.

Expected advances in coal technology and mining methods by 1985 will make coal cheaper and relatively more important than it is now as a primary source of energy in those parts of the world with substantial coal resources, but this fuel will be used principally for the production of electrical energy.

3-2 Water

In terms of water availability, two regions must be distinguished. In the non-arid regions, total rainfall, less the evaporation, is adequate

for all uses in 1985. In these regions the water problem is not so much one of shortage as it is one of proper management.

By 1985 the water problem in the non-arid regions will be solved by better water management. Measures taken will include the control of stream and lake pollution, and better utilization of available water. In some areas two parallel water systems will be used, one for salt water which is acceptable for some uses.

In arid areas desalting sea water or brackish water for household or even industrial use will be economically justifiable. It is expected that by 1985 desalted water will be in widespread use for these purposes in Southern California, Israel, certain arid oil-producing lands and certain islands. Since the minimum foreseeable cost for desalting is of the order of \$0.50 per thousand gallons, it will not be feasible to use desalinated water for irrigation purposes.

Only a dramatic decrease in the cost of power, such as might be conceivable if fusion power ever became a technical reality, would make practical the desalination and distribution of water from the sea to irrigate arid areas. (See also pages 5-10 of Earth Sciences Annex.)

3-3 World Agriculture and Food Supply

At the present time major crop production in the developed areas is more than twice per acre and three times per capita than in the less

developed areas. Furthermore, the disparity in animal protein production is five times. This gap has become greater in recent years and will not be closing in the next two decades. It is projected that per capita food supply will increase by 14 per cent in the developed regions, but only 10 per cent in the less developed regions.

A concomitant factor in improving food consumption and productivity is a rise in the level of economic activity of a nation. To achieve the projected increase of per capita food availability in the underdeveloped regions will require an increase in the total personal income of about 5 per cent per year. This does not appear to be possible in most underdeveloped countries through their own unaided efforts. There will have to be subsidies by the prosperous countries and various international and voluntary agencies.

The Far East constitutes the chief world problem with respect to food. Most of Latin America, with the exception of the River Plate countries, will also have difficulty producing enough food, even to maintain present insufficient dietary levels, because of the extremely rapid population growth. Africa has the best potential of the underdeveloped regions if political problems can be resolved.

The acceptance of new agricultural technology by farmers generally lags its discovery, even in the developed countries. In the underdeveloped countries the first step in technological advance will be improvement of

general education and establishment of better communication so that the farmers' resistance to change can be overcome.

Extending cultivated land areas is not as promising a solution to world food deficits as increasing the yields of existing arable lands through better water and soil management, use of fertilizers and insecticides, use of hybrid and disease resistant plants, and other techniques commonly used in the highly developed areas. Extensive mechanization will not come about in these areas in two decades.

The greatest progress toward rationalization of productive operations will come from cooperative sharing of equipment, rather than from increasing the size of productive units. Land reform that gives the cultivator a real stake in the increased product of his labor is essential. Furthermore, sheer political necessity will make such reform a reality in the next 20 years in nearly all the places where large tenant farming exists. Where large commercial farms are broken up, a diminution of productivity will occur. On a worldwide basis, however, land reform will produce more positive than negative effects in terms of productivity.

Worldwide urbanization will take place (e.g., in the United States the labor force engaged in agriculture will decrease by 1985 from the present 6.5 to 3.5 per cent of the total labor force) but will not per se alter the food production or consumption per capita. The labor preempted by urbanization is almost universally redundant.

Despite the fact that the underdeveloped countries have shown a 4 per cent increase in crop foods per capita since prewar years, they have experienced a 2 per cent decline in animal food supplies. Thus, the basic food deficiencies in these countries, which have been in animal proteins, have not improved. Even if half of the predicted per capita increase in grain availability were converted into livestock products in 1985, animal protein consumption would only increase from 9 to 14 grams per capita per day compared to the current rate of 44 grams in the developed countries. As for such means of food production as hydroponics, cultivation of algae or synthesis of protein molecules, they can make only negligible contributions to the solution of worldwide food problems.

It is expected that world production of cotton, wool, and other natural fibers can be increased to keep pace with world needs and demands.

3-4 Marine Resources

The most likely addition to the animal protein supply will come from food sources in the oceans. Food resources of the oceans, however, are not unlimited. Limitations are established principally by the supply of nitrogen and phosphorus, and by the effective amounts of solar energy for photosynthesis. Assuming that enough nitrogen and phosphorus could be made artificially and introduced into the ocean, the solar energy available still fixes the upper limit of productivity to an increase by a factor of 5.

The present productivity of the oceans is about 15 per cent of the amount that is ultimately limited by the solar energy input.

By 1985 a 3- or 4-fold increase in fish cropping is possible.

This may be achieved through more effective means of locating, capturing and processing fish; conserving fish populations and forecasting their migration; and marine husbandry--especially herding and selective breeding for herding and growth traits. Research will be done on location and habits of fish populations, and on recognition of unfamiliar species that could be exploited. High quality proteins for direct human consumption in the form of "fish flour" will be produced from fish species now regarded as unpalatable.

In fresh waters the development of "fish ponds" with dense populations of edible fish species maintained by fertilization will certainly continue, but complete control and modification of biological communities in the open sea is not likely to become feasible.

Discharge of waste products into the sea can have a profound effect on biological populations. Sewage, chemical wastes and radioactive wastes are particularly serious problems and their disposal will need to be controlled by legislation and policing. Biological processes that allow a body of water to recover from sewage pollution may be inhibited by chemical industrial wastes. Selective biological uptake of deleterious elements in

waste may seriously affect the use and safety of potential marine food supplies; hence regulation and policing will be increasingly important.

Furthermore, increased development of food sources in the oceans will depend upon increased management of this resource. This will necessitate international agreements, policing and enforcement of regulations, possibly extensions of national sovereignty to larger areas of the sea, and development of international conservation policies.

3-5 Processed and Synthetic Materials

For the purposes of this study, the materials used in modern society can be grouped into a number of classes: (a) the "traditional" materials such as metals and alloys; (b) fabricated materials such as plywood and fiberboard whose development is based on their gross physical characteristics; (c) materials such as semiconductors and ceramics in which microscopic physical characteristics are the basis of their development; and (d) those like polymers and synthetic fibers whose chemical composition is the predominant factor. Our attention here will be limited to the latter two categories.

Here, again, predictions are based on observation of areas under investigation at present. Of great interest in all areas of technology are the mechanical properties of materials. It is not expected that materials in general will be susceptible to methods of direct synthesis to satisfy

prescribed mechanical properties by 1985, although in the case of polymers considerable success in this direction will be achieved.

As for optical properties, on the other hand, it is expected that materials and techniques (such as infra-red) will be developed which will make possible true "night vision." In the development of coherent radiation (lasers and masers), the fundamental effect is now understood and the problems now unsolved will yield to solution by 1985.

Continued improvement in the understanding of electrical and magnetic properties will lead to increased miniaturization of devices. Whether or not true "molecularization" (the synthesis of a complete electronic system in a chain of molecules, each of which performs a function such as amplification or switching) will have occurred by 1985 is a subject of controversy. Majority opinion is that, sheared of all self-serving propaganda and implications of exotic terminology, claims of molecularization are not justified.

It is likely that new polymers having properties of conductors and semiconductors will be developed within 10 years on the basis of polymeric π complexes now under investigation.

Some understanding of superconductivity has recently been achieved. It is expected that the use of superconducting materials will lead to profound technological advances. One of the immediately successful areas is in the development of extremely high magnetic fields.

The problems in the development of theoretical and experimental techniques for understanding phase transitions will probably not all be solved by 1985 so that control of phase transitions on a microscale will not have been achieved. When this is achieved, it will lead to new materials of greatly desirable characteristics.

An increased understanding of the constitution of matter will come about from research now under way in extreme environments: high pressure (up to 10^6 atmospheres), high vacuum (down to 10^{-18} atmosphere) and low temperatures (down to 10^{-5} degrees K).

The general principles of polymer formation are now well established and provide a basis for predicting the properties of new polymeric systems. No startling developments or dramatic advances are expected from extensions of conventional methods of polymer synthesis. But polymer chemistry will provide materials better matched to their use and new combinations of properties in one material. Extraordinary savings will be made possible by specifying only engineering requirements, or required properties, rather than specific materials, since polymers can be synthesized for a wide range of properties.

In the area of plastics, significant improvement in strength and physical properties can be expected. Wider use of such materials as machine parts will lead to lighter machines, lower maintenance costs and ease of fabrication.

Polymeric alloys (like metal alloys) and less intimate composite materials will provide materials of improved properties. Fibers and textile-like materials will be fabricated on modified paper machines at speeds a thousand times that of conventional looms.

All in all, the variety of polymeric materials and their uses seems almost unlimited.

Chapter 4

PUBLIC HEALTH AND MEDICINE

4-1 Incidence of Disease and Expected Cures

It is not expected that dramatic cures for all cancer and cardiovascular disease will be found by 1985, but there may be conspicuous success in dealing with special types. Nervous disorders will also not abate because the nature of our culture, which underlies these maladies, will not change. However, prevention will play an increasingly important role in the incidence of these diseases. As more and more is learned about the epidemiology and pathophysiology of these diseases it is becoming obvious that the management of the established disease is often discouraging. It will be more and more the function of the medical profession to identify individuals who may be especially susceptible to these diseases and the (often multiple) predisposing environmental factors in their etiology. Then the public must be educated by every available means in schools and via mass media, primarily, to collaborate with health agencies in preventing its own diseases. The beginnings of this change are already apparent in the fluoridation and cigarette--lung cancer developments.

Respiratory ailments will probably not decrease unless there is a great reduction in air pollution in the urban areas. Some success in immunization against certain of the remaining infectious diseases is to

be expected, but those, such as the common cold, which may actually be caused by any of a considerable number of different organisms will probably still plague us in 1985, because it will not be practical to immunize against all of their possible causative agents. The likelihood of tailor-making chemotherapeutic agents by scientific design by 1985 is not great and they will still largely be found empirically. It is expected that allergies and ill effects of toxic residues will increase, partly because we are constantly adding new natural and synthetic organic substances to our environment. All in all, the state of health of the United States and the world will not improve dramatically. Life expectancy in the United States will not be significantly different from that of today.

4-2 Social Conditions Influencing Health

The state of public health in 1985 will be greatly influenced by urbanization, pollution of air and water, and population increase. The concentration of great masses of people in densely populated urban areas increases the possibility of epidemics of viral disease. The problems of sanitation and hygiene multiply.

The sanitation problems brought about by increasing pollution of air and water could become quite severe by 1985 unless attention is directed toward these problems. The attention must be of a technological nature as well as political. That is, techniques and processes must be devised for reducing or eliminating industrial pollution of the air. Adequate methods of sewage treatment must be developed and effluents of industrial wastes.

must be controlled so that natural biological purifiers of lakes and rivers are not inhibited by the organic and inorganic materials in such wastes. These measures all require appropriate legislation. Also required is legislation to control air pollution introduced by automobile exhausts.

We foresee that technological means for the control of air and water pollution will be developed, partly spurred on by appropriate legislation prohibiting the production of pollutants, which we also predict will be passed. As noted in Section 2-1, we foresee the widespread use of electric exhaust-free cars in urban areas by 1985.

The problems of population increase are not as easily overcome. Both major factors leading to this increase--the lowered death rate because of improved general conditions of health but also because of medical efforts to keep sickly people alive, and the increased birth rate, especially among those who in the past were not likely to have surviving offspring--tend to cause a pollution of the human pool of germ plasm. It is known, for example, that descendants of those who received heart surgery in infancy show a higher than normal rate of cardiac anomalies in their offspring.

At the mention of genetic control of human beings, present mores of society conjure up a Big Brother vision of a totalitarian society. However, whether it wants to or not society is tampering with human genetic heredity by releasing atomic radiation into the atmosphere and by

interfering with nature's controls through controlling disease. Serious thought is being given by responsible individuals in biology and medicine to means for genetic improvement. Whether or not efforts in this direction will be successful by 1985 are not clear, but it appears unlikely.

4-3 Organization of Medical Practice and Education

The specialization in medicine, as in other areas of activity, will increase so that by 1985 almost all physicians are likely to be specialized. In most communities, it can be expected that physicians will practice in independent groups, with much inter-referral within groups and some enlistment of consultative aid from adjacent groups or from the nearest Medical Center. Many diagnostic procedures will be automated and the number of available diagnostic aids will greatly increase. Furthermore, routine medical care (immunizations, well-baby care, etc.) is likely to be provided by nurses and technicians rather than by physicians. Fewer and fewer house calls will be made.

Medical education will not lack in facilities by 1985. The curriculum will be upgraded and a progressive "scientification" of medicine will occur, and the physician will have the same type of relation to biology as the engineer has to physics. Most medical students will be paid a stipend while they are attending school, much as graduate students in science are now supported.

The costs of health care will continue to increase. This will lead to a greater degree of public support of medical care in one form or another, possibly through public subsidy of insurance programs to keep up the myth of private enterprise. By 1985 most medicine will be "socialized" but private care for those who want to pay will be available.

SOME RECOMMENDATIONS

In considering the implications of the findings of this study on the operations of the Marine Corps, we have isolated three items which we consider to be of particular significance. Certainly those more familiar with the operations and needs of the Corps will find many others, but we felt these to be of sufficient importance to mention them specifically.

1. The Marine Corps probably requires a mobile power source which would be used in the field for electric power. In addition to such requirements as portability, ruggedness, etc., a requirement for nondetectability probably exists. A gasoline engine, for example, is quite noisy. It is also "noisy" thermally; that is, it runs hot and emits thermal radiation which can be detected by infrared detection methods. For moderate power requirements, the fuel cell recommends itself as a portable noiseless source whose thermal radiation is lower than alternative sources.

2. In the area of transportation the value of hydrofoil vessels as landing craft in military operations was noted. The high speed of the hydrofoil boat would make it quite attractive for this purpose. However, problems of stability are not yet solved and more basic research in this area is needed. Practical problems, such as the vulnerability of submerged foils to debris, also exist.

3. The development of remotely located intercommunicating computers was noted. This development offers the possibility of decentralized digital data handling and processing at forward positions with mere assembly (and little concomitant processing) at the command post. This has implications for command and control.

We recommend that the Marine Corps consider the value of these three items to its operations, and consider conducting research in the development of the appropriate equipment.

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