UNITED NATIONS

A

General Assembly

Distr.
GENERAL

A/46/364
17 September 1991

ORIGINAL: ENGLISH

Forty-sixth session
Item 60 (k) of the provisional agenda*

GENERAL AND COMPLETE DISARMAMENT

Charting potential uses of resources allocated to military activities for civilian endeavours to protect the environment

Report of the Secretary-General

1. By its resolution 45/58 N of 4 December 1990, the General Assembly requested the Secretary-General, with the assistance of a group of qualified experts, to undertake a study of potential uses of resources such as know-how, technology, infrastructure and production currently allocated to military activities for promoting civilian endeavours to protect the environment. Recommending that the study be based on open information and taking into account relevant national and international studies and such further information as Member States might wish to make available for the purposes of the study, the same resolution also invited all Governments to cooperate with the Secretary-General so that the objectives of the study might be achieved. The Secretary-General was requested to submit the final report to the General Assembly at its forty-sixth session, and in the interim, to make relevant results of the study available, as appropriate, to the Preparatory Committee for the United Nations Conference on Environment and Development.

2. Pursuant to that resolution, the Secretary-General has the honour to transmit herewith to the General Assembly the study on chortiag of potential uses of resources allocated to military activities for civilian endeavoura to protect the environment.

---

* A/46/150.

718.

ANNEX

Study on charting potential uses of resources allocated to military activities for civilian endeavours to protect the environment

CONTENTS

/...

CONTENTS (continued)

FOREWORD BY THE SECRETARY-QENERAL

Ours is an era of opportunities. Vast political energies have been released by the end of the cold war. New possibilities have been opened for a more productive utilisation of the world's resources. Several major areas of international concern can now benefit from a re-direction, re-orientation and redeployment of resources released through the unprecedented progress in actual reductions of armaments and armed forces.

Environmental protection is surely an international concern of the utmost importance. Mankind, in its own interest, needs to strengthen the planet's capacity to replenish itself.

The present study on environmental uses of military-related resources is very timely. It examines the unique potentials of worldwide military establishments for augmenting the civilian capabilities of the international community in meeting the environmental challenge. In its recommendations to national Governments, the study asks for a cost-benefit analysis of finding new resources for environmental protection as compared with utilizing those already allocated to the military sector. The environmental challenge is essentially global) military-related resources are inherently national. The study, therefore, recommends that mechanisms should be explored for making global use of national resources put at the disposal of the international community. It asks the United Nations to assume greater responsibilities for strengthening the multilateral international response to environmental emergencies.

The world is just beginning to grapple with the full implications of making military-related resources serve non-military purposes. The study's illustrative survey of environmental applications of military-related technologies makes an opportune contribution towards mobilization of additional resources for environmental protection, The technical information and the political message of the study merit serious attention. I sm confident that it will be a useful input for the forthcoming United Nations Conference on Environment and Development to be held in Brazil in 1992.

I commend the conclusions and recommendations of the present unanimously adopted study, which I am forwarding to the General Assembly for its consideration.

/...

LETTER OF TRANSMITTAL

15 July 1991

Sir,

I have the honour to submit herewith the report of the Expert Group on the Study on Charting the Potential Uses of Resources Allocuted to Military Activities for Civilian Endeavours to Protect the Environment, appointed by you in pursuance of General Assembly resolution 45/58 N of 4 December 1990.

The members of the Group of Experts appointed in accordance with that resolution were as follows:

Dr. Carlos E. Garcia
Office of Energy, Environment and Technology
Los Alamos National Laboratory
New Mexico, United States of America

Group Captain Kofi A. Jackson (Rtd.)
Director
Sontech Energy Research
Accra, Ghana

Dr. Grigori Khosin
Professor, Department of Sociology
Moscow State University
Moscow, Union of Soviet Socialist Republics

Professor Celso Lafer
Conselho Brasileiro de Relaçoes Internacionais
Faculdade de Direito de Universidade de São Paulo
São Paulo, Brazil

Ambassador Maj Britt Theorin
Chairman, Swedish Disarmament Commission
Ministry for Foreign Affairs
Stockholm, Sweden

Ms. Wang Zhiyun
Counsellor
Ministry for Foreign Affairs
Beijing, China

His Excellency
Mr. Javier Pérez de Cuéllar
Secretary-Generel of the United Nations
New York

/...

The report was prepared between February and July 1991 during which period the Group held three sessions in New York: from 5 to 8 February, from 13 to 24 May, and from 8 to 12 July 1991.

We wish to express our gratitude for the invaluable assistance provided by the staff of the Department for Disarmament Affairs throughout the preparation of the present report. We wish to convey our appreciation to Mr. Yasushi Akashi, Under-Secretary-General for Disarmament Affairs and Mr. Prvoslav Davinic, Chief of the Monitoring, Analysis and Studies Branch. We are particularly grateful to Mrs. Swadesh Rana, who served as the Secretary of the Group.

The Group wishes to express its gratitude to the technical consultants Dr. Andrew Forester and Dr. Jürgen Scheffran for their contribution to the consideration of the issues involved. The Group also wishes to thank Mr. Jean-Claude Faby, Director, and Dr. Erwin Ortiz, Special Adviser, of the United Nations Conference on Environment and Development for their cooperation in the course of work of the Group.

In my capacity as the Chairman of the Group, I have been requested by its members to transmit to you the present report, which has been unanimously adopted.

Accept, Sir, the assurances of my highest consideration.

(*Signed*) Amb. Maj Britt TREORIN
Chairperson
Study on Charting the Potential Uses of Resources Allocated to Military Activities for Civilian Endeavours to Protect the Environment

I. INTRODUCTION

A. Mandate

1. In its resolution 45/58 N of 4 December 1990, the General Assembly requested the Secretary-General to carry out a study on the potential uses of resources such as know-how, technology, infrastructure and production currently allocated to military activities for promoting civilian endeavours to protect the environment. The resolution also requested the Secretary-General to make relevant results of the study available to the Preparatory Committee for the United Nations Conference on Environment and Development to be held in 1992 in pursuance of General Assembly resolution 44/228 of 22 December 1989.

2. Emphasizing the global character of environmental problems, the 1392 Conference is expected to examine strategies for national and international action to strengthen activities aimed at restoring the global ecological balance and preventing further deterioration of the environment. In that respect, in its resolution 44/228, the General Assembly takes note of the crucial role of science and technology. In seeking to promote international cooperation for further global efforts towards environmental protection, the Assembly also draws attention to the need for access to environmentally sound technologies, processes, equipment and related research or expertise.

B. Framework

3. In the 20 years since the first international Conference on the Human Environment was held under the United Nations auspices at Stockholm, there has been a growing awareness of the nature and magnitude of environmental problems. Follow-up conferences such as those on population (Bucharest), habitat (Vancouver), water (Mar del Plata), and desertification (Nairobi) have deepened an understanding of specific areas. Special international groups like the Brundtland Commission have forcefully made the case for common environmental destiny of the planet Earth. With the creation of the United Nations Environment Progranune (UNEP), environmental concerns have been injected into the entire United Nations system. Some global issues like climate change are entrusted to international negotiating committees for purposes of assessment and formulation of strategies.

4. While addressing specific aspects of damage, degradation and vulnerability of the environment, most international attempts at meeting the environmental challenge also warn against despairing. As pointed out during a recent "United Nations of the Next Decade Conference" organized by the Stanley Foundation:

> Despoliation of the planet is not inevitable. Industrial and economic progress need not bring about abuse of ecosystems. Exhaustion of natural resources and destruction of the environment are not foregone conclusions. 1/

/...

5. The stakes of environmental neglect are so high that the case for environmental protection can hardly be overstated. The resources available to the world community for promoting that cause, however, are limited. The complexity and intractability of environmental problems demand continuous scrutiny and scientific assessment for the formulation of effective strategies, itself a resource consuming exercise. There is thus an urgent need for mobilfsation of adequate resources for environmental protection.

6. The mandate of the present study rests on a twofold recognition: the need to mobilize adequate resources for meeting the challenge of global environmental protectioar and the unique potential of the worldwide military establishments to augment the capabilities of the civilian international community in achieving that objective.

7. In carrying out that mandate, the saperts were mindful of a broader interaction between environmental concerns and military activities. Within the United Nations, such an interaction has been generally discussed in areas like the environmental impact of testing, production, stockpiling and risk of the use of weapons of mass destruction and development of new types of weapons; effects of the arms race on the prospects for international cooperation on environmental issues; military competition for limited resources that could be used for civilian endeavours; and ecological consequences of military conflict, for example, in the mass movement of refugees. The United Nations discussions on these issues, and any decisions taken thereon, also provide the wider framework for the present study.

8. Relevant in that context are several General Assembly resolutions, for example, resolution 38/165 of 19 December 1983 and 40/200 of 17 December 1985 on international cooperation in the field of the environment and, resolutions 35/8 of 30 October 1980 and 36/7 of 27 October 1981 on the historical responsibility of States for the preservation of nature for present and future generations. In recommending measures for meeting the environmental challenge, including the aspects affected by military activities, the General Assembly has acknowledged the comprehensive treatment of the issues in the reports on environmental perspective to the year 2000 and beyond (see resolution 42/186 of 11 December 1967, annex) and the report of the World Commission on Environment and Development (resolution 42/187 of 11 December 1987). The Secretary-General of the United Nations is also the depository of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, which entered into force in October 1978.

C. <u>The present study</u>

9. The present study concentrates mainly on the possible environmental uses, through reorientation, redeployment or redirection, of resources currently put primarily to military ends or those which may be released through arms reductions. Viewing such military-related resources as potential environmental tools, the study surveys the possibilities explored so far and

describes the prospects opened up by the rapid advances in science and technology. In the limited time available for carrying it out, the study neither could, nor has made any attempt to, provide an exhaustive inventory of the environmental potential of military-related resources. The study is based upon open information and the understanding gained through the contributions about actual experiences of the experts participating in its work.

10. Chapter II briefly surveys the background against which environmental problems have moved towards the centre of the international agenda. Environmental implications of military activities and arms reductions are surveyed in that chapter. It describes recent changes in the international situation that might either release military-related resources or turn them idle. An overview of some actual national experiences is provided with a view to developing pragmatic strategies to promote a potential use of military-related resources for environmental protection.

11. Chapter III examines the nature of military-related resources to establish their suitability as possible environmental tools. It describes the costs and constraints on making civilian uses of military-related resources and the characteristics of the environmental sector in this regard. Bearing in mind the actual national experiences described in chapter II, that chapter also highlights the special role of military-related technologies. Transfer of technology, training and education are seen as strategies for meeting the global environmental challenge.

12. Chapter IV provides an illustration of the environmental applications of military-related technologies. Techniques, instruments and systems deployed for military missions are surveyed here with a view to highlighting their environmental applications. The chapter gives a broad overview of technologies for environmental monitoring, impact assessment and decision-making, as well as actions that may be undertaken to influence the environment, such as environmental compliance and clean-up. Technical information is included in the appendices.

13. In chapter V, the expert group sets out its conclusions and recommendations. Bearing in mind the differences as regards activities on national jurisdiction and "global commons", that chapter reaffirms the need for: continued scientific assessment of data on global environmental hazards; promotion of appropriate technologies for sustainable development, strengthening of quick response capabilities in case of environmental emergencies; development of human resources to deal with environmental damage especially in the developing countries; mechanisms for international cooperative ventures. It also recommends a further role for the United Nations as a clearing-house for information; for promoting technology assessmentt and in providing environmental assistance.

II. BACKGROUND

A. The environmental challenge

14. Mankind is bound by a common environmental destiny. No part of the world can claim an immunity from the natural disaatsra and man-made abuses of environment. Risks like those of habitat alteration and destruction, species extinction and loss of biological diversity, ozone depletion and climate change are clearly transboundary in character. So are the likely repercusaiona of environmental hasards emanating from specific parts of the world.

15. An illustration of the vulnerability of different parts of the world to each other's environment can bو seen in the following tablet 2/

Table 1

	Impacts on		
Impacts from	Industrial world and newly industrialised countries	Third world	Global environmental sys terns
Industrial ɥases; world and newly industrialised countries	Multiple impacts, many from inadequate waste management	Deforestation for timber and ranching1 mine tailings] industrial accidents	Greenhouse chloro-fluorcarbonsr toxic and nuclear waste disposal; fish stock depletion; pollution of sea lanes
Third world	, Transborder migration	Desertification, deforestation, soil erosion; saliaisation; water-table depletion	Deforestation - implications for CO_2 and global warming

16. The broader ramifications of localized and regional ecological problems are likely to become a considerable factor in international relations. Wind movements, ocean currents and the major bioqeochemicul cycles (carbon, nitrogen, phosphorus, etc.) inextricably link the actions of one nation to consequences felt by another. These complex environmental issues add new challenges and opportunities for cooperation for preventing or solving disputes about access to sea lanes, territorial waters, airspace and international boundaries.

/...

17. The world's coastal regions are home to up to one third of the world's population and more than one third of the planet's industrial infrastructure. A rise in sea levels could alter the boundaries between nations and challenge existing sovereign structures. Existing patterns of energy consumption constitute another area of ecological concern. It is estimated that the world energy supply would have to increase by a factor of five in order to provide the same level of energy consumption to the entire world population. Development of efficient and ecologically benign methods of power generation, distribution and use is extremely important for sustaining critical life support systems.

18. An area larger than the African continentis already threatened by deserts. Every year 25 billion tons of top soil are lost. In 1984-1985, over 10 million refugees were reported to be fleeing across borders to escape from environmental problems like desertification, soil erosion and disruption of their subsistence base. Up to two thirds of all refugees worldwide are by now considered to fall in that category. In the tropics today, 10 trees are being cut for every one planted. In Africa, the ratio is 29 to 1. Lack of water is already a serious constraint in 80 countries that have 40 per cent of the world's population. Water use doubled globally between 1940 and 1980 and will double again by 2000. Access to potable sources of water could become a cause of growing internal and international competition and dispute. 3/

19. The growing public consciousness concerning these problems is a positive factor in protecting the environment. While major environmental problems have existed for some time, these has been a greater public awareness of environmental issues in recent years. A series of tragedies in the last few years such as at Bhopal, Chernobyl, in Alaska and several other recent disasters, like desertification and the destruction of tropical rainforests, have received worldwide attention, Local environmental problems involving air, water and hazardous waste pollution have faced people in both industrialized and developing countries. Longer-term ecological hazards like ozone depletion and global warming have come nearer home in such personalized concerns as risks of skin cancer, weather changes and impact on soil productivity. Generous media coverage of environmental issues has become both a cause and consequence of growing public awareness. Political activists and intellectuals have become partners in attempts at a "greening" of international relations, There is an increasing public pressure for dealing effectively with environmental emergencies where and when they occur, whether due to a natural disaster or man-made accident, including a military conflict. Unfortunately, there is less evidence of concern about the gradual accumulation of environmental degradation due to everyday practices.

B. Environmental impact of military activities

20. The recent Gulf conflict has been a poignant reminder of the environmental consequences of military conflict. Scientists are still grappling with the full implications of the marine oil slicks of unprecedented size, hundreds of oil well fires consuming millions of barrels of oil daily,

/...

the pall of smoke, soot and pyrotoxins in the atmosphere and destruction of the desert surface, and the devastation of industrial infrastructure, carrying with it the risk of disease and starvation. The United Nations undertaking to destroy the chemical weapons and other weapons of mass destruction in Iraq have forcefully revived public concern over the environmental impact of military activities and reinforced the need to look for ecologically safe methods of weapons disposal.

21. Virtually all military activities during war and in peacetime have some environmental implications. Destruction of the environment has been an established method of warfare, both defensive and offensive, from ancient time. An extreme form of hostile environmental damage, also referred to as environmental terrorism, was seen in the recent gulf War. Damage is caused by direct weapons effects and secondary effects, All kinds of dangerous wastes, including unexploded munitions, abound in a theatre of war for a long time after a cease-fire.

22. Historically, environmental war damage has mainly been confined to the battlefield, exemplified by Flanders during the First World War. Indirect effects, especially on agriculture or forestry, have sometimes affected larger areas, as have the results of intentional environmental destruction, such as floods caused by the destruction of dams and dykes, forest defoliation by chemicals or the pollution of the air by smoke from burning oil wells as recently in Kuwait. Both localized impacts and subtler, more widespread effects may take decades or centuries to heal.

23. The environmental impact of a large-scale nuclear war would be of a different order of magnitude. It seems that the combined effects of radioactive fallout over large areas, ozone depletion by the nitrous oxides from nuclear explosions and climatic changes caused by the smoke from widespread and long-lasting fires would spell major environmental disaster over most of the globe.

24. Military activities affect the environment even in peacetime. Such activities include the production and testing of weapons, training and exercises, the establishment of military bases and installations, the maintenance of a state of alert and combat readiness, and accidents of various kinds. The scrapping and destruction of weapons and other military equipment, be it pursuant to disarmament agreements or for other reasons, also create environmental problems.

25. First and foremost are questions related to the production and testing of nuclear weapons. Some production sites in 'the nuclear weapons complexes of both the United States of America and the Union of Soviet Socialist Republics are reported to be heavily contaminated owing to radioactive and chemically toxic was tea. The United States Government is engaged in an extensive programme for the clean-up and remediation of such sites, although solutions still have to be found for some of the problems. While this accumulating environmental damage is still mostly local, there has also been contamination of larger areas. The most severe one occurred in 1957 at Kyshtym in the

/...

Soviet Union, when an explosion in a waste dump necessitated the evacuation of an area of 1,000 square kilometres.

26. Very early, atmospheric testing of nuclear weapons oaused health and environmental concerns, whioh oontributed to the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (the "Partial Test Ban Treaty") 4/ between the United States, the Soviet Union and the United Kingdom of Great Britain and Northern Ireland to prohibit nuclear testing in all environments except underground. France and China are not parties to the Treaty, and those States oonduoted atmospheric tests until 1974 and 1980, respectively. The total amount of radioactive debris released into the atmosphere by all atmospheric teats over a period of many years, is estimated to be between 100 and 1,000 times that released in the Chernobyl accident, but that does not seem to have had any serious, long-lasting impact on the environment as such, Underground testing is considered much less of an environmental burden, even though some areas, for example in the Pacific, are more direotly concerned than others.

27. The bulk of military-related, industrial produotion in the world is concerned with conventional weapons and other equipment such as vehicles, vessels and aircraft. The processes involved are basically *the* same as those in the civilian sector. In the absence of detailed data, it may be assumed that military produotion contributes to global industrial pollution and waste in proportion to its share of global industrial production, that is to say, about 5 per cent. One significant difference between military and civilian production, however, is that the former uses more than its proportional share of rare and expensive and often dangerous raw materials. The contrast between resource allocations for military and civilian purposes, therefore, tends to highlight not only the amount but also the nature of resources consumed by the military sector.

28. Peacetime training and military exercises require temporary or permanent use of land areas that are subject to environmental degradation of one kind or another. Most of the damage is local as, for instance, the destruction of topsoil by heavy tracked vehicles, or the noise from aircraft and ordnance disturbing animal life. The sire of the areas involved, however, may be considerable, depending on the geography of the oountry and the extent to which military resources are used. For the European nations, between 0.3 and 3 per cent of their land areas are set aside for military purposes. It is worth noting that the demand for artillery and tactical missile testing grounds tends to expand with increases in the ranges of these weapon systems.

29. In some countries the military have to pay compensation for damage to farmland or forests used temporarily for exercises. This is an incentive to develop practioas that are more environmentally acceptable. For example, the Finnish army has issued a "green book" advising how environmental damage caused by field training and exercises may be minimized.

30. The various pollutants generated at ground or low altitudes by peacetime military exercises are probably an insignificant addition to those originating

/...

from civilian activities. Nevertheless, emissions into the stratosphere caused by exhaust gases from high-flying aircraft and rockets whether in training, on routine patrol or reconnaissance missions have been noted for their environmental impacts.

31, Accidents involving military equipment occur frequently and under many different circumstances. Most accidents are environmentally unimportant while some - such as oil spills - may have an impact on the environment but are similar in nature to those associated with civilian activities. From an environmental point of view, the military accidents receiving widespread attention are those involving nuclear weapons or nuclear reactors on satellites and ships. Crashes of United States nuclear-armed B-52 bombers such as at Palomares, Spain, in 1966 and Thule, Greenland, in 1968 entailed laborious and oostly clean-up operations although no nuclear explosions occur red. Recent instances have been the accidents involving the reactor-powered Soviet satellite Cosmos 954 in Canada in 1978 and, more recently, the sinking of Soviet nuclear-powered submarines in the North Atlantic in 1988 and 1989. In the case of submarines, the environmental impact has been minimired because sunken submarines lie at some considerable depth, but a similar disaster in shallow waters might cause serious problems.

32. In the last few years, the environmental impact of disarmament measures has also raised concerns. Tanks, guns and so on can be dismantled and materials recycled, provided that this procedure is considered cost-effective. Munitions cannot be discarded in this struightforward way, as their active contents must be recovered or destroyed. Chemical weapons create special problems. After the Second World War, large quantities of chemical munitions were dumped in the Baltic Sea and in waters adjacent to the North Sea, causing pollution that lasted decades to the detriment of Danish and Swedish fisheries . The withdrawal of troops and the abandonment of bases and installations may leave scars on the local environment, as has been attested in Eastern Europe following the withdrawal of Soviet troops from the former Warsaw Pact countries. The concern over the environmental implications of reductions in armaments and armed forces have become particularly pronounced recently.

C . Current changes in international military and political postures

33. Two parallel developments have taken place in the last few years: a marked relaxation of political tensions among the major military Powers accompanied by a historically unprecedented spate of measures for reductions in armaments, armed forces and military expenditures; and a subtle change of political emphasis in the rising environmental concerns.

34. After reaching a peak of close to a trillion dollars by 1986, annual worldwide military spending is beginning to decline and is expected to drop by at least 5 per cent among the major military Powers in the near future, An entire class of weapon systems was eliminated with the signing of the Treaty

/...

between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles (INF Treaty) 5/ in 1988. In the offing is a 30 per cent cut in strategic offensive weapons under the treaty now being negotiated by the United States and the Soviet Union. The Warsaw Pact has already been dissolved and NATO has also announced plans drastically to cut back its forces. A large-scale reduotion of conventional arms and armed forces in Central Europe has resulted from the conclusion of the Conventional Forces in Europe (CFE) talks at Vienna. Negotiations are proceeding for a multilateral convention on chemical weapons. Under the Treaty on Conventional Armed Forces in Europe 6/ signed in June 1990, the United States and the Soviet Union will begin to destroy their chemical weapons reducing the stocks to a level substantially lower than that calculated for the multilateral convention.

35. Eliminating weapons and other military equipment, reducing the number of armed personnel and curtailing military expenditures is nothing new. Nations have routinely retired old weapon systems, discarded capital stock as they reach the end of their useful lines, oarried out reductions in their armed forces after periods of major military involvements, and revised their military spending downwards in the past. But in many ways, the latest trends in arms reduction are unparalleled in their scope, and in the larger political context, each with its own environmental implications.

36. The implementation of recent measures of arms reduotion would imply: fewer men and women paid to build, bear or service nrmamentsr fewer machines to buy and maintain] and less of a nation's industrial sector devoted to military production, Millions of armed personnel, hundreds of thousands of plant6 and design bureaux, and thousands of industrial enterprises would no longer be required by the military sector. As of now it is too early to estimate which and how many of the military personnel, machines and equipment would be suitable and available for environmental purposes.

37. Most of the arms reductions agreements prior to the late 1980s, e.g. the Treaty on the Non-Proliferation of Nuclear Weapons (General Assembly resolution 2373 (XXII)) and the Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems, 7/ were designed to ensure that certain types of activities would not take place (with the exception of the Convention on the Prohibition of the Development, Produotion and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (General Assembly rosolution 2826 (XXVI), annex). These agreements did not require the destruction of existing weapons as is stipulated in the ongoing chemical weapons negotiations and the CFE Treaty of 1990. The destruction of all existing chemical weapons invokes serious environmental concerns, whether they are part of a current military stockpile, or are relics of past wars. Such an exercise would involve tens of thousands of tons of mustard gas, nerve gas and other chemical agents along with the munitions and containers in which they are stored.

38. Different environmentally acceptable methods of destruction, neutralization and disposal of weapons are being discussed. The mechanical

/...

destruction of the munitions is not always practical an& aaorptable. Incineration is the available technology for destruction of material8 suah as rocket propellants; similar considerations apply except for the specialized concern for the nature of the chemical/biological munitions.

39. while choosing environmentally aooeptable methods for deatroying *any* kind of weapon, it is necessary to estimate the capabilities of ammunition plants from the viewpoint of their possible effective uses in the programmes of destruation and neutralisation of all kinds of weapons.

40. The method of disposal must inolude suitable provisions for the proteotioa of personnel. All operations require suitable safeguards to aoatain accidental release of the munitions' contents, neutralisation of the ohsmiaals if possible and appropriate disposal of the end-produote. Incineration is the principal method now used. Other methods are being investigated with the primary goal of cheaper operations, whiah would result in environmentally benign by-products. Not an inaonsequeatial aoneideration, which also presses for these newer technologies, are evolving national laws such as the Clean Air Act in the United States and similar laws in other oountriea.

41. Besides the environmental hazards involved in weapons destruction there is also the element of cost. Disposal of conventional equipment is comparatively leas expensive and could be met through the sale of metal as scrap in the instance where it is needed. But the destruction of chemical weapons is costly, perhaps 3 to 10 times greater than the costs of production. Chemical *warfare* agents are, in prinoiple, easily destroyed through incineration but very few oountriee have the appropriate facilities.

42, A political problem that has so far received scant attention in consideration of environmental issues is *the* environmental condition of Eastern Europe, about whiah little was known until the revolutionary *changes* of 1989. In most of that region, the emphasis on produotion quotas and reliance on antiquated technologies have taken their toll. Chronio health problems have come to be associated with severe pollution caused, in some cases, by the use of energy produced from lignite. Lignite is a high-sulphur, eoft coal that puts out more pollution per heat per unit than hard coals. Some of the rivers are believed to be so polluted that their water cannot be used even by industry. Sizeable areas have been damaged by acid rain.

43. In general, Western Europe has stricter environmental regulations but environmental problems *are* still serious. The North Sea and the Mediterranean are increasingly polluted by industrial *and* household waste. Aoid rain has also become a serious problem for several areas of Western Europe.

44. *A* major feature of the latest developments is a subtle shift in political emphasis from military to economic issues with important implications for the environment. For a long time, the possession of overwhelming military strength was widely believed to be an adequate protection against threats to national security. Clearly, military strength

provides no immunity from environmental degradation, Earlier, it was mainly the influence of industrial development on environment that aroused concern. Now, in a growing number of areas, the destruction of the environment is seen as affecting the prospeots of suetained growth and economic development. The full impact of these changing perspectives will take time to be incorporated into national policies. But there are already indications that cost-effective national strategies for environmental protection include the potential use of military-related resources.

D. National experiences

4s. National experiences in using military-related resources for environmental ends vary, owing in part, to the relative size of individual military establishments. Also relevant here are policy decisions about environmental priorities, levels of teohnologiaal sophistication and institutional and organizational faators governing the mobility between the civilian and military sectors of national economies. An illustration of some national experiences is given below.

46. In the United States, many regulations have been implemented that address the different aspects of environmental contamination. For example, in the period of 1955 to 1988, more than 20 substantial documents were published. Efforts are already under way within the defence industrial sector to direct a part of their effort toward environmental protection. Compliance with weapons reduction treaties and self-imposed reductions in armaments adds an additional substantial challenge. Examples of these are the disposal of missiles and chemical weapons, The Department of Defense oan influence an immense number of people in the United States and overseas because of its 2.1 million military employees, 2.9 million dependents, 1.1 million civilians, 1.7 million National Guard and Reserve personnel, nearly $300 billion annual budget, teas of thousands of contractors and 532 major installationa, including overseas bases in 21 countries and United States territories. The installations comprise air *and* sea ports, industrial facilities, laboratories, training ranges and more.

47. Significant resources are being redirected to environmental management. The Department of Defense has focused its efforts in the Defense and the Environment Initiative. Over $200 million has been directed to haaardoue waste minimization projects. Approximately $50 millioa a year is spent on environmental research and development programmes and the Department has instituted The Installation Restoration Technology Coordinating Committee as a forum for exchange of teahnioal information derived from the Department's environmental and research and development (R&D) programmes. A recent initiative is the Strategic Environment Research and Devslopment Program, which will involve the Department of Energy, the Department of Defense, and Environmental Protection Agency laboratories. The programme was allocated $150 million in fiscal year 1991 and this is expected to increase for several years. The legislation would increase the efficiency of individual agencies by pooling resources and minimizing duplication. Technology transfer is also a part of the legislation.

/...

48. The Department of Defense aohieved an 18 per cent reduotioa in energy us per square foot between 1975 and 1985; since 1985, another 5 per cent reduction has been achieved, and this results in a commensurate drop in pollutant emmissions and other environmental impacts.

49. Primarily because of its defence mission related to auolear weapons and energy research, the Department of Energy has introduced quantities of radioactive and haaardoua ohemioal pollutants into the air, soil, ground sad surface waters over a period of 40 years. These have migrated or threaten ta migrate, through groundwater, The result is large volumes of low-concentration contaminated soils and groundwater, which are both difficul to access for treatment and to clean to regulatory standards. Current technologies do not allow the Department to determine rapidly, accurately or efficiently the character and boundaries of sub-surface contamination, migration pathways and migration rates, nor does current technology permit rapid and effeative waste plume containment and remediation even when locations and specific oontaminaats are known.

50. The Department of Energy has established a multi-billion dollar programm as a part of a commitment to restore sites and to upgrade future waste management operations. The Research Development Demonstration Testing and Evaluation Program is intended to implement ourrently available technologies and develop newer methods for environmental management that are faster, better, aheaper and more effective. Alloaations for this are expected to increase from about $200 million in fiscal year 1990 to about 10 per cent of the total environmental restoration and waste management programme budget. Cooperative programmes with the industrial sector on environmentally responsible manufacturing, and the coupling of energy and waste reduction ar providing additional requirements for an already vigorous technology transfe activity in the Department's laboratories.

51. Examples of initiatives to involve national entities in tho internation community include an ad hoc International Environmental Technology Transfer Advisory Board reporting to the Administrator of the Environmental Proteotio: Agency; several international forums such as the ECO World '92 Conference; t exhibition developed by the American Society of Mechanical Engineers) and a broad coalition of national and international government agencies, private-sector associations and professional societies. (A list of environmental, energy and communications technologies that are either available or under development is given as appendix I.)

52. In the Soviet Union, the political, economic, scientific and technological establiehmente are undergoing radical changes. These changes favour conversion as well as other forms and methods of redirecting military-related resources into the civilian sector. Environmental protect1 is an integral part of these shifts. The military establishment has vast research and manufacturing capabilities: up to 40 per cent of the Soviet machine production and nearly 75 per cent of its research and development efforts are estimated to be military-related, Ecological conoeras have figured in recent Soviet attempts at redirecting its military-related

resources into civilian areas. This transfer from the military to civilian fields has already started in more than 420 enterprises, and 200 research institutes and design bureaux belonging to the defence industries. In 1990 alone, more than 500,000 persons from the military were estimated to have commenced working for the civilian sector, including those areas important in environmental protection, Forms of organization and management are becoming decentralized.

53. Conversion projects, including those intended for environmental protection, are implemented by special committees (including those on the Union Government level), ministries, design bureaux, production plants, scientific organizations (mainly consultative in nature) and even by new companies and funds, among which the International Fund Conversion is one of the most important. There is a Special Conversion Committee in the Academy of Sciences, which is engaged primarily in scientific studies in the field of conversion. Different professional unions and associations also participate in such work. However, major conceptual and instrumental approaches to conversion are formulated by the military, which in many cases are unaware of the specific features of operation of the civilian sector and ways and means of satisfying social needs. Some industries and individual plants try to make use of productive capacities, skilled personnel and available material resources for production, within the shortest possible time, of any kind of marketable products.

54. Another set of imperatives for urgent actions to improve the quality of the environment, among which transfer of military-related resources for this purpose is just one, though very promising element, derives from the growing evidence of further deterioration of the environmental situation in the Soviet Union. The statement of the Supreme Soviet of the USSR "on urgent matters of improvement of the ecological situation in the country" as at 27 November 1959, confirms the existence of zones of ecological disaster that require special assistance from the central Government. Official representatives of the Committee on Ecology of the Supreme Soviet of the Russian Federation state that at least 1 per cent of the total territory of Russia is considered to be an ecological disaster area, The most severely affected areas are the territories affected by the Chernobyl catastrophe, the Aral Sea and its adjacent territories. The manner in which the most severe ecological problems in those areas could be eliminated was analysed in detail in the statements of the Supreme Soviet of the USSR issued respectively on 4 March and 19 April 1991. Because there is a general lack of resources suitable for environmental protection, the idea of transfer of such resources from the military-related sectors may receive wide support from the Soviet public.

55. One of the major tasks of the State programme of environmental protection and rational use of natural resources is to rationalize ecologically the economic activity throughout the country. Conversion of military-related resources is considered to be a promising prospect using the intellectual, technical and industrial potential of research, design and industrial organizations, as well as those of the military sector, for overcoming the

/...

ecological crisis. Some science and engineering groups in the Soviet Union propose to organise a new environmentally oriented sector based on the military-related industries.

56. In China, the military-civilian transfer in the last decade has focused on economic and social development. A conversion coordination office has be established to implement the policy of combining military and civilian productions and transferring defence technologies to the civilian sector. During the same period, increasing efforts have been made to meet the challenge of worsening environmental pollution. The Conversion Coordinatior Office, the State Bureau of Environmental Protection and other concerned institutions have provided forums for the exchange of information and contac between the defence industries and the civilian sector, and held fairs and exhibitions on new environmental technologies and produces.

57. The military establishment with its advanced technologies, equipment a more skilled personnel has played an important role in China's environmenta programme. Military Personnel and aircraft have participated in tree planting, forest protection and emergency relief work. The military resear institutions have also undertaken environmental research, for example, on research on radiation decontamination and protection against chemical warfa and other harmful effects of military activities. The fruits of that work, for example, equipment for reducing energy consumption and improving waste treatment, have been shared with the civilian sector. Equipment developed produced by the navy to treat oil spills has been used in both military and civilian ports. In recent years, an environmental monitoring centre has be set up by the military establishment to monitor pollution from both militar and civilian industrial activities.

58. In unified Germany, the end of the cold war has offered extraordinary opportunities for the conversion of the military sector, especially for environmental protection. Over more than 40 years the world's largest troc concentration, along the inner-German border, caused substantial stress on environment. This has raised the public consciousness and led to the introduction of several measures intended to reduce the military impact. Before unification, the Armed Forces of the Federal Republic of Germany sp more than DM 600 million (more than $US 350 million) per year on environme protection. 8/ In the German Ministry of Defence there is a special department for environmental protection and several military institutions responsible for environmentally related research, notably the monitoring a control of the environmental impact of military equipment and installation Under the auspices of the North Atlantic Treaty Organitatioa (NATO) Commit on the Challenges of Modern Society, German personnel are involved in environmental impact assessment for the military sector.

53. Activities include the training and education of military personnel o ecologically sound behaviour; development of motors, including efficient aircraft engines that generate less noise and pollution; testing of solar energy devices; minimization of waste and chemical pollution in military installations; disposal and elimination of toxic wastes; recycling of

resources; use of'enviroxxnentally benign materials; and application of personnel and equipment (cranes, diggers) *for* landscape improvements and remediat ion.

60. As a consequence of the disarmament process in Central Europe, a large number of military sites and manoeuvre grounds have become available for use a6 natural biological reserves or for human recreation. The use of simulators reduces the adverse impact of testing *and* manoeuverfng on the environment. The German Navy operates vessels equipped to deal with oil spills and which carry support equipment (e.g. embankments), vehicles (boats, helicopters) and personnel to deal with environmental emergencies. Surveillance flights by special aircraft help to discover and monitor oil spills. The existing military communication and navigation *systems are* used in that endeavour. The transport of toxic substances across borders is controlled and facilities are available for decontamination. A German scout tank used for the detection of chemical weapons and radioactive contamination under battlefield conditions has been modified for the detection of air and soil pollution. *As* a different example, a heavy fire extinguisher set has been adapted for use from large military aircraft.

61. Information science is important *for* both civilian and military environmental protection. Extensive efforts are devoted to environmental computer simulation and computer information systems. Germany is involved in several projects on environmental monitoring, computation and telecommunications, which demonstrate the application *of* dual-purpose technologies to environmental protection. The Ministry for Research and Technology decided in 1989 to support the Federal Armed Forces in an intense development of dual-purpose information technologies, including those for environmental protection, 9/

62. In Sweden, military resources, *for* example, army helicopters, tracked vehicles and bridging equipment, have been put to use in a variety of environmental emergencies such as wildfires, snowstorms and floods. Both army and navy units have been used to deal with oil spills. Airborne radioactive debris are collected by military aircraft; ships with hasardous cargo are monitored by naval command posts; and river ice dams are blown up *(to* prevent flooding) by engineering units. The Swedish Civil Defence - a civilian agency - organizes a relief and rescue force for domestic or international deployment, which relies in part on the use of military equipment such as traasport aircraf t, diesel power generators, tents and so on.

63. There is a trend towards the use of military research capabilities, mainly the National Defence Research Establishment (NDRE), in environmental protection. In some cases, the idea has been to apply techniques already devised for other objectives to environmental problems, for instance to use lasers to detect certain atmospheric or hydrc pheric pollutants. In other cases, NDRE ha6 undertaken well-defined research projects such as the analysis of combustion gases from waste incineration.

64. Sweden established the Centre for Environmental Research at Umeå in 1907, Member institutes are NDRE, the University of Umeå, the Swedish

University of Agricultural Sciences and the National Institute of Occupational Health. The Centre was entrusted with the task of promoting research in environmental sciences at Umeå by achieving cooperation between the member institutes. Of special interest in that context is NDRE. In contrast to the three other institutes constituting the Centre, environmental research is not the primary mission of NDRB. The nuclear, biological and chemical department of NDRE at Umeå conducts research into protection against chemical, biological and nuclear warfare. Its expertise is also available to the civilian sector. Through the cooperative approach of the Centre, research on dispersion meteorology, protective materials, haeard evaluation, airborne micro-organisms sampling and analysis, and radiology at NDRE has been undertaken with respect to environmental concerns. Examples of environmental research projects involving NDRE include the fate of radionuclides from the Chernobyl accident in boreal ecosystems; development of a strategy for ranking toxicity of chemicals that occur in the environment; sampling of airborne micro-organisms in the work environment; study of methods for sampling organic substances in flue gases, particularly dioxins; and exposure measures in epidemiology.

65. In Brazil, the armed forces have been traditionally associated with the protection of the environment. The Constitution of 1988 contains a specific section, Article 225, which prescribes general duties regarding the preservation of the environment and which applies to the armed forces as well. Army, air force and navy units have been extensively employed in preventing environmental accidents within the country and its territorial waters. Internal regulations require the crews of both military and civilian aircraft6 to report all environmental problems such as oil spills and wildfires to the appropriate authorities. Moreover, navy units survey, on a regular basis, extensive areas of the Amazon rain forest, the pantanal and the territorial waters to prevent the smuggling of endangered species and illegal fishing. Brazilian military personnel are also responsible for carrying out emergency programmes at nuclear power plants.

66. The armed forces provide logistic support to those institutions charged with environmental protection. Representatives of the armed forces also cortribute to the work of many recently created national commissions dealing with environmental issues, in particular those responsible for ecological and economic zoning.

67. A series of environmental activities have been carried out as part of army educational programme in units all over the national territory. These aim to create and promote an environmentally oriented consciousness among not only the army personnel but also among the civilian popuiation in the areas surrounding each military unit. The activities include tree planting and the protection of endangered plants and animal specie.8 of the local flora and fauna. The army has also recently signed agreements with other public agencies with a view to combining efforts in order to preserve forests in sites under army jurisdiction,

68. The technological capabilities of the military establishments in most developing countries are not adequate to meet the environmental challenges.

/...

Wherever possible,' military personnel have been used by national environmental protection agencies. Ghana, for example, has ueed its armed forces to assist in increasing the mobility, accessibility and monitoring capabilities of the National Environmental Protection Council, and take on some measures themselves. On request, the air force carries out reconnaissance flights to monitor encroachment on foreet reserves, land usage and desertification, poaching and dumping at sea, and coastal pollution and erosion. They could carry out aerial spraying and are considering aerial tree planting by dropping seeds, such as those of the neem tree. The navy helps fight Bumping at sea, poaching and over-fishing, and illegal fishing methods like use of explosives and undersize mesh nets and so on. Army engineering unite have assisted in erecting barriers and drains for flood control and helped supply water.

69. The above selective survey of national experiences indicates that the world is juet beginning to grapple with the potential for using military-related resources in the protection of the environment. Even at the present early stage, however, it is possible to discern some of the considerations and constraints likely to weigh with national decision makers. International strategies for integrating military-related resources into environmental policies, therefore, demand a close scrutiny of a whole range of issues such as the availability, suitability and costs of using those resources. Those issues are addressed in chapter III,

III, ENVIRONMENTAL STRATEGIES AND MILITARY-RELATED RESOURCES

A. Environmental strategies and needs

70. Strategies are generally understood as a set of measures to achieve a well-defined objective through the optimal utilization of available resources. To attain the objective of environmental protection, a comprehensive set of measures are required8 protective measures for damage prevention and control) restorative measures for repair and rehabilitation) and remedial measures for environmental compliance and development of energy-efficient technologies.

71. Public perceptions and scientific assessments of environmental hazards do not always coincide. There are some estimates that up to two decades of intensive research may be required in the area of global climatic change alone, before major policy decisions can be made on the nature of measures required to deal with the problem. 10/ Scientific standards of environmental compliance and patterns of public consumption of natural resources are also at variance in many instances. There is, thus, a need for improved scientific understanding of natural processes and informed public awareness of the environmental impact of everyday practices. Preventive measures for pollution control, remedial efforts at clean-up and restorative actions are available to the global community as a whole but are beyond the reach of a single country or group of countries. There is thus a need to include in environmental strategies a global inventory of resources suitable and available for environmental protection.

72, Broadly speaking, environmental strategiee involve monitoring the Earth's environment; assessment of monitored datat coordination of scientific work; management of negotiations; encouragement of new patterns of international cooperation; dissemination of information; and raising publin conecioueneee on environmental issues. The coats of implementing those strategiee are yet to be calculated with any degree of certainty.

73. Some estimates indicate that the initial cost of reversing the global environmental crisis might amount to $774 billion over the next 10 years, and that figure may prove far too conservative. It is estimated that, in the United States, up to $115 billion a year wae being spent for environmental protection in 1990, which amounts to approximately 2 per cent of the United States qroee national product. The European Community (EEC) is estimated to be spending nsarly 1.5 per cent of its gross national product for environmental purposes. In Eastern Europe, a minimum of $250 billion to $300 billion may be required to start dealing with the environmental decay in *any* eatiefactory manner. Among the developing countries, proposals have been made oonoerning the establishment of a planet protection fund with annual contributions at the rate of 0.1 per cent of gross domestic product from all countries, excepting the least developed, Such a fund is expected to cover only the cost of developing or purchasing conservation-compatible technologies for the benefit of both the developed and developing countries.

74, The costs of environmental protection appear enormous until placed against the possible costs of environmental neglect. Only in certain well-defined cases such as the damage caused by acid rain, for example, is it possible to put a connneraial value on the resources deetroyed. In other cases, as for example, the risk of the loss of biodiversity, it is difficult to estimate the coete'of losing entire species. If global environmental damage were seen ax threatening the very survival of mankind, then no price tag could be considered too costly for environmental protection. A comparison could be made here, for example, between the aurrent expenditures fur environmental and military purposes. Based upon available information about national allocations, it appears that, even after recent trends in arms reductions, worldwide military expenditures are three to five times greater than those directed to environmental protection.

75. The estimated costs of environmental protection may not appear so formidable if a part of the required resources can be made available through redeployment, reorientation and retraining of the existing manpower, equipment, infrastructure and technological capabilities currently devoted to non-environmental purposes. It is in that context that the international community needs to take a serious look at the potential environmental use of military-related resources, especially now that there is a real possibility that they may either be release6 or made idle through recent trends in reductions of armaments and armed forces.

/...

B . Integrating military-related resources into environmental strategies: costs and other considerations

76. The utilisation of military-related resources for environmental purposes would essentially depend on two major steps: an inventory stage, identifying the suitability of the particular resources; and a political action plan to ensure their availability, each with its own requirements of cost and benefit analysis.

77. Military-related resources vary greatly from one nation to another in size, composition and technological sophistication, These resources comprise in principle8

(a) Manpower, including regular armed personnel, coaecripts, as well as civilian, technical and support staff;

(b) Professional skills and technical know-how embodied in commanders and soldiers, as well as in scientists, technician6 and other staff in institutions and agencies eupporting the military organisation proper,

(c) Equipment of all kinds, from handguns to tanks, ships and aircraft to advanced laboratory instruments;

(d) Funds alloaated by the Government for salaries to employees in the various branches of defence, for maintenance of existing equipment and for research, development and procurement of new equipment)

(e) Infraetruoture covering land use, capital stock, production plants, machinery, factories, design bureaux and buildings in various stages of their useful life;

(f) Technological capabilities including the ongoing R&D endeavours.

78. In some waye, military establishments are uniquely placed to strengthen the international civilian capabilities for the implementation of environmental strategies. Military personnel are well-equipped for dealing with catastrophic situations, which could be useful in responding to environmental disasters and handling and disposal of highly toxic radioactive or otherwise harmful substances. The defence community hae at its disposal a wealth of information gathered by intelligence sources that can assist in tracking changes in the atmosphere, the oceans and the ourfaoe of the Earth. Military aircraft, eurfaae ships and submarines have the ability to collect additional information about climatic changes and the flow and temperature of oceans. Techniques used for military surveillance such as "tagging" could be easily employed for monitoring transportation of pollutant6 and toxic materials, and for ensuring compliance with ecologically safe methods of weapons diepoeal. The "tagging" technology hae already been cited in verification of treaty imposed numerical and geophysical limits as, for example, in the 1990 Treaty on Conventional Armed Forces in Europe. 6/

/...

79. Baaed upon aatual national experiences, and the specific charecterieticn of military establishments, it is possible, in principle, to envisage many environmental roles that could be undertaken using military personnel and equipment. A careful distinction needs to be made between the environmental use of military personnel and equipment within national frontiers, across global commons and over areas within the jurisdiction of other sovereign nations. The possible employment of military-related resources within the framework of multilateral international efforts to deal with environmental problems could, thus, only be undertaken in conformity with the established principles of international law and respect for national sovereignty. Some lessons could also be drawn from the United Nations experience in promoting international technical cooperation:

(a) Military personnel could undertake temporary assignments for cleaning up and/or restoration of polluted or maltreated areas, For all practical purposes that work would be a variation of field engineering, so engineering units would be best suited. One partiaular kind of clean-up operation where special military units might be useful involves chemical or radioactive materials or accidents. In cases where the volume of work to be done is very large but can be done without special skills, engineering units may be reinforced by troops of other kinds;

(b) Another possible application would be to use military-related capabilities for monitoring environmentally harmful activities, Collection of environmental data and observations could be facilitated by using ships, aircraft or spacecraft, and also by the policing of waterways or remote land areas to prevent - or at least to detect and track down - environmental abuse such as waste dumping and oil spills, or natural hasarde such as wildfires. In particular, surface or air surveillance could be useful on the high seas whereas space-baaed surveillance will be more or less global. Naval ships and units could have a useful role for the protection of the marine environment. The seas and oceans of the world - covering more than 70 per cent *of* the earth's surface - *are* a global common6 in accordance with international law, As stated in the conclueione of the United Nations study on the naval arms race 11/ of 1985, naval personnel and equipment could contribute to effective multilateral ocean management policies for peaceful uses of the sea as a confidence-building measure. Such management, under United Nations auspices, could also include monitoring of the marine environment, protection measures and verification of international environmental agreements!

(a) Emergency relief and damage limitation within national boundaries msy be undertaken by military units with their ability for swift response. To use that ability, special unite mry have to be assigned to those tasks and alert procedures be devised. A disaster relief corps composed of both civilian and military personnel might be established for dealing with environmental emergencies following the example of a number of countries. The military elements of such a force could be drawn from field engineering and medical units. It could use special types of equipment from the military sector, such as light tracked vehicles, amphibious vessels, helicopters and transport aircraft;

/...

(d) As a particular form of international assistance tailored to specific environmental needs, national resources of this kind could be assigned to the United Nations so that, upon request, they could be placed at the disposal of a country suffering from an environmental disaster.

80. A major consideration determining the availability of military-related resources for environmental protection would be the coat-and-benefit factor. The costs would include not only the expenditures required for reorientation, retraining, redeployment and reimbursement but also political constraints on non-military uses of military equipment, Military personnel, for example, could be used for undertaking environmental operations with little or no retraining, provided they were willing to undertake the assignment and were accepted in that role by the host nation. But the potential non-military use of military equipment and infrastructure may involve considerable costs other than those necessary for refurbishment. Borne important lessons can be learned here from the general experience of reorienting the military sector towards civilian production in the wake of recent trends towards reductions in armaments and armed forces.

81. In general, the defence production sector, especially of the major military powers, tends to be more R&D-intensive, uses a larger proportion of advanced technologies and production techniques, employe more highly skilled production workers, engineers and scientists, and is relatively less dependent upon demand fluctuations than the civilian sectors of the economy. In general, the nature of the civilian sector and its call on resources and technologies are quite different from the demands of the defence sector. Not only are techniques, technologies, capital equipment, and human capital and experience different, but so too are the appropriate managerial talents, design emphases and end use of civilian products. There are many cases, of course, of overlap: a factory or design bureau working on fighter aircraft may turn relatively easily to transport aircraft, or the heavy casting and forging capabilities of a tank plant may be applied to railroad locomotives and rolling stock. But, more generally, the matches may be imperfect and the resource6 usable, only with costly modifications. 12/

82. Most of the tanks, guns and other military equipment to be rendered redundant by arms limitation agreements will end up as scrap unless recycled. Similarly, the capital stock affected by reduction of certain types of weapons may have a limited life and the costs of its refurbishment may exceed the' value of its discounted output. Enterprises, design bureaux and machinery may or may not have the capability for civilian products.

83. Recent experiences in diversifying or converting the military sector towards civilian production have also shown that, in many cases, it may be cheaper to close down and mothball enterprises than to incur the costs of refurbishment . The fact that any plane for conversion to non-military uses will need substantial inputs before they start to bring returns has been emphasised on many occasions. In the Soviet Union, for example, an eventual rearrangement of the operational capacities and creation of new civilian facilities at defence enterprises has been estimated to require an additional

/...

40 billion rubles besides an equal amount necessary for R&D devoted to civilian production of the military-industrial complex. 13/

84. Any financial savings resulting from arms reduction6 may not fully compensate for the costs of remodification and reorientation of military equipment sad infrastructure. The infrastructure to support military personnel and production is not directly proportional to the number of people or plants being supported. The fixed costs are incurred regardless of the volume of work. The team that design6 an aeroplane will be the same regardless of whether 100 or 1,000 aeroplanes are made. Thus, most nations can no longer afford to design and build a new fighter aeroplane by themselves. Any reduction in the number of items bought in a given period will result in a proportionately smaller budgetary savings. 14/

85. The civilian conversion of military equipment rendered unusable, or banned, by arms limitation agreement8 could raise security problems. The negotiators will want to ensure that the proscribed or converted equipment cannot be reconverted for military use. Even when there are possibilities, for example, of using tank6 as fire-fighting vehicles for use in nuclear disasters, there is always a concern, whether warranted or not, that the converted equipment could circumvent the intent or? the arms control treaty to render it unusable. Security-related consideration6 will also need to be taken into account while exploring the prospects of using a major military-related resource that holds the maximum potential for environmental purposes, namely, the scientific and technological capabilities of military establishments.

C. Technological capabilities of military establishments

86. The technological capabilities of military establishments include their RQDendeavours, laboratories, equipment and expertise of the scientific community. In the case of major military powers, those capabilities are not only vast, but have also remained relatively unaffected by the recent trends in budget cuts. For example, research and development in most NATO countries is funded at a higher level than ever before. In the Federal Republic of Germany, the R&D budget of the Ministry of Defence was estimated to have increased by 11.3 per cent in 1990. The French 1990 budget for R&D of conventional weapons increased by 14 per cent and the space programmes of the Ministry of Defence increased as much as 52.3 per cent. In the United Kingdom the situation is somewhat different. In a generally declining public R&D budget (in real terms), the share of R&D of the Ministry of Defence has stayed constant. The Government has tried to encourage private companies to bear some of the RCD expenditure6 themselves. Currently, Governments in most countries seem to follow a double-track strategy. Conventional arms control negotiations are undertaken more seriously than before and negotiated cuts in manpower and equipment are official policy. On the other hand, the process of 'developing new and sophisticated weaponry has not been halted. Few major project6 have yet been cancelled, although some small and low-priority programmes have been deferred and sometimes the number of systems to be

acquired has been reduced. The global military sector is, therefore, likely to be a leading consumer of advanced technologies in the near future, as it has been in the last four decades.

87. Most of the modern technologies are essentially dual-purpose and can be used for both military and civilian applications. That duality encourages the prospects of redirecting military-related technologies into the civilian sector without costly modifications, including their application to environmental problems. Practical steps in that direction, however, must acknowledge that the highly complex military systems based upon advanced technologies are not explicitly aonetructed for environmental purposes. In many cases, they are overspecified, too complex and not cost-effective for civilian, environmental use. Nevertheless, it should be possible to take advantage of the investments already made in the development of the technological capabilities of military establishments, especially in the area of R&D.

88. Defence R&D in many countries is often more diversified and multifaceted than is generally perceived. One reason may be tradition, coupled with the fact that it aould take many years to establish whether a scientific finding ha6 applications and, if so, for what. Consequently, and perhaps contrary to publicly held views, defence laboratories devote a large share of their effort6 to research that is not purely military per sat the applications may serve both types of purposes. Until they become available, they could only be identified as potential environmental tools. Examples include material6 technology and the much less new nuclear technologies such as those *for* transmutation of radioactive waste. A similar approach could be used for other major technology fields as well.

89. The modern military rely upon five major fields of technology, that is, nuclear, space, materials, information and biotechnology, the last named being already subject to very stringent international taboo against military use. The report of the Secretary-General on scientific and technological developments and their impact on international security (A/45/568) points out that in the near future no major breakthroughs are foreseen in the field of military use of nuclear technology. Developments in space technology continue to be fed by a multitude of different scientific disciplines from the chemistry of a rocket propellant, through the mathematics of orbital calculations, to the psychology of virtual isolation in zero gravity conditions. Major advances continue to be made in both the material6 and information sciences.

90. Information technology (both hardware and software) seem6 to be in the near term especially relevant to the needs of environmental protection. Baaed upon a cluster of interrelated innovations in microelectronics, computers and telecommunications, information technology is an extraordinarily pervasive technology. It underpin6 advance6 in materials, space, nuclear and biotechnologies, yet is itself dependent only on materials. All major technologies are dependent on information in their research, management and control systems, to such an extent that information is sometimes singled out as being at the centre of the present wave of technological change. 15/

/...

the national infrastructure and indigenous resources. Such skills could be most usefully applied for environmental risk evaluation, technology assessment and development of ecologically benign and *energy* efficient technologies.

95. A crucial factor *in* the environmental reorientation of military establishments would be the economic incentive based upon the consequences of considering, or ignoring, the environmental challenge. The use of military-related equipment like supercomputers and navigational aide as environmental tool6 is increasing at a time when hundreds of defence contractor6 among the industrialized countries are facing a shrinking market for their producte. The military establishments might like to weigh the costs, for *example,* of using a frigate as a platform for meteorological observation at sea instead of leaving it idle in a dock.

96. A distinguishing feature *common* to all military-related resources is that they are, in principle, at the immediate disposal of the Government. Governmental decisions for relocation would be facilitated if a comparison were made of the costs of any environmental task being carried out through the use of military resources with the corresponding costs of using other means. Such a comparison, when included *in* any national strategy for making alternative use of military resources, might promote the military establishments' willingness to cooperate, particularly where sizeable portion6 of military production and R&D are carried out in the private sector of industry. Possibilities are that retraining military personnel and refurbishing military equipment may be less than optimal from an environmental point of view but still the best option with regard to the overall national economy.

97. For Governments, a policy decision for putting military-related resources to environmental use within the nation would be easier than to place such resources at the disposal of a global environmental effort. Military-related resources are unevenly distributed among, and within, the industrialized and developing countries. For many countries the human, technological and material capabilities of their military establishments are not adequate for the enormity of the environmental challenge6 faced by them. National actions may also address some of these problem6 in the short term, but thoee are unlikely to provide long-term solutions to global environmental problems. Each country must assume, therefore, a corresponding share of responsibility for environmental protection in accordance with its capabilities. In that context, cooperative international endeavour to make environmental use of military-related resources could serve a dual purpose. It could serve as a politically symbolic exercise in confidence-building through joint ventures. It could also encourage the world-wide military establishments to assume a share of environmental obligation6 commensurate with their capabilities. Two major area6 eminently ripe for such cooperative ventures would be technology transfer, training and education.

/...

2. Education and training

102. National willingness to make global use of military-related resource6 as environmental tools could be strengthened by sensitising public opinion through education, Awareness of the degradation of the environment by human endeavoure is inadequate among many countries. Not all of them are aware *of* the impact of their everyday practice6 on the environment. Countries without the necessary skills would benefit from having their personnel trained to strengthen their environmental protection organizations. Such personnel would help carry out public education to create broad awareness of the actual or potential hazards threatening their country's environment and of what the people themselves can do to reduce those hazards. Public support for using military-related resources as environmental tool6 could also be strengthened by involving both civilian and military personnel in environmental education.

103. It is in the interest of all countries that they make optimal use of available resources, including those currently devoted to the military sector. To that end, investment *in* education and training is of major importance to promote the ecologically effective use of natural resources. Also, some of the financial resources saved from cuts in defence budget6 could help in switching to environmentally sensitive patterns of growth and consumption. Military-related method6 for disposal of haxardoua substances will be useful in ensuring that toxic wastes are suitably disposed of instead of being dumped in area6 not equipped to deal with them.

IV. ENVIRONMENTAL APPLICATIONS OF MILITARY-RELATED TECHNOLOGIES

104. The central role of science and technology in environmental protection has been acknowledged in General Assembly resolution 44/228 on the United Nations Conference on Environment and Development. Environmental interest in military-related technologies is broadly twofold. Advanced technologies are necessary for responding effectively to the environmental challenge. There is, however, a continued inadequacy of resources available for environmental protection. Advanced technology is available, but is simply not oriented enough towards environmental goals. The military sector, on the other hand, continues to be a leading consumer of advanced technologies.

105. Of all the military-related resources, technologies qualify most *for* environmental use and most technology is inherently dual-purpose. In many cases, the environmental applications may not differ fundamentally from the military, except where the latter is more complex and costly. Many sys terns have been developed in parallel, or if developed *for* military purposes, have resulted in spin-off to the non-military sector. In the market economies, manufacturers and R&D organizations may supply both sectors and defence laboratories and agencies often have a major commitment to non-military work, and vice versa. The result of having some of the costs of R&D, and production, for technology with civilian application underwritten by military budgets is sometime6 seen as beneficial by the industrial sector. Although the present etudy addresses military-related resources, it is not always

feasible to differentiate between the military and non-military, especially with respect to technology. Obviously the reverse applies, and it can be argued that the civilian sector leads in many areas.

106. Information technology, in particular, is easily adaptable for environmental purposes. Many of the results of military applications of information technology can be used for environmental ends without oostly modifications of equipment and retraining of personnel. In some respects, the technological requirements are less demanding for environmental purposes compared with military uses. Applicability in many cases, of course, depends on the technical charaatsristias.

107. Clearly long-term objectives of environmental protection require an understanding of the technical issues underlying natural and man-induced risks, the ability to formulate clear policy decisions and the capability to respond swiftly to environmental emergencies. Military establishments oan assist in achieving those objectives by contributing the methods and systems for monitoring the environment and by strengthening the quick response capabilities for dealing with environmental emergencies, environmental impact assessments and decision-making, and taking actions to influence the environment.

108. For the performance of military missions, modern military establishments have developed sophisticated equipment and methods, for example, sensors; platforms, such as satellites; computers, communication networks, global positioning systemsr and exercises, such as simulation modelling. In some instances, environmental applications are either already undertaken or are under way. In others, the underlying technology can be adapted. The present chapter has concentrated on those areas where the duality of military-related technological capabilities encourages its use for environmental protection.

A. Environmental monitoring

109. The threats faced by the environment are often the cumulative results of long periods of neglectand abuse. Whether in meeting global challenges like stratosphere ozone depletion, climate change and loss of biodiversity, or in responding to environmental emergencies in specific parts of the world, a forewarning of events is invaluable. Monitoring of the environment is, therefore, accepted as a major preventive and diagnostic measure for environmental protection, Technology is a valuable tool for environmental monitoring and is widely used, for example, in international programmes such as the Global Environmental Monitoring System, the Global Resource Informatlon Database, and the World Ozone Programme. 16/ Existing capabilities, however, are insufficient to meet the environmental challenges. Technological capabilities and resource constraints in the environmental field could substantially improve through the use of existing military-related technologies. Particularly relevant for environmental monitoring would be the use of military facilities and techniques.

110. The defence community has collected vslusble data on the oceans, sea-ice, atmosphere, hydrologic and vegetative systems and other domains that, through proper integration, could contribute towards an improved understanding of the natural and man-perturbed environment. The existing defence laboratories could use their computational and modelling resources to exploit more fully the readily accessible data. Advanced computations1 methods can be used to interpret results from sensor systems.

111. Military establishments can locate relevant data, verify their suitability and develop a better understanding of local, regional and global climate phenomena and models. An effort csn be to use highly sensitive, advanced instrumentation from the defence laboratories to extract more information from geological and atmospheric samples to reveal details about past climatic behsviour, glacial history, aquifer recharge, biogeochemicsl cycles and atmospheric circulation and chemistry.

112. Enhanced dats collection can address a wide range of environments1 snd health issues, ranging from the effects of carbon dioxide and other energy-related emissions to the impact of the potential accidental release of hasardous materials. Existing gsps in the ability to determine the Earth's radiation budget and to acquire high-vertical-resolution measurements of such key climate variables as water vapour, aerosols, winds and temperature need to be addressed. Although a good capability for mapping the changing concentrations of osone is evolving, studies of atmospheric dynamics and chemistry need to be extended to improve predictions of future osone levels and the effects of chlorofluorocsrbon substitutes. Both emergency response and sustained environmental monitoring are needed and could be facilitated by advanced sensors snd platforms developed by the military.

113, Remote sensing platforms are well suited to collecting information needed for a better understanding of the environment, for example, the atmosphere (gaseous layer); lithosphere (solid earth crust); organic biosphere (life-be&ring layer); and hydrosphere (water layer), including the cryosphere (ice layer). (A survey of satellite sensors and their environmental applications in vsrious components of the environment is given in appendix III.)

114. Sensors are either active or passive. They can be fined, or mobile *on* aircraft, satellites and remotely piloted vehicles. (A technical survey is given in appendix III.)

115. A lsrge number of ground surveillance rsdsrs, either fixed or mobile, farm the backbone of the strategic and tactical air defence operations. Airborne systems carry out far-reaching reconnaissance of the air and ground space frontiers. The United States SR-71 and TR-1 reconnaissance aircraft provide a high-altitude system for near-real-time battlefield surveillance. The National Aeronautics and Space Administration (NASA) operates a civilian version (the ER-2) as an Earth resources research aircraft. 17/ Other aircraft are also avsilsble.

116. Earth satellites are ideal platforms for remote sensor8 used in global studies, Majc: military satellites include photo-reconnaissance satellites; radar-reconnaissance satellites; electronic reconnaissance estellitesr early-warning satellites; ocean surveillance satellites; and weather and geodetic satellites. (Examples of United States satellites are given in appendix III.)

117. Some of the sensor techniques available in the military sector could be used on trucks, helicopters, planes and ships. Environmental applications include water and fire analysis, determination of pesticides, pollution measurement after an accident.

118. Isotopically labelled tracers, in conjunction with sensitive chemical analysis, have been developed to map pathways and measure contaminant migration times. Aaoelerator mass spectrometry and other techniques allow the detection of low concentrations of environmental isotopes in very small samples. Radioisotopes may be used in water cycle studies, in measuring erosion, to trsae the flow of energy through aquatic food webs, and age determination of groundwater, ice, roak, sediment, and so on (see appendix III).

119. Where invasive measurements are required, faster, cheaper and less disturbing methods of drilling can be developed, and end-of-drill pipe sensors can be used for in situ measurements and long-term monitoring of the progress in remediation. Existing non-invasive technologies for geophysical surveying can be coupled with improved ground-penetrating radar and advanced dats combination and computer imaging to provide clear, three-dimensional sub-surface images in real time.

120. Advanced remote sensors enable land and inland waters, oceans and both natural and managed ecosystems to be studied, Passive sensors can detect the thermal infrared and microwave regions of the radiation spectrum, which are not appreciably absorbed in the atmosphere, and some of the visible and near-visible parts of the spectrum. Active sensors, which scan the Earth's surface with a source generating electromagnetic radiation in the radar and optic81 ranges, are independent of the planet's natural radiative emissions. Both passive end active sensors are useful in environmental monitoring (see appendix III).

121. Passive sensors are particularly useful in the assessment of land-forms and how they change (basic geomorphology such as faulting, altitude of beds, folding, coastal geomorphology, land cover, water resource assessment, ice cover, volcanology, etc.). Thermal infrared sensing, for example, is very effective in the study of secondary volcanic activity; ocean and coastal currents; forest fires; and groundwater discharges.

122. Radar are used to monitor floods, ocean oil spills, sea-ice and soil moisture. Lasers have increasing appliaation in environmental work as in remote sensing of atmospheric constituents, conditions and properties.

123, Expected improvements include the next generation of laser-based remote sensors with emphssis on field robustness, minimal-attendance operation, ease of use, miniaturisation snd extension of the use of lasers to space platforms. Existing and upgraded airborne platforms, such as aircraft and smart balloons, can be used *for* aloud studies and experiments requiring atmospheric chemistry and monitoring,

B. Strengthening the quick response capabilities for dealing with environmental emergencies

124, In many reaent environmental emergencies resulting from an accident or s natural disaster, the human and material losses would have been considerably lower if relief agencies could have responded more rapidly. Swift response requires both prompt distribution of information and effective command *and* control of remedial actions.

125. As part of their command, control, communicstions and intelligence (C^3I) system, the military hsve developed communiastions systeme ensbling the coordination of large numbers of complex, diverse elements with minimal delays. The vast smount of data from military reconnaissance satellites is transmitted in near real-time to fixed or mobile ground terminals. Sensor data are collected and evaluated in military control and operation centres, which in principle could be used for environmental monitoring. *For* example, since declassification in 1973, data from the United States Defense Meteorological Satellite Programme were msde partially available to the scientific community.

126. NATO is developing the NATO Integrated Communications System, which comprises different communications systems, such as radio communications in different frequency *ranges,* telephone and telegraph systems, satellite communications and fiber optics. 18/

127. Military communicstions systems are sble to process and transmit lsrge amounts of data, from many different (remote) sensors and integrate it in a short time, often resl-time. They would be sppropriate to environmental applications in the advent of a major emergency, such as a large volcanic eruption, earthquake, reactor meltdown or bolide impact. The military systems are able to set up teams and mobile communications systems. A military approach to data processing and network design could be of great relevance to environmental assessment, particularly as more satellites come on-line.

128. A computerised emergency response network can be used to predict the dispersion and consequences of the release of hssardous chemicals, for example, discharges from tsnks, pipelines, multi-component evaporation from a liquid pool, building infiltration and other aspects. Other examples from the civilian sector include the German SAFER, the Austrian UMBLDR and UMBL-NET, the Swiss NABEL and the IIASA RAINS. 19/

129. The German Federal Civil Defence Agency operates a surveillance and information system that performs continuous monitoring of surface

/...

radioactivity and disseminates information on radioactive and chemical dsngers to the public. A similar eystem exists *for* the physical and chemical surveillance of *waters.*

130. Both the United States and the Soviet Union hsve launched accurate satellite global positioning systems. The civilian code of the United States Navstar system is sufficiently aaaurate to yield data on real-time navigational data for aircraft, ships and land vehicles. It can be used in mapping during environmental survey work or eavirosmental crisis management.

131. The more aoourste military access code obviously would hsve advantages in civilian applications, many of them environmental, for example, in geophysical and oceanographic research. The accursay of tne civilian channel can be increased, but at great oost of data acquisition, storage, transmission and processing. (A teahaicsl description is given in appendix IV.) Those limitations would be avoided if access to the military channel was given.

C. Environmental impact-assessment and decision-making

132. Environmental impact assessment (EIA) is a process used for identifying the likely consequences (risk assessment) to the environment and human health and welfare as a result of human activities such as the construction of dams, power-generating plants and other such major undertakings. The ultimate objective is to provide decision makers with an indication of the likely consequences of their actions, in the form of an eavirosmental impact statement. 20/ UNEP has provided guidance on the assessment of development proposals and supported research *on* EIA in developing countries. Attention has recently foaused increasingly upon EIA within the overall decision-making process. Decision makers need appropriate information to evaluate the actual state with respect *to* gains, aosts and risks, and they have to choose appropriate measures on the basis of models on the environment. Al though hum&n, organisationsl and financial resources are mostly needed, technology can contribute to the effectiveness of EIA decision-making through data processing, modelling and simulation, and systems analyses.

133, The large amount of data obtained from both military and environmental sensors can only be processed on large and fast computers, many of which are to be found in the military sector of the industrialized countries.

134, Computers are widely used in environmental studies for the evaluation of data acquired by remote sensing, analysis of data banks, expert systems applications, monitoring and prognosis of environmental changes and in numerical modelling and simulation.

135. Meteorologic81 satellites transmit millions of data per second to the Earth, which have to be either stored or processed in real-time. For this task fast computers are required. An exsmple is that of recording damaged forests. For those purposes one needs comprehensive databases, for example, a geographical information system.

/...

136. Expert systems for environmental services assist in the interpretation of seemingly unrelated data gathered from disparate sources. In the United States, for example, the Man computer Interactive Data Access System (McIDAS) can integrate conventional and satellite data together and permits real-time monitoring of rapidly changing weather situations. Expert systems have already been implemented in monitoring air quality, pesticide levels, ground and surface waters? environmental planning) and in the integration of conventional and satellite data in real-time to assist in the monitoring of rapidly changing weather systems.

137. Artificial intelligence, expert systems and robotics have significant roles in the development of new methods of intelligence gathering and weapons/defence systems and research into those areas has been heavily funded by military establishments. (A short survey on artificial intelligence and related issues is given in appendix IV.)

138, Clearly, many of the uses to which artificial intelligence and expert systems are put in the military would have application in environmental protection. Anything that renders industrial processing more efficient must reduce aaaidents, fugitive emissions, and so forth, and the decision support and options analysis functions would have a role to play in dealing with environmental disasters. The appliaation of some of those methods in the develupment of remote sensing techniques for monitoring and assessment, decision-making in crises, process control, remote analysis -of hazardous and radioactive materials is beyond doubt;

139. Assessment and interpretation also require the ability to model and simulate a broad range of phenomena associated with hazardous waste migration, clean-up and emergency response. Those phenomena involve complex processes that are generally amenable only to computer modelling. For process simulation, there must be the additional ability to model phenomena over long and short time periods. The simulation approach forms a basis for cost estimates of remedial measures, assessment of effectiveness and provides the rapid analysis needed in emergencies.

140. Simulations must inaorporate the physics and chemistry of flow through the environment. Eaah situation in clean-up or emergency response may be expected to have different environmental properties and waste characteristics. An understanding of the transport processes and effectiveness of remedial methods learned at one site can be extended to another, or from the laboratory to the field, only by computer simulation.

141. Atmospheric, surface-water emergency response and the other simulators for groundwater and surface water flow and transport already exist in moat of the military establishments of the advanced countries. Work with industry in the area of improved oil recovery is direatly applicable to that problem. Programmes such as those for dealing with atmospheric release and advisory capability provide a basis for emergency response models. Computer codes exist for understanding transport in groundwater.

groundwater. They evaluate the residual products from various industrial processes (e.g. the solvents used in the semiconductor industry or the smoke from fossil-fuel combustion) and can serve as risk-management tools. On a computer screen, the models show how contaminants move through the air, soil and water, and how much will be absorbed by people (e.g. of radionuclides, lead and arsenic, dioxin and benzene). Such models include the effects caused by chemical residues of burned or detonated waste explosives; 23/

(c) The Atmospheric Release Advisory Capability is an emergency response system that provides real-time prediction of the dose and deposition resulting from accidents involving the release of radioactive or toxic materials into the atmosphere. Real world events have been analysed, as in the nuclear reactor accidents at Chernobyl in the Soviet Union, at Three Mile Island in Pennsylvania, United States, and the re-entries of Soviet nualear-powered COSMOS satellites. Visual data to show the movement of the contaminant materials in the atmosphere and over the terrain are included. 24/

145. Systems analysis and management capabilities in the military sector can also serve as useful environmental tools. They could include information management and expert systems, such as distributed databases of environmental data; decision analysis through development of a framework to prioritize and select components for any proposed project; exposure assessment, that is, development of credible methods to quantify exposure and dose for all agents of concern; analysis of health risks resulting from energy and environmental alternatives resulting from the projects) systems analysis and simulation in the application of advanced simulation technology to evaluate process- and technology-alternative tradeoffs and system design and scheduling; and benefit-cost analysis for estimation of the costs of the project's technologies or processes, the market to which they can be applied and quantification of the health and financial benefits afforded by the technologies or processes.

D. Actions to protect the environment

146. Environmental protection often requires a multisectoral and multi-disciplinary approach, for example, in the development of energy-efficient and ecologically benign technologies; improvement of environmental compliance standards; and effective methods of environmental clean-up. 25/ Military establishments, for different reasons, have also been concerned with these issues. The military and environmental sector each stands to gain by pooling their expertise and resources in these areas of mutual concern.

1. Improvements in energy production, storage and utilization

147. Two important areas of concern to many nations, energy security and environmental impact , result from the current pattern of energy consumption.

problems at defence sites may include clean-up and disposal of both conventional and chemical and biological weapons, propellants, mixed hasardous and radioactive waste, groundwater and soil contamination from fuels, propellants, solvents and metals. Similar needs world wide are increasingly being identified, Bringing underground contaminants to the surface for treatment is often difficult, expensive, or ineffective. To date, most attempts at in situ treatment or destruction of underground contaminants have been unpredictable or ineffective because the relevant sub-surface process and their interactions were not properly understood.

153. At least four possibilities can be explored within this area: (a) waste minimisation; (b) waste treatment and disposal; (c) remediation strategies; and (d) instrumentation, The most efficient and effective way to handle waste is to generate the minimum possible by taking a structured waste minimisation approach. Advanced instrumentation for measurement and monitoring during waste minimisation and treatment activities, site characterization and application of clean-up methods are very effective tools.

Waste minimization

154. Most manufacturing leads to the generation of waste that requires energy for its collection, transport and disposal. Waste streams are also generated in the repair and reworking of equipment. The overall objective is to develop alternative, environmentally acceptable manufacturing processes and to use advanced systems analyses to eliminate, or drastically reduce, the generation of waste. That can include cleaning, coating, joining, packaging and closed-loop (zero-effluent) manufacturing processes. In addition, efforts involving the development of chemical sensors and automated analysers can be used to put in place process control systems for waste minimisation and to facilitate clean-up.

155. An environmental focus can be on techniques and processes for the minimisation of wastes. Examples of such an effort can include advanced technologies for metals, polymers, lead-free ceramics and glasses. One goal would be to eliminate volatile organic compounds, osone-depleting chemicals and heavy metals. Chemical and mechanical models can be developed for predicting reliability and ageing characteristics of assemblies manufactured using these new technologies. Supercritical carbon dioxide or other benign solvents could be used for polymer processing and would have significant environmental and energy conservation benefits. Plasma-based mitigation and plant cell-based concentration of metal ions also need evaluation.

Waste treatment and disposal

156. Recent advances, coupled with growing public concern about hasardous wastes, render many current waste treatment technologies inadequate or undesirable, New capabilities are urgently needed for the treatment of both the hasardous and, in the case of radioisotopic waete, the mixed (radioactive and hasardous) wastes that are produced. Those new technologies and facilities must comply with all existing and expected regulatory requirements.

162. Methods can be developed to devise and test integrated techniques for detecting and measuring sub-surface contamination; to monitor contaminant transport and fate; and to simulate, evaluate, and extrapolate the effects of clean-up alternatives. Site characterization supports site remediation, policy analysis, and strategy formulation by providing information about initial and limiting conditions, active processes and anticipated trends for laboratory and field-scale assessments and remediation.

Instrumentation

163. Analytical instruments for characterizing environmental contaminants are used in a wide range of problems. Sources of air, soil and groundwater contamination must be identified and the extent of contamination measured. Advanced instrumentation is required for an environmentally benign process of control.

164. The technologies described above cover a wide range of applications and also vary in the extent to which they are used. Some are available now, others will be in the near term and some remain in the future. As a complementary activity to technology transfer, cooperative efforts among nations having technological resources bring about earlier application. Present approaches can be expensive and may be ineffective or mostly shift the environmental impact elsewhere.

V. CONCLUSIONS AND RECOMMENDATIONS

A. The context

165. The accelerating impact of human activities on the environment has become a decisive factor in planet Earth's prospects for survival and well-being. The global environment is remarkably resilient and life on Earth has survived many onslaughts far more cataclysmio than any human intervention. Yet there are limits to nature's capacity for self-preservation that are not known. Mankind, for its own sake, needs to support the planet's inherent capability for replenishment.

166. Environmental integrity and sustainability of development are issues of paramount importance. In a fast-changing international climate, the preservation of the environment might be the next arena for new initiatives on multilateralism and the role of the United Nations. The global nature of the environmental challenge makes it imperative that international actions go hand in hand with national actions.

167. The world of today is very different from the time when environmental issues were first put on the international agenda. The 1970s were marked by a series of national initiatives to address environmental problems. The 1980s witnessed a global environmental awakening. It is hoped that the 1990s are poised for a comprehensive rescue plan for the global environment.

164. The environment recognises no divisions into political blocs, military alliances or economic systems. The opportunities for translating that recognition into praatioal actions were never more promising than now. Advances in technology have opened up new possibilities for understanding and meeting the environmental challenge. Public concerns over environmental issues are constantly rising to seek remedial measures. In recent years, environmental concerns have been addressed by more heads of State and Government, a larger number of economic and political organisations, and a greater variety of expertise than at any other period in recent history. Preservation of the environment is one new channel for the vast energies released from the end of the cold war.

169. Political détente has promoted the prospects of military de-escalation. Peace is being viewed as more than an absence of war. Concepts of security are being reviewed to include provisions for meeting other and non-military threats to security. Hopes have been revived for seeking security at lower levels of armaments and armed forces.

170. Either as a result of negotiated bilateral and multilateral agreements, or as a unilateral action, many Governments are reducing the size of their military establishments. The human, material and technological resources devoted to the military sector are either being reduced, released or turned idle. Even where no measures of arms reductions have been undertaken, the existing capabilities of the military establishments could be profitably used as environmental tools.

171. Protection of the environment requires a comprehensive set of measures for damage prevention and control) restorative measures for repair, rehabilitation and environmental compliance; remedial measures for development of ecologically benign and energy-efficient technologies; and promotional measures for raising environmental consciousness through education. There is also an urgency to develop capabilities for responding promptly to environmental disasters and to forestall such occurrences through constant monitoring of the environment.

B. The findings

172. In many ways the world-wide military establishments have a unique potential for augmenting the civilian endsavoure to protect the environment. Military organisations are well-equipped for dealing with catastrophic situations. Suitably qualified military personnel could be employed for responding to environmental disasters and handling and disposal of highly toxic radioactive or otherwise harmful substances. The de fence community has at its disposal a wealth of information gathered by intelligence sources that can assist in tracking changes in the atmosphere, the oceans and the surface of the Earth. Military satellites, aircraft, surface ships and submarines have the ability to collect additional information about climatic changes and the flow and temperature of oceans. Techniques for military surveillance could be easily employed for monitoring transportation of pollutants and toxic

materials, and for ensuring compliance with ecologically safe methods of weapons disposal.

173. Of all the military-related tosources, technology qualifies most for environmental use as it is inherently dual-purpose. Information technology is particularly easily adaptable for environmental purposes. Many of the results of military applications of information teahnology can be used for environmental ends without costly modifications of equipment and retraining of personnel. Clearly long-term objectives of environmental protection require an understanding of the technical issues underlying natural and man-induced risks, the ability to formulate clear policy decisions and the capability to respond swiftly to environmental emergencies. Military establishments can assist in achieving those objectives by contributing their technical expertise, advanced equipment and communications and surveillance systems.

174. A significant portion of the military spending of the technologically advanced countries is devoted to R&D. This is an area of military endeavours that has remained unaffected by the recent trends towards reductions in military expenditures. This is also an area requiring enormous investment of resources for environmental protection. National decisions to incorporate environmental concerns in the ongoing R&D endeavours could be particularly rewarding in the development of ecologically benign sources of energy, environmentally safe methods of weapons disposal and techniques for treatment of haeardous and toxic substances.

C. Conclusions

175. Bearing in mind the necessity to sustain the political momentum for effective global environmental cooperation, the group has reached the conclusion that:

(a) The world is only beginning to grapple with the full implications of the recent trends in arms reductions and national experiences in other uses of military-related resources are somewhat limited. There is thus a need to build upon the lessons learned so far and encourage greater efforts in that field by making the military sector a stakeholder in environmental protectioni

(b) Military-related resources are inherently national assets and the environmental challenge is global, There is thus a need to devise means for international cooperation in the use and redeployment of such resources as potential environmental tools;

(c) Public perceptions and scientific assessments of environmental hazards do not always coincide. There is thus a need for improved understanding of natural processes and their environmental consequences. The R&D endeavours of military-related establishments and their advanced equipment could be an additional tool to gaining such an understanding;

(d) The estimated costs of environmental protection have yet to be matched against the possible costs of environmental neglect. There is thus a need to attempt a cost-benefit analysis of environmental strategies. These ehould include the potential redeployment, reorientation or relocation of military-related resources, released or rendered idle by recent trends in arm8 reductions;

(e) The common goal of restoring the health of the planet's ecosystem cannot be attained in isolation from the issues of equity in the utilisation of global resources. There is thus a need to facilitate international technical cooperation and promote transfer of appropriate military-related technology as a strategy rather than a constraint for environmental protection;

(f) Public concern over ecological degradation and environmental emergencies requires establishment of priorities in national decieion-making. There is thus a need for responding effectively to environmental emergencies, an area where the skills and equipment af military establishments could be readily used with good results;

(g) While standards of environmental compliance vary from nation to nation, consequences of environmental abuse transcend national frontiers. There is thus a need for improving standards of environmental conformity that can be met within a shorter time with the involvement of aerial and maritime monitoring techniques and equipment available to national military establishments.

D. Recommendations

176. In view of 'the urgency of meeting the global environmental challenge, and the inadequacy of resources available for environmental protection, the Group recommends that the United Nations promote the possibilities of environmental applications of military-related resources through:

(a) Facilitating global sharing of environmental data, including that obtained through the use of military-related satellites and other information-gathering platforms;

(b) Developing plans to create international environmental relief teams making use of personnel, equipment and facilities from the military sector put at the disposal of the United Nations by national governments to strengthen other multilateral, international capabilities for responding to environmental emergencies;

(c) Acting as a clearing-house for international exchange of information about actual national experiences in environmental applications of military-related resources;

(d) Encouraging the involvement of military personnel in promoting, through education and training, public awareness of the need for environmental compliance and in providing skills for monitoring environmental abuses;

/...

(e) Giving due consideration to sustainable development and the transfer of military technology to the nor-military sectors, and exploring ways of overcoming constraints on transfer of environmental technologies within and among States.

177, Because actual experiences in the field are limited, and sovereign national cooperation is vital for a global effort in employing military-related resources for environmental purposes, the Group recommends that national Governments:

(a) Make inventories of their environmental needs and military-related resources applicable for environmental purposes, use such resources in national environmental action plans, and report their experiences to the United Nations ;

(b) Consider what military-related resources they aould place at the disposal of the United Nations or other international bodies on a temporary, long-term or stand-by basis as instruments of international multilateral cooperation for responding to environmental disasters and emergencies;

(c) Ensure that military activities conform to environmental norms and regulations and correct effects of past negligence in that respect)

(d) Develop environmentally sound technologies for weapons disposal)

(e) Incorporate environmental concerns in their military R&D programmes;

(f) Integrate the aims of environmental preservation and sustainable development in their concepts of security;

(g) Make greater efforts to promote disarmament as military activities impinge on the environment in both war and peace time.

178. The Group also recommends that the Preparatory Committee for the 1992 United Nations International Conference on Environment and Development consider the incorporation of the conclusions and recommendations of the present report into the elements for an "Earth Charter** and "Agenda 21".

Notes

1/ Environmental Problems: A Global Security Threat, report of the Stanley Foundation, 1989.

2/ Jim MacNeil, "The greening of international relations", International Journal, vol. XLV, No. 1 (Winter 1989-1990), pp. l-35.

3/ Ibid.

4/ United Nations, Treaty Series, vol. 480, No. 6964;

Notes (continued)

5/ The United Nations Disarmament Yearbook, vol. 12: 1987 (United Nations publication, Sales No. 88.IX.2), appendix VII.

6/ Ibid., vol. 151 1990 (United Nations publication, Sales No. 91.1X.81, appendix II.

7/ United Nations, Treaty Series, vol. 944, No. 13446.

8/ Umweltschutz in Bereichen der Bundesregierung [Environmental protection within the Federal government], Bonn, Press and Information Department, 1989.

9/ Zukunftskonzept Informationstechnik [Future concept for information technology], Bonn, Federal Ministry for Research and Technology, 1989.

10/ C. Boyden Gray, David B. Rivkin, Jr., "A 'No Regrets' Environmental Policy", Foreign Policy, No. 83, Summer 1991, pp. 47-65.

11/ The Naval Arms Race (United Nations publication, Sales No. E.86.IX.3), paras. 308-326.

12/ Arthur A. Alexander, "National Experiences in the Field of Conversion: A Comparative Analysis", paper presented to the United Nations Conference on Conversion: Economic Adjustments in an Era of Arms Reduction, MOSCOW, 13-17 August 1990.

13/ Yuri Andreev and Alexander Kislov, 'Conversion in the USSR: gaining Experience" , Peace and the Sciences, No. 4, 1990, pp. 22 and 23.

14/ Alan Shaw, "Problems arising from the implementation of disarmament measures", paper presented to the United Nations Conference on Disarmment Issues, Kyoto, Japan, 27-30 May 1991.

15/ New Technologies in the 1990s: A Socio-economic Strategy, OECD, Paris, 1988, pp. 35-37.

16/ World Resources 1990-1991, a report by the World Resource6 Institute, Oxford University Press, 1990, 227 p.

17/ A technical description of these systems is given in: The C^3I Handbook, Third Edition, Palo Alto', 1988.

/...

Notes (continued)

18/ A survey on the NATO C31 system and related information and communication technologies can be found in the following sources: J. Grin, Military-Technological Choices and Political Implications: Command and Control in Established NATO Posture and a Non-Provocative Defence, Amsterdam: VU University Press, 1990; P. Stares, Command Performance: The Neglected Dimension of European Security, The Brooking6 Institution, Washington, D.C., 1991; J. Schef fran, NATO Command and Control Between High-Tech Warfare and Disarmament, Peace Research Institute, Frankfurt, 1991.

19/ The different systems have been described in: W. Pillman, A. Jaeschke (eds.) , Informatik für den Umweltschutz, [Computer science for environmental protection], Springer, 1990.

20/ P. Wathern (ed.), Environmental Impact Assessment, London, Hyman, 1988.

21/ For a more detailed description of the models, see W. Pillman, op. cit.

22/ M. C. MacCr:acken, "Global Atmospheric Effects of Nuclear War", Energy and Technology Review, May 1985, pp. 10-35.

23/ T. E. McKone, "GEOTOX: simulating Contaminant Behaviour and Human Exposure", in Energy and Technology Review, May 1987, pp. 14-20.

24/ R. D. Belles, H. Walker and T. J. Sullivan, "Data Visualization and the ARAC Emergency Response System", in Energy and Technology Review, January/February 1990, pp. 3-15.

25/ Most of the information contained within the present section has been extracted from a draft document provided by the Department of the Environment weapons laborstories to that Department in response to the Department of Defense Strategic Environmental Research and Development Program. With respect to energy, the following reference is in placer Energy Technology for Developing Countries: Issues for the US National Energy Strategy, Lawrence Berkeley Laboratory, December 1989.

APPENDIX I

The United States Department of Defense Critical Technologies Plan a/

Applications to Products and Processes / Critical Technologies	Weapons					Platforms				Information Systems						Support							
	Small Weapons	Ballistic Missiles	BM/D/ASAT	Electronic Combat	Electromag Weapons	Tanks/Ground Vehicles	Submarines/Ships	Aircraft	Spacecraft	Search & Surveillance	Reconnaissance	Battle Mgmt/C3	Non-Cooperative ID	Guidance & Control	Arms Control	Design & Integration	Manufacturing	Maintenance/Logistics	Test & Evaluation	Training	CBD	Medical	Combat Environment
1 Microelectronic Circuits and Their Fabrication	a	x	x	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
2 Preparation of GaAs and Other Compound Semi-Conductors	x	x	x	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
3 Software Producibility	x	x	x	X						X	X	X	X	X	X	X	X		X	X	X		X
4 Parallel Computer Architectures		X	x	X						X	X	X	X		X			X	X			X	X
5 Machine Intelligence/Robotics	x	x	x	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X
6 Simulation and Modeling	x	x	x	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7 Integrated Optics	x	x	x	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
8. Fiber Optics						X	X	X	X	X	X	X				X	X	X					
9. Sensitive Radars	x		x	X	X					X	X		X		X	X	X				X	X	X
10. Passive Sensors	x	X	x	X		X	X	X		X	X		X	X	X	X	X	X			X	X	X
11 Automatic Target Recognition	x	a	x							X	X	X	X	X	X	X							X
12. Phased Arrays	x	X	x	X						X	X	X	X		X	X	X						
13 Data Fusion	x		X	X		X	X	X	X	X	X	X	X	X	X	X			X	X			X
14 Signature Control				X		X	X	X	X	X	X	X	X			X							X
15 Computational Fluid Dynamics						X	X	X	X							X			X				
16 Air Breathing Propulsion	x		x			X		X								X	X						
17 High Power Microwaves					X					X	X	X				X	X						
18. Pulsed Power			X		X	X	X	X	X														
19 Hypervelocity Projectiles			X		X																		
20. High-Temp/High-Strength/Light-Weight Composite Materials	X	x	x	X	X	X	X	X	X							X	X	X					
21 Superconductivity	a	x	x	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
22 Biotechnology Materials and Processing																X	X				X	X	

a/ Critical Technologies Plan, Washington, D.C., Department of Defense, 1989.

APPENDIX II

Technological capabilities of waste management

Supercritical carbon dioxide

Orgonics are soluble in supercritical carbon dioxide, thus a selective extraction process for solid phases can be developed which concentrate8 the organics while the solvent is recycled. The process is a possible pretreatment for extraction of organics by concentration to be followed by a destructive treatment such as supercritical water oxidation.

Supercritical water oxidation

Destructive oxidation of haaardous wastes to carbon dioxide, water, and other small molecules can minimize waate volume and detoxify many haaardous compounds. Supercritical water is a unique solvent medium in which oxidation can take place at lower temperatures than those of the most common oxidation technique of incineration in air at atmospheric pressure. Possible applications include propellants, munitions, gunpowder, flares, explosive wastes, groundwater contaminated with pesticides or animal wastes, nitrates from fertilizers and industrial wastes.

Electrochemical oxidation

Two technologies are involved8 (1) electrochemical oxidation of liquid and solid wastes at low temperatures and pressures, and (2) use of advanced membranes in conjunction with electrochemical cells to remove organics from water.

Robotics

Robotics are used to produce automated systems for remotely analysing the chemical content of hasardous and radioactive materials. This work hae been underway for several years as a basic need and use for the defence effort.

Magnetic separation of waste

With the development of high-field strength, superconducting magnets, it is possible to magnetically separate a wide variety of compounds, including actinides, from liquid, solid or gaseous wastes.

Plant 0811 (jimsonweed) clean-up

Development of cell cultivators and engineering methods for using jimsonweed cells for sequestering plutonium, barium, and other metals from aqueous solutions and for cleaning up the "pink water" the results from machining explosives.

Performance assessment, data interpretation, and models

Efforts in support of performance assessments and data interpretation include atmospheric pathways, surface water contaminant transport, sub-surface migration, site characterization data interpretation, waste characterization and predicted behaviour, and application of isotopic tracers for model verification. Future directions may apply to neural networks and uncertainty analysis to the suite of computational tools.

Environmental biotechnology

Biological processes are an attractive cption for degrading organic wastes. Microorganisms wil metabolize an impressive variety of organic substrates. During metabolism, the organics are chemically transformed into metabolic intermediates which the microbes use for production of energy and biosynthesi to cellular material. Consequently, the organic substrates are chemically converted into harmless products: carbon dioxide, water, minerals and biomass. Many haxardous chemicals including the chemical classes found in mixed waste, e.g., hydrocarbons, halogenated aliphatics and polychlorinated biphenyls have been shown to be degraded by microorganisms. Natural microorganisms have been isolated that will use explosives as a food source. Currently, organisms have been isolated that are capable of destruction of TN and nitroglycerin. Organisms to digest HMX, PBX, and nitrocellulose are bein selected.

Closure and containment of waste sites

Defence-related waste site closure technologies that are directly transferabl to mixed and haxardoue waste sites with some changes to meet the close-in-place requirements. An integrated cover design for such closures that addresses water balance on the surface and subsurface, biotic intrusion effects, and seasonal effects is one technology. For faster regulatory acceptance, a demonstration of the design on a semi-arid and humid site containing mixed wastes could complote the full utilization of the technology

Chemical sensors

For use in the remote determination of radionuclides and hasardous organics. The use of electrochemical, piezoelectric oscillators and spectroscopic technology with selective polymers, supports or encapsulants, protective coatings, and attachment of polymers to substrates with an emphasis on selectivity, durability, and repeatability.

/.

Optical Diagnostics for real-time remote in-situ-monitoring of environmental contaminant8

The technology includes the selection and integration of optical diagnostic methods for a range of contaminants, i.e. organica, inorganica, radionuclides and mixtures. Included are phytothermal spectroscopy and laser-induced fluorescence, near- and mid-infrared absorbance/luminescence, vibrational Ramen spectroscopy, laser photoionisation spectrometry and laser light detection and ranging (lidar) .

Destructive technologies for waste

Under investigation in this category are plasmas, microwave8 and Accelerator Transmutation of Waste (ATW). The latter technology uses an accelerator to generate a high flux of neutrons by directing a beam of subatomic particles into a lead-bismuth target. The interaction of beam and target releases neutrons from the target) these neutrons then enter a surrounding heavy-water moderator which slows them down. The system is designed 80 that the neutron8 then interact with radioactive waste into short-lived radioactive or stable (nonradioactive) substances. The transformed refuse would in many cases still require isolation from human contact but demands upon storage would be reduced from tens of thousands of years to only hundred8 of years, or leas.

APPENDIX III

Sensor fundamentals and applications

Sensors *are* the physical trsasducers by means of which specific environmental attributes *are converted into* information, usually *in* the form of a quantitative, electronic signals. The principal indices *of* sensor performance are its spatial resolution, or accuracy, and its ability to discriminate between the object's signal and random variation8 in the object, a threshold called the signal-to-noise ratio (SNR). Overall performance is a compromise between resolution *and* area covered.

Sensors CM react to physical, chemical *or* biological phenomena often in combination. Depending on the basic physical principles used for measurement one can distinguish between seismic-acoustic sensors which react to mechanical pressure (e.g. sonars), magnetic sensors which measure disturbance8 in the earth magnetic field, detector8 measuring radioactivity and electromagnetic sensors which are sensitive to different regions of the electromagnetic spectrum, In the last mentioned category, moat important are radar wave sensors and sensors operating in the visible and infrared (IR) parts of the spectrum (generally called opto-electronic sensors). Remote sensing, as its name implies, means the detection of (environmental or military) changes at a distance from the sensor and is now almost synonymous with the use of airborne and apace platforms. a/

1. Passive sensors

Passive sensors consist *of* a receiver that detect8 some attribute of the object (e.g. the amount of heat emitted from different landforms or an enemy tank). Some illustrations of their environmental use are given below:

(a) Photographic: visible and near infrared

Under optimum conditions, aircraft photography can provide spatial resolution in the range of approximately 1 cm. Military reconnaissance satellites are reported to provide resolutions down to 10 cm and civilian satellites down to 10 metres. This disparity suggests that non-military application8 could benefit from military technology and data. Photography, from both aircraft and satellites, is a major tool *for* remote sensing of the lithosphere. being particularly useful in the assessment of landforms and how they change (basic geomorphology, land cover, water resource assessment, Ice cover, vulcanology, etc.) and provides quantification *of* distance, areas, volumes, height, and directions. High resolution photography, coupled with photogrammetry and computerised image enhancement (digitization of the density data) is extremely versatile.

(b) Vidicon camera: visible and near infrared

The vidicon camera is the electrical analogue of the conventional camera in which an optical image is formed on the photo-sensitive surface of an electron gun which then converts the image into an electrical signal. Vidicon TV cameras are deployed on a number of meteorological satellites, and the Landsat series has an improved version called the Return Beam Vidicon (RBV).

(c) Thermal infrared scanner

In thermal infrared radiation, the detector convert8 intensity to electrical signals which are input to a single-line cathode ray tube (CRT) which records a line on film. As the sensor moves, successive new lines are swept and an image, perpendicular to the direction of movement, is formed. Thermal infrared sensing is particularly effective in the study of secondary volcanic activity (fumaroles, gas vents that follow an eruption); ocean and coastal currents; forest fires; and ground water discharges. Thermal inertia mapping is also able to study near surface conductive heat transfer.

(d) Optical-mechanical, multispectral scanner

Optical-mechanical, multispectral scanners (MSS) using detector8 calibrated or designed for specific spectral band8 of radiation can collect simultaneous data over a range of wavelengths. For example, the MSS on the Landsat series of satellites provides simultaneous data on the Earth's surface at four different bands. The Computer Compatible Tape (CCT) from the Landsat MSS allows advanced methods of pre-processing, enhancement and classification of information. Because clear water transmit8 energy in the blue-green range and absorbs in the near infrared, MSS can detect turbid, sediment laden waters and has proven valuable in studies of river flooding.

(e) Microwave sensors

Passive microwave sensors (PMS) detect emitted, reflected and transmitted radiation in the microwave part of the radio spectrum. Compared with optical (visible and infrared) sensors, PMS are effective at night, in poor weather and can penetrate clouds. However, their resolution is poor (several metres) and the strength of the signal is determined by the temperature and dielectric properties of the Earth's surface. An Electrically Scanning Microwave Radiometer (ESMR) is fitted to the Nimbus-5 satellite. Passive microwave sensing is particularly effective in monitoring water resources.

2. Active sensors

Active sensors comprise a transmitter which scans the object, usually with some type of electromagnetic radiation (e.g. microwaves, infrared radiation, radio waves), and a receiver which detects how the beam interacts with the target object (e.g. how the radar beam is reflected back from an aircraft, sea surface, or landform).

(a) Radio detection and ranging (radar)

Radar systems were developed for military uses, primarily to detect targets (typiaally aircraft). In addition to measuring distance, radar can be used to measure the velocity of moving targets (Moving Target Indication, MTI) by determining the frequency difference between the emitted and received radio waves (the Doppler effect). Of greater relevance to environmental sensing is the ability of Side-Looking Airborne Radar (SLAR), which uses short pulses of radio waves emitted perpendicular to the flight path of an airborne platform, to generate two-dimensional images of the terrain from the reflected signal.

Phased Array Radars (PARs) use a static (i.e. non-scanning) antenna which enables greater scan rates, multi-target tracking, reliability and accuracy to be achieved. Synthetic Aperture Radars (SARs) are able to simulate the performance of a very large antenna, by computation, to provide a very high resolution. Radars working at the short wavelengths (millimetre-wave) provide greater accuracy and are less susceptible to disturbances. Electronic miniaturization has resulted in the development of very small radar units that can be mounted on unmanned platforms.

Radars, particularly SAR, can be used to monitor floods, ocean oil spills, sea-ice and soil moisture, to measure wind Speed and the intensity of rain and snow. In recent years Doppler radars have been developed specifically to detect tornadoes and other forms of storm.

(b) Light detection and ranging (lidar)

The complement to radar in the visible and infrared region of the spectrum is called lidar (light detection and ranging). It finds military and civilian application8 in the location of objects in the atmosphere and in space. The differential absorption lidar (DIAL) provides range-resolved measurements of the concentration of chemical pollutant8 by reflecting pulses of laser light at two wavelengths. As a pulsed laser is used, the time-resolved recording of the backscattered photon8 gives information on the altitude.

Lidar systems have been tested on balloons and aircraft, and designed for space applications. Commonly, spaceborne lidar technology is focused on temperature profile estimation, determination of minor atmospheric constituents like ozone (mainly in the upper atmosphere) and aerosol determination. b/ Applicable pulsed lasers which are tunable in the appropriate wavelength region may be selected from semiconductor diode lasers, spin-flip Ramen lasers, optical parametric oscillators, high pressure gas lasers, and others. c/ Some of these laser types are developed in the military field, Their main differences relates to spectral resolution, which is best frr the semiconductor diode lasers, and output energy, which is best for the gas lasers. The main disadvantage8 are the high costs of such eyetems and/or their weight (especially for high-energy lasers). There are limitations in detecting chemicals which are covered by clouds.

/...

(c) Sonar

Sonar (sound navigation and ranging) is a technique for detecting and determining the distance and direction to underwater objects by acoustic means. In the military, sonar is used in submarine detection and applied to acoustic homing torpedoes, acoustic mines, and mine detection. For environmental purposes, sonar can be used for detecting icebergs, fish finding, depth sounding, mapping of the sea bottom and Doppler navigation. Small sonobuoys can be air-launched by helicopter.

(d) Isotope tracing

Natural variation in stable isotopes of carbon, nitrogen, and sulphur can be used to trace the flow of energy through aquatic food webs. Tritium, deuterium, and oxygen-18 content in precipitation has been monitored monthly. since the early 1960s by the global network of stations jointly operated by the International Atomic Energy Agency (IAEA) and the World Meteorological Organieation (WMO). Observation data show that the concentration in air of some trace constituents such as carbon dioxide, methane, carbon monoxide, ozone, CFCs, nitrogen and sulphur oxides, is changing as a result of anthropogenic emissions. In the Chernobyl area, investigations are directed at the migration of radionuclides released as a result of the nuclear power plant accident in 1966. In the future, it is necessary to develop more adequate interpretative and prognostic models, and to establish databases on typical characteristics of pollutant migration under typical geological and thermodynamical conditions. d/

3. Platform8

Scout tanks

The German scout tank "Fox" is based on the TM-170 already in production and service. e/ Instruments on board the tank essentially include gamma detectors for the detection of nuclear radiation and mass spectrometers for identifying organic substances like chemical warfare agents. A database stores up to 900 substances, and print-outs are provided. Meteorological sensors on-board can measure temperature, humidity, wind speed and direction and barometric pressure. A military land navigation system is used to determine the exact position. The mobile mass spectrometer can work under extreme conditions of temperature and humidity and is totally controlled by microprocessors. Environmental applications include water and fire analysis, determination of pesticide and pollution measurement after an accident.

US Reconnaissance satellite8

The moat advanced military photo-reconnaissance satellites like the US "keyhole" satellites (KH-11, KH-12) consist of an array with millions of small pixels and a reported spatial resolution of 15-30 cm, which would be much better than for civilian photo-satellites. Images at night can be made through the use of infra-red detector8 and photomultipliers which have a

/...

substantially lower resolution than the visible-light images. Lacrosse is a cloud-penetrating all-weather radar in space with a number of sensors specially designed for long life. Its resolution is assumed to be in the range of 2-3 m. Depending on the frequency used, the Synthetic Aperture Radar (SAR) of Lacrosse is estimated to be capable of penetrating one to several meters of mature green crops. f/ Reconnaissance satellites are important for crisis monitoring, early-warning and disarmament verification but could principally perform functions for environmental monitoring with very high resolution.

The US Defense Support Programme (DSP) provides a satellite surveillance system for early warning of a ballistic missile attack. It consists Of three geostationary satellites, several ground processing stations and a communications network. The primary sensor is a large telescope which coneiets of an array of *infrared* detectors, each of which sees a terrestrial *area* less than two miles square, g/ Besides detecting a missile's heat plume, it is able to locate large heat sources (fires), either from natural or man-made disasters.

The US Defense Meteorological Satellite System (DMSP) collects data with a number of different sensors: high resolution sensors (scanning radiometers) in the visible and the thermal infrared channels which are used to analyse cloud patterns in eupport of military operations (e.g. storm warning); passive microwave and infrared temperature soundersr a microwave imager that penetrates cloud cover to obtain a variety of environmental data) an electron spectrometer measuring Earth's charged-particle activity2 a TV camera. A lidar is planned to measure the three-dimensional wind field of the atmosphere, a vacuum ultraviolet sensor to determine the height of cloud tops and aerosol content of clouds, and an ionosonde that measures the high-frequency radio reflection heights of the atmosphere. h/

4. Environmental applications of remote sensing i/

(a) The atmosphere

The collection of meteorological data has been traditionally ground-baaed with the use of such etandard instruments as barometers, thermometers, anemometers, rain-gauges and sunshine recorder8 distributed in a dense network of stations over a country. Specialized sounding rockets have been employed to obtain pressure, temperature. density and wind data of the uppermost layers of the atmosphere for meteorological and geophysical studies. Remote-sensing satellites are particularly useful in the measurement of temperature structures; surface radiation studies; cloud classification; rainfall estimation; water vapour analysis; wind field analysis; production of severe storms; weather analysis and forecasts; assessment of ozone depletion; and monitoring the greenhouse effect.

(b) The lithosphere

Major environmental applications of remote sensing of the lithosphere from aircraft and satellites are to detect, identify and map earth features on the surface and sub-surface and to infer the processes at work. Aerial photography has been used to record volcanic eruptions, e.g. the eruption of Mount St. Helens. The thermal infrared scanner is suited to monitor secondary volcanic activity, such as fumaroles, gas vents, etc. In the coastal environment, aerial photography reveals details of macroscopic coastal feature6 and circulation pattern6 of the sea water. Other lithospheric use6 of satellite remote sensing include: geological reconnaissance of concealed terrains in harsh environments; floodplain delineation and groundwater flow system detection; mapping of geothermal phenomenal thermal inertia mapping; detection of silicate rocks; determination of terrain slope; detection of structural linear features) extraction of drainage network parameters; geological mapping in heavily forested terrain; snowfield and cryosphere mapping; mapping of surface deposits in desert regions; assessment of grass and forest fire damage) landform analysis; and mapping of surface structures.

(c) The organic biosphere

In the study of vegetation, crops and soils, there is invariably the need to carry out surveys with a view to discover their spatial distribution, structure and type. This information is indispensable for the purpose of management in agriculture and forestry, for informed decision-making in planning, for feasibility in land development project6 and many engineering works. Biospheric use of satellites is well established for vegetation damage assessment) crop identification and discrimination; detection of crop conditions; soil mapping; forest inventory; wetland vegetation; soil moisture determination; crop temperature and crop yield prediction; estimation of the amount of green vegetation. Other missions have been undertaken as, for example, to rescue a crashed aircraft or a sinking ship by detecting its emergency signals from space. j/

(d) The hydrosphere

The importance of remote sensing satellite6 in collecting data concerning the physical, biological, geological and chemical characteristics of the sea is obvious. Both aerial and satellite photography can be used to traok the drift and dispersion of industrial wastes in the sea, for instance, of heavy metals and organic chemical compounds. Aerial observation is essential to investigate and gather evidence of violation for: illegal and permitted dumping of chemicals, incineration of chemicals, surveillance of sea traffic, fishing protection, off-shore activities, search and rescue, ship traffic control, sea ice mapping, smuggling activities and general environmental investigation. To detect oil slicks, ultraviolet, thermal infrared and microwave sensors are potentially suited. The laser fluorosensor gives a coarse-type classification of oil. Passive microwave radiometers have been used in detecting sea-surface temperature, sea ice and salinity. Radar ha8 been employed in mapping sea ice, measuring wave heights, detecting aquatic plants and fish stock, determining water depths and sensing oil slicks. k/

Table 1 (continued)

Satellite	Country	Sensor	Wavelength or frequency	Spatial resolution
Lacrosse	USA	Synthetic aperture radar (SAR)		1.5 - 3 m
Landsat 4-5	USA	Multi spectral scanner (MSS) Thematic mapper (TM)	Four channels. visible and reflected Infra-red Visible, near infra-red Thermal infra-red	80 m 25 m 100 m
METEOSAT	ESA	Multi spectral scanner	Visible 0.5 - 0.9 µm Infra-red 10.5 - 12.5 µm	2.5 km 5 km
M. Ross (Cancelled)	USA	Altimeter Scatterometer Lou frequency microwave radiometer (LFMR) Special sensor microwave imager (SSM-1)		
RADARSAT	Canada	Synthetic aperture radar (SAR) Microwave scatterometer Microwave radiometer Optical sensor	5.3 (c-band), 1.3 GHz (L-band)	E-30 al
Salyut 6	USSR	Multi spectral scanner (MSS) Film camera Returned-beam vidicon (RBV)	Visible Infra-red Visible Visible	20 m 50 m 80-120 m 100 m

/...

Table 2. Sensors mounted on the Nimbus 7 satellite, their scientific purposes and applications m/

Sensor	Channel wavelengths	Scientific parameters	Applications
CZCS	.44, 0.55, 0.56, 0.67, 3.75, 11.5 µm	Temperature, spectral radiances, chlorophyll, sediment	Geodynamics of coastal regions, chemical and thermal pollution, fishery resources, deep ocean monitoring, oil spill monitoring
ERB	10 solar viewing covering 0.2-50 mm; Earth viewing channels covering 0.2-50 µm	Earth fluxes, solar fluxes, zonal insolation	Climatology, ocean/atmosphere dynamics, weather modelling, terrestrial reflectance studies
LIMS	6.25, 6.75, 9.65, 11.35, 15.25, 1 broad channel 13.2 - 17.2 µm	Gas concentrations and temperature profiles in the stratosphere	Atmospheric pollution monitoring photo-chemical studies, atmosphere gas dynamics, climatology
SAM'S	9 channels defined by cell modulation 4.1 to 15.0 µm and 25 to 100 µm	Gas concentrations and temperature profiles in the stratosphere	Atmospheric pollution monitoring, photo-chemi crl studies, atmosphere gas dynamics, climatology
SAM II	1 µm	Aerosol extinction and extinction ratio profiles and stratospheric optical depth	Atmospheric sources and sinks, earth radiation budget studies, aerosol injection dynamics
SBUV/ TOMS	12 fixed wavelengths from 0.255 to 0.380 µm and continuous scan from 0.160 to 0.400 µm	O^3 profiles, total atmospheric 03, solar irradiancer, terrestrial radiances	03 dynamics/modelling, climatology and meteorology, O_3 solar relationship
SMMR	6.6, 10.7, 18.0, 21.0, 37.0 GHz (frequency), scanning multichannel radiometer	Sea-ice parameters, ocean surface conditions, atmospheric conditions, land parameters, glacial features	Ocean dynamics, ice dynamics, ocean/atmosphere interactions, climatology and weather monitoring
THIR	0.75, 11.5 µm	Surface temperature, cloud top temperature	Effects of cloudiness on other Nimbus-7 instruments data

Table 3. Applications of Landsat-4 thematic mapper bands a/

Band	Spectral range	Application
1	0.45-0.52 µm	Water body penetration, coastal water mapping, differentiation of soil from vegetation.
2	0.52-0.60 µm	Measurement of visible green reflectance peak of vegetation for vigour assessment.
3	0.63-0.69 µm	Chlorophyll absorption band useful in discriminating vegetation.
4	0.76-0.90 µm	Determination of biOma88 content. Delineaticn of water bodies.
5	1.55-1.75 µm	Determination of vegetation moisture content and soil moisture. Differentiation of snow from clouds.
6	10.40-12.50 µm	Vegetation stress analysis. Soil moisture discrimination, thermal mapping.
7	2.08-2.35 µm	Discrimination of rock types. Hydro-thermal mapping,

Notes

a/ A good description of sensor technologies for environmental applications is given in C. P. Lo, Applied Remote Sensing, Longmans, 1986.

b/ In 1977 NASA convened an international study group to develop concepts for an atmospheric Shuttle lidar system, which suggested 26 experiment8 to demonstrate the whole range of lidar applications. A scaled-down version is called LIT& (laser in space technology experiment). See D. B. Ho::gan and A. Rosenberg, 'Spaceborne Lidar Sensors: Opportunity and Challenge@', in A. Sahnapf (ed.) , Monitoring Earth's Ocean, Land, and Atmosphere from Space, New York, American Institute of Aeronautic8 and Astronautics, 1985.

c/ R. Trapp, "Verification of an international agreement banning chemical weapons - the possible role of satellite monitoring", in B. Jasani and T. Sakata (eds.), Satellites for Arms Control and Crisis Monitoring. Oxford University Press, 1987.

d/ See the special edition on isotopes in environmental research of the IAEA Bulletin, April, 1990.

e/ "NBC version of TM-170 unveiled", in Jane 8 Defence Wee-, 13, August 1988, p. 278.

f/ See R. Kokoski and S. Koulik (eds.), Verification of Conventional Arms Control in Europe, SIPRI, Stockholm, Westview Press, 1990.

g/ The C^3I Handbook, 3rd ed., Palo Alto, 1988.

h/ L. Gomberg, "Remote Sensing of the Earth with the Defense Meteorological Satellite", in A. Schnapf, op. cit.

i/ An illustrative and detailed examination of the different environmental region8 can be found in C. P. Lo, op. cit.

j/ The multinational COSPAS/SARSAT programme ha8 demonstrated 8ome success in this respect.

k/ There are specific types of satellite-borne sensors designed for oceanographic applications, such as the Coastal Zone Colour Scanner on board Nimbus 7 designed specifically to provide information to marine biologist8 and pollution detection agencies (see table 2), and the SEASAT experiment to study the ocean surface by microwave sensors. Encouraged by the results, future satellite systems have been planned, such a8 MOS-1 of Japan, SPOT-2 of France and the ERS-1 mission of ESA.

l/ K.-H. Szekielda (ed.), Satellite Remote Sensing for Resources Development, Graham and Trotman, 1986; B. Jasani, op. cit.; and A. Schnapf, op. cit.

/...

Notes (continued)

m/ R. Router and R. H. Gillot, Remote Sensing of Pollution of the Sea, Proceedings of the International Colloquium, University of Oldenburg, March 1907.

n/ R. Reuter, op. cit.

APPENDIX IV

Trends in computing, communications and modelling

1. Computers

In microelectronics, there is a continued trend towards very large scale integration and very high speed integration. Supercomputers with thousands of microprocessors working in parallel are able to process tens of billions of operations per second, providing the basis for near-real time simulation of complex military and environmental systems. Computing speed and information storage/retrieval capacity have far outstripped the ability to programme the computer and develop reliable software code. This software crisis lead to the development of new methods of software engineering. The increasing integration of software and hardware is manifest in the development of chips, designed to perform specific functions.

2. Machine intelligence and robotics

Expert systems store knowledge in a specific subject or area, and provide conclusions, answers and options to specific questions to be given within that area according to formal rules. Robots are machines controlled by computer progrsmmes that attempt to imitate human capabilities and activities, and can also be used in training. Methods of artificial intelligence (AI) are developed for automatic pattern recognition, classification, identification, and reproduction according to defined criteria and characteristics. In reverse, these methods can be used in the generation of graphics and speech synthosis. The mathematical concepts of fueey logic and fractal geometry are increasingly used in decision-support, and character recognition/generation algorithms, respectively. Neural networks intend to apply principles of the human brain for technical problem solution.

3. Communication systems

Communications systems transport messages from a transmitter to a receiver through communications channels which can be cables (metal or fibre-glass) or radio propagation paths. The radiofrequency spectrum ranges from very low frequencies (VLF) to extremely high frequencies (EHF) and is divided into eight bands. Satellite communication (SATCOM) is important up to the highest frequencies and is able to transmit extreme amounts of data within short time, which is relevant for environment&l monitoring, Compared with metallic cables, optical fibres have significant advantages: they have reduced weight, volume, electronic signatures, installation time, and possible costs, combined with increased bandwidth, data rate, security, reliability and immunity to electronic countermeasures (ECM).

As a standard for telecommunications, the International Telegraph and Telephone Consultative Committee (CCITT) and the International Standard Organization (ISO) have agreed upon the Open Systems Interconnection (OSI) reference model. OSI prescribes a set of rules (protocols) to be obeyed by specific computer networks which are divided into seven layers. For digital network communications the Integrated Services Digital Network (ISDN) has been introduced to transmit all types of messages (voice, telex, fax, data) in atandardiaed format by digital computers.

4. Global Positioning System (QPS)

The United States Navstar GPS consists of a series of satellites orbiting such that, under ideal conditions, a ground station can receive simultaneous signals from four satellites. After processing, it provides precise information on the geographical and altitude coordinatea of the receiver, The satellites and receivers contain synchronised atomic clocks and the time delay6 between the transmission and reception of the signals enable the distances between satellites and receiver to be determined: the four separate distances describing a unique location in three-dimensions on the Earth's aurf ace. Some receivers are small enough to be carried by individual soldiers and have been deployed on a wide range of military vehicles and by personnel. The United States system transmits on two channels, under the policy of "selective availability": a raw code (C/A) which is available for civilian use with an accuracy of 100 m and a military code (P) accurate to 17.8.m horizontally and 27.7 m in altitude. a/

5. Modelling and simulation in command aud control

Modelling and simulation play an important role in the military command, control, communications and intelligence (C^3I) system. Equipment, personnel and know-how from this field may be applicable to environmental applications. Some examples are given below: b/

1. From a conceptual point of view, Lawson's cybernetic model of the command and control decision-making loop is important which breaks down the whole process into several subfunctions: sense (environment), process (data), compare (actual with desired state), decide (according to mission), act (on own forces).

2. Process models describe the dynamic interaction in command and control and with the environment: two-aided combat and conflict models; the timeline approach (e.g. for ICBM attack and Launch on Warning)) deterministic differential equations like the Lanchester model; probabilistic and statistical models; or models applying fuaay logic, catastrophe and chaos theory, control theory and game theory.

3. Detailed models exist which describe and analyse specific aspects of C^3I: decision-making and decision-support in command centers and headquarters) surveillance and information fusion for reconnaissance, warning and forecasting; physical and mathematical aspects of communications (e.g. on the data capacity, connectivity, error rate), information control and electronic warfare (deception, jamming). While in communications theory the design procedures are well understood, the theory of information fusion is

much less understood, partly because of the vast amount of data and the problem to decide what is essential and what is not.

4. Evaluation models define measures of performance (MOP) and measures of effectiveness (MOE) of C^3I systems. While MOP measure the capability to perform a system's own "internal" activities, MOE measure the degree to which a system performs a given military mission.

5. The complexity and vulnerability of C^3I systems increase the importance of simulation, training, testing and realistic field exercises. To be useful, a model must correspond to a realistic scenario and has to be explainable to the decision-maker in his terms. In the USA, a large number of simulation facilities and test beds is known, In field exercises the integrated operation of all categories of weapons and troops has been trained, including the C^3I structures. Knowledge-based systems were used in field exercises to support planning.
