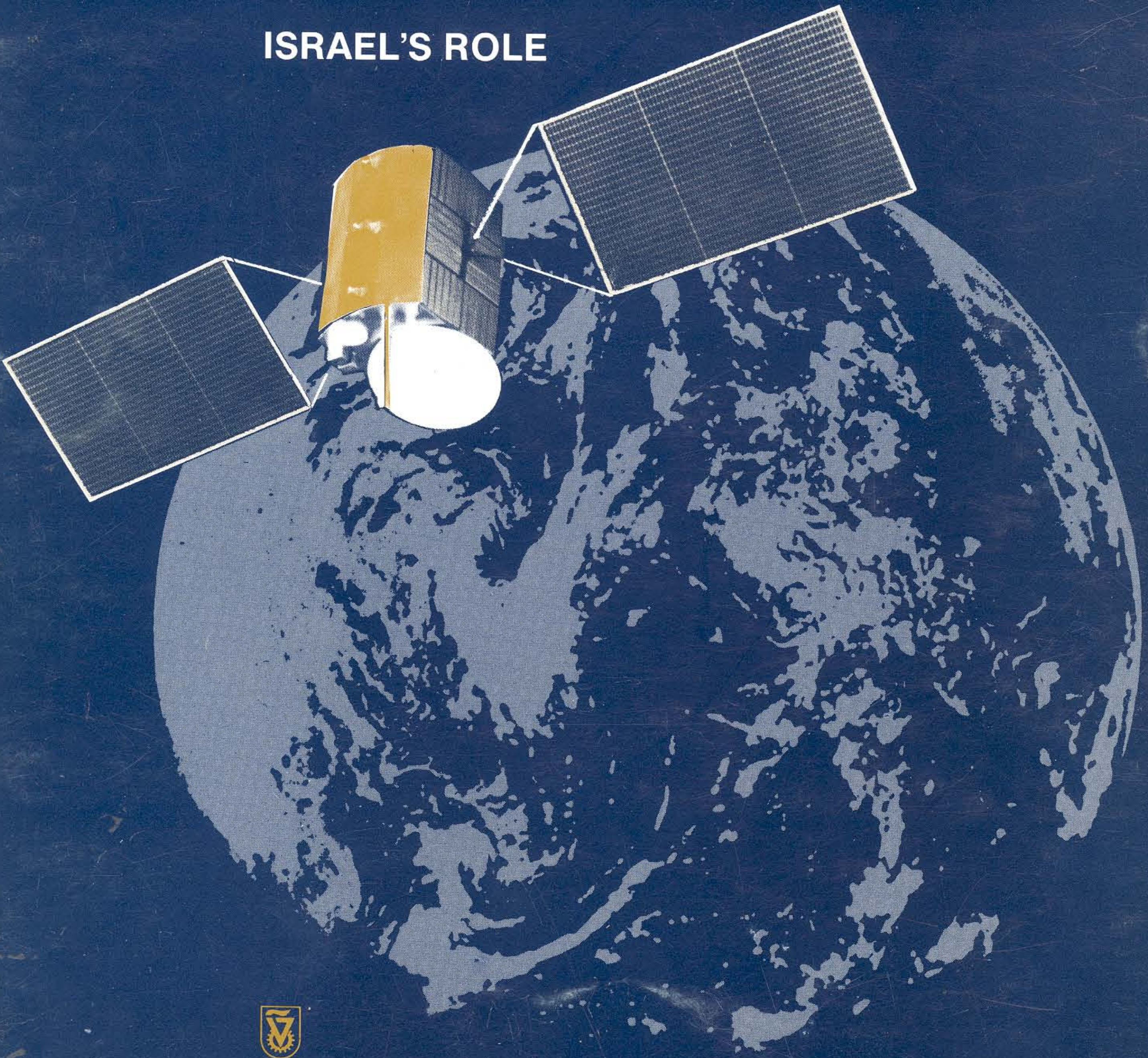
CIVILIAN SPACE APPLICATIONS

ISRAEL'S ROLE



TECHNION — ISRAEL INSTITUTE OF TECHNOLOGY

THE S. NEAMAN INSTITUTE FOR ADVANCED STUDIES IN SCIENCE & TECHNOLOGY
THE NORMAN AND HELEN ASHER SPACE RESEARCH INSTITUTE

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CIVILIAN SPACE APPLICATIONS

Israel's Role

Proceedings of the International Workshop
Haifa, March 7-8, 1988

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WORKSHOP PROGRAM

Monday, March 7, 1988 – Student Union Building

09.00 Registration.

09.30 First Session – Chairman: D. Weihs, Technion

Greetings: Dr. M. W. Reis, President, Technion – Israel Institute of Technology.

Professor Y. Neeman, Chairman, Israel Space Agency.

Professor S. Abarbanel, Chairman, NCRD.

Professor Z. Tadmor, Director, S. Neaman Institute.

10.15 Lectures

Opportunities in Space Science and Applications – B. I. Edelson, Fellow, School of Advanced International Studies, Johns Hopkins University, U.S.A.

11.00 Coffee Break.

11.30 Second Session – Chairman: E. Reshotko, CWRU, U.S.A.

The French Space Programme – Main Trends in the Fields of Space Sciences – I. Revah, Centre National d'Etudes Spatiales, France.

Small Applications satellites – D. Brown, European Space Agency, The Netherlands.

13.00 Lunch.

14.30 Third Session – Chairman: D. Sadeh, Israel Space Agency

New Directions in Low–Gravity Science, Applications and Commercialization – S. Ostrach, Case Western Reserve University, U.S.A.

A National Israeli Space Program – Do we need it; can we afford it; and what should it be? – M. Klajn, Infrastructure Committee, Israeli Space Agency.

16.00 End of Third Session.

Tuesday, March 8, 1988 – Aeronautical Engineering Building

10.00 Fourth Session – Meeting of Working Groups

1. Communication and Electronics – Chairman: A. Livneh, Room 149.
2. Mechanics and Energy – Chairman: M. Bar–Lev, Room 150.
3. Materials and Processes – Chairman: Z. Lev, Room 240.
4. Remote Sensing – Chairman: H. Eshed, Room 241.

12.30 Lunch.

14.00 Fourth Session – Chairman: Y. Timnat, Technion

The AMOS Project – A Domestic Communication Satellite for Israel – P. Rosenbaum.
Report of the Working Group – Discussions by their Chairmen.

OPENING ADDRESSES

Prof. Daniel Weihs
Chairman, Organising Committee
Dean, Faculty of Aeronautical Engineering, Technion

I am happy to open this International Workshop on the Civil Applications of Space and Israel's potential for entering this field. One of the purposes of this meeting is to try and establish possible niches in which Israel entrepreneurs, technologists and researchers can successfully compete and contribute to the growing space oriented industry; for this we have invited today some very distinguished guest speakers to tell us today about national space efforts and pinpoint industrial and commercial fields that can be utilized in space. Tomorrow's sessions will be dedicated to discussions from the floor in four groupings - dealing with remote sensing, mechanics & energy, processing and materials, and communications & electronics, respectively. Later tomorrow these discussions will be summed up by the session's chairmen. This workshop is in a sense the third and final stage of a study performed under the auspices of the Samuel Neaman Institute for Advanced

Study. The report summing up the first two stages of this research are in the conference materials. These include a review of various national space programs and their effects on the respective economics and the results of a survey questionnaire distributed among leading Israeli industrialists. The results of today's and tomorrow's discussions and talks will be written up and collected in a conference proceedings book that will be mailed to the conference participants within a few months. Before going on to start the meeting officially, I would like to thank the Samuel Neaman Institute for supporting this Study and Workshop; the Asher Space Institute at the Technion for joining in the support of this meeting and hopefully in the fruits of this meeting; and the Technion for hosting the workshop, and study, and especially I would like to thank David Kohn, Ruth Rifkin and Ruth Cohen for all the work which culminated, finally, in having you people here at this meeting, which I hope will be a great success. Thank you!

Dr. Max W. Reis

President, Technion – Israel Institute of Technology

Professor Neeman; distinguished guests from Israel and from abroad; the Dean, Professor Weihs; Professor Tadmor; ladies and gentlemen.

I am very glad to welcome you to the Technion this morning for this, for us, very important international workshop on civilian space applications. I think, it is fitting that an interdisciplinary meeting like this should be held at the Technion which contains under one roof many scientific and engineering disciplines: aeronautical engineering, electrical engineering, physics, mechanical engineering, materials engineering, computer science, chemistry, biology and others. All of these are essential for space research and I hope they will be part of such an effort. We are an institution devoted to research and to the education of a new generation of researchers and fully 70% of the engineers, and half the scientists in Israel, are Technion graduates. The economic future of our country in the 1990s, as with all the other industrialized countries, especially in the Western world, must and will be based on high technology. But, and I think this is something which we ought to realize, although there will still be a need for traditional products; growth will increasingly come from service functions, electronics, information technology, new communication techniques, bio–technology and advanced new materials. Different and new organizational patterns will evolve in Israel, and in other countries, to support these new techniques, and the Technion will be a major factor in Israel in this technological revolution. This means staying ahead all the time, and identifying early, the new areas of science and technology that we shall need in the future. We have to be prepared in the universities in this country for such a period in the form of teaching, research programs and the appropriate equipment. This planning and prediction process is a very difficult task, and it is seminars such as these, and meetings such as these, that can formulate our ideas about the future. Whereas as recently as twenty years ago, science and engineering students were being educated using the curricula and text that their parents studied, today we worry about technologies becoming obsolete within the four or five years it takes our students to finish their degrees. Some years ago, our Faculty of Aeronautical engineering foresaw the entry of Israel into the space era and began preparing for that eventuality. And the result of that decision was the inauguration, in June of 1987, of the Asher Space Research Institute, headed by Professor Timnat, who is with us here today. Under the umbrella of the Faculty and this space institute, staff and faculty members conduct essential research and give instruction on both the under-graduate and graduate levels on the wide-ranging subjects vital to aerospace scientists and technology.

This workshop will consider the feasibility of industrial, commercial and scientific ventures in space, an area of great interest to our university. We are actively promoting research and development programs which will bring the results of Technion research to the marketplace, to aid in the economic future of this country. We see our role as providing the ideas and the manpower to promote this economic advance. I would like to thank the Asher Space Research Institute, and the Neaman Institute for Advanced Studies in Science Technology whose director, Prof. Tadmor, is with us today, for bringing together the leaders of Israel's research and development groups in this field, Israeli industrialists and the many international experts, in this very important meeting. I wish this workshop every success.

Prof. Yuval Neeman, M.K.
Chairman, Israel Space Agency

President Reis, dear colleagues. Israel is known to be a part of the advanced West and yet it has a rather inhomogeneous presence in different fields. One of the weaknesses, one of the areas in which we have been falling behind, and stayed behind while others went ahead and made a lot of progress, is the area of space science and technology and perhaps, its application in space industries. It is a very important part of human activities and nowadays Western society has been changed in a very great number of ways by the presence of space applications and space technology. Israel has just managed to be on the receiving end. Back some fifteen years ago, for instance, the antenna in Emek Ayala (where David fought Goliath) was built simply in order to get satellite pictures because viewers in Israel wanted to see football games wherever they were taking place. And yet we did nothing in terms of active participation, not at the receiving end, but at the producing end. Some beginnings were laid in the 60s as far as the scientific side was concerned. In Tel Aviv University, for instance, we created in 1965, an institute for space studies which evolved naturally into a department of planetary science. At that time, that was what could be done in universities as you had more possibility to make progress without investing much on the financial side, was the scientific aspect. And so in terms of astronomy, astro-physics, hi-atmosphere physics, Israel is sharing now in world progress. But again, when it came to the coupling with technology, and with industry, and with the creative aspects of industry in Israel, nothing happened. And it is a characteristic fact, that we were, I think, probably the only country in the developed world that did not have a space agency until 1983. There are countries that are not part of large efforts, like Austria. When it comes to science, we produce twice as much science as Austria does in terms of scientific papers, and in journals. But Austria has had a space agency many years and has been involved and connected with various space activities. I am taking as an example a country that is really on the margin of space activity. But at least it tried to couple into it. Israel did not. We have tried to bridge that gap in the last five years since the space agency was created. The Technion made a very important decision in creating its Space Research Institute. I congratulate the Technion on taking this step because an institute here will naturally evolve more in the direction of technology and become a lever for the development of this technology in Israeli industry. We have tried, with meager funds that were put at our disposal, to somehow use these funds to create an interest within industry itself, in entering the field. I would say that we have had some success. I could point to a variety of cases in which Israeli industry has now entered this area. There is the Israeli Aircraft Industries which has set up a unit that deals with space technologies. Given the size of the Israeli Aircraft Industries, I think that is a promise of real results in the future. We are trying to steer all these activities, somehow, without intervening too much, but steer them with that seed money, into some kind of homogeneous activity. One way in which we are thinking of doing it, perhaps in a more aggressive way in the near future is by instead of having technology help science, using science to help technology; by, for instance, pushing a project of a scientific satellite. Of course the satellite will give the opportunity to some scientist to do some very interesting experiment but from our point of view, it will be more in order to have Israeli industry to contribute as much as it can to that satellite. And using, whether it is communications or science, as triggers or as carrots in order to pull industry in that direction, for its own good and for the good of Israel. I think that now is a very opportune time to hold such a meeting here, and hear more about the experience, both in the United States and in Europe, and learn from this experience. This should create more of a consciousness among the various people who deal with such projects, whether in industry or in the universities. This awareness of the complete picture in which they play their role can afterward really lead to some concrete results. In that spirit, I am very happy to be able to congratulate the Technion on holding this meeting at the Technion and the Neaman Institute. Let me congratulate them on their activity and I would hope that the Technion will continue in this path. I think it will pay the Technion to preserve the momentum in this direction, sometimes even if they feel the nation as such does not understand very well why they concentrating on it. I would like to encourage the Technion to continue going in that direction and the end product will be very important for the country, and it will be yet one more gift of the Technion to the nation. Thank you!

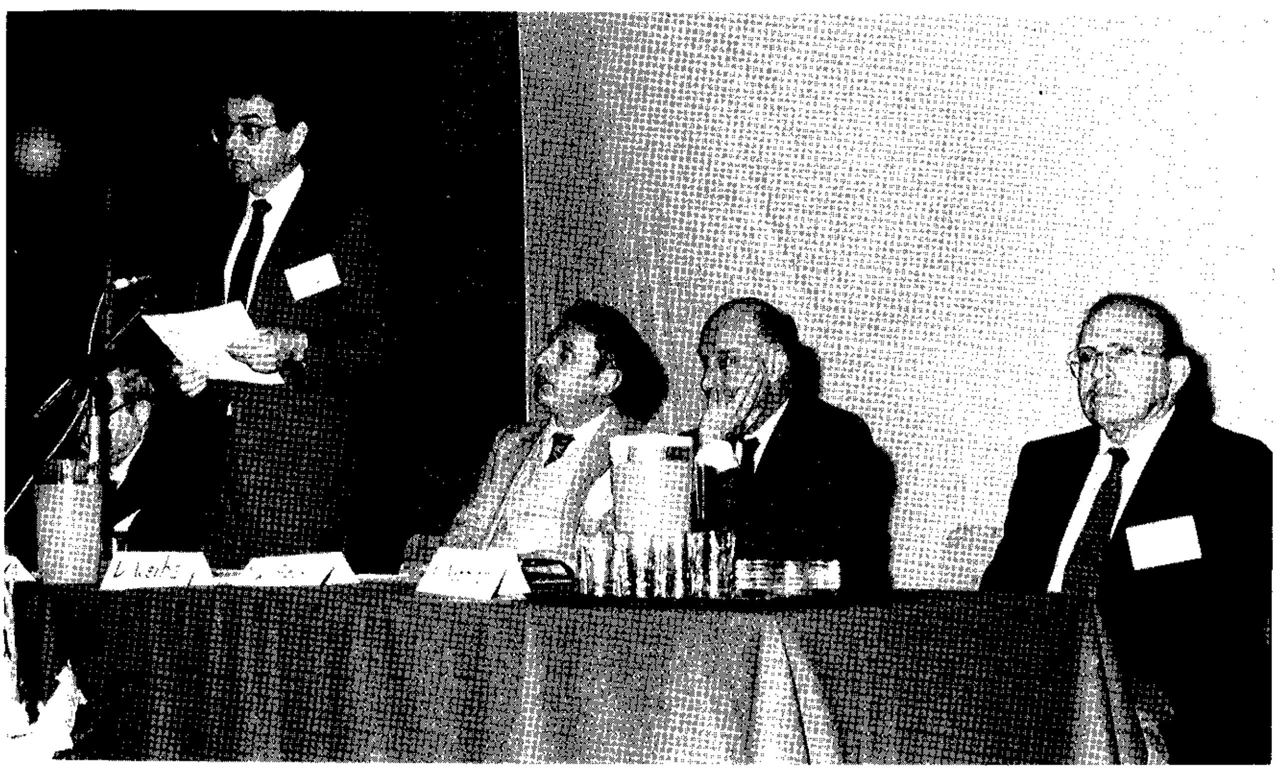
Prof. Shaul Abarbanel
Director, National Committee for Research
and Development
in the Ministry of Science

Minister Patt, the Minister of Science and Development in Israel is very much interested in the subject of space utilization, not only because the Israeli effort in space (the little effort there is) is formally under the ministry, but he is genuinely interested in what can be done, utilizing science for scientific and technological uses. Prof. Neeman covered all the high points of the difference between utilizing science and technology. I would like to point out only a tiny little segment of the whole spectrum of utilizing space science. People understand of course that you can use space for technology. We use it for communication, they understand even that maybe in the future we will be able to do better meteorology from space. Even the science which most people think of in terms of kind of science which is related to space, such as telescopes to make astro-physical observations. But the real science, which is really Earth science, still can be done better in space. One example may be, (it has not been proven) is the study of the evolution of biological molecules. But the real basic, basic science, that will be done in space for people that are really interested in what is happening here, or maybe on some other planets. For example, if you want to study the phase diagram of liquid helium, what really happens near the Lambda Point, that can be done best under conditions of micro-gravity. And one can give other examples where science is not just technology driven, but often science driven and of course the usual interaction. Since I allotted myself only three minutes, I decided to illuminate just one tiny little point to show that the business of space cannot be segmented, just as the business of science and technology of earth cannot really be completely compartmentalized. Everything that you can study in space can be useful, not only in technology but in basic science, the kind of science you would like to do in our laboratories which are earth-bound but is difficult. I wish all the participants, especially our guests from abroad, two useful days of discussions. So I wish the Neaman Institute and the Technion not only the two days of full and successful deliberations, but many years of concentrating on the mission in space. Thank you!

Prof. Zehev Tadmor
Director, The Samuel Neaman Institute for Advanced Studies in Science and Technology

President Reis, Member of the Knesset Prof. Neeman, Prof. Abarbanel, Prof. Weihs, distinguished guests, ladies and gentlemen.

Israel is a small country, but in order to survive it must maintain a scientific and technological base beyond its size and, as some claim, beyond its means. Its scientific research must exceed a critical size and must match the quality of international science. Its technology must be updated and competitive on a global scale. The driving force for such a technology can only be the science-based hi-tech industry; space technology is by definition such an industry. It is also a symbol of pioneering efforts and great vision, two characteristics intimately intertwined with modern Israel's history. The Samuel Neaman Institute for Advanced Studies of Science and Technology,



established to assist in the search for solutions to national problems in science and technology, education and economy, health and social development, drawing upon the rich human resources of Technion faculty and other scientists and specialists from Israel and abroad, has recognized the significance of space technology for Israel and has sponsored, with others, Professor Weihs' research efforts in trying to identify Israel's capabilities, potential and role in this technology. The Samuel Neaman Institute is delighted to have the opportunity to collaborate with the Asher Space Institute at the Technion, headed by Prof. Timnat, in organizing this workshop and in bringing together an outstanding international group of experts in space technology. We hope that the lectures, panel discussions, and working groups will crystallize the role Israeli technology and science are to play in this magnificent new frontier. I wish you all a very successful conference. Thank you!

THE NORMAN AND HELEN ASHER SPACE RESEARCH INSTITUTE

The Norman and Helen Asher Space Research Institute, founded in April 1984, has provided Israel with a foothold in the Space Era. Its function is to promote the development of national interest and capability in aerospace science and technology, by developing space-related research and its applications and by creating interdisciplinary ties among researchers.

Space Research has been conducted at the Technion for some 20 years. It was done previously by individual faculty members, mainly from Aeronautical Engineering and Physics with occasional contributions from scientists in the Material Engineering, Chemistry and Mathematics Departments. Now we have 26 members integrated in the Institute.

Academically, Institute members offer a considerable number of courses at the advanced undergraduate and graduate level, which are related to space science and technology. They cover the following scientific subjects: astrophysics, cosmology, plasma physics, rarefied gas dynamics, dynamics of real gases and trajectory mechanics. The main technical areas treated are space propulsion, spacecraft control, remote sensing, materials for spacecrafts, spacecraft structural design, damping of dynamic reactions and deformation absorption.

A number of graduate students are conducting research towards M.Sc. and D.Sc. degrees on space-related topics under the guidance of Institute members, utilizing equipment belonging to the Institute. Monthly seminars and occasional lecture series by guest speakers, which have proven a great success, complete the academic program.

Ongoing research projects involve the following areas of interest: upper atmosphere aerodynamics, trajectory mechanics, combustion and rocket propulsion, image processing, X-ray astronomy and very high energy cosmic phenomena.

LECTURES

OPPORTUNITIES IN SPACE SCIENCE AND APPLICATIONS

Burton I. Edelson
John Hopkins Foreign Policy Institute School of Advanced International Studies

The launch of the first Sputnik by the Soviet Union thirty years ago ushered in the Space Age. It started as a race between the Russians and Americans--first to orbit a spacecraft, then to fly a man in space, to land on the moon, and to visit the planets. But with these early spectaculars also came a realization of the practical applications and scientific potential that space technology and space systems offered. Well within the first decade some very useful space applications were demonstrated; space was seen to offer splendid new scientific opportunities to gain in understanding of the origin and evolution of the universe, to explore the solar system, and to observe, measure, and calibrate our own planet.

The second and third decades of the Space Age saw the development of practical and cost-effective systems for satellite communications, weather prediction and Earth resource assessment. Cameras, telescopes, spectrometers and other scientific instruments in space have given mankind new scientific knowledge of inestimable value. Missions to the planets have extended our exploratory frontier by several billion miles. Men and women, animals and plants, instruments and facilities have flown in space for long periods of time to give us much new knowledge of the behavior of chemical, physical and biological processes in a microgravity environment.

As the Space Age developed, the race between the two space superpowers diminished, then vanished. Cooperation replaced competition in space science and exploration, and in the space applications arena commercial competition replaced national rivalry. Many countries became involved in space, and a number of international cooperative space projects were undertaken. Today, a dozen countries have significant space development programs of their own and over 100 are participating in operational space activities. Global expenditures on civil space development and operations amount to about $25 billion per year.

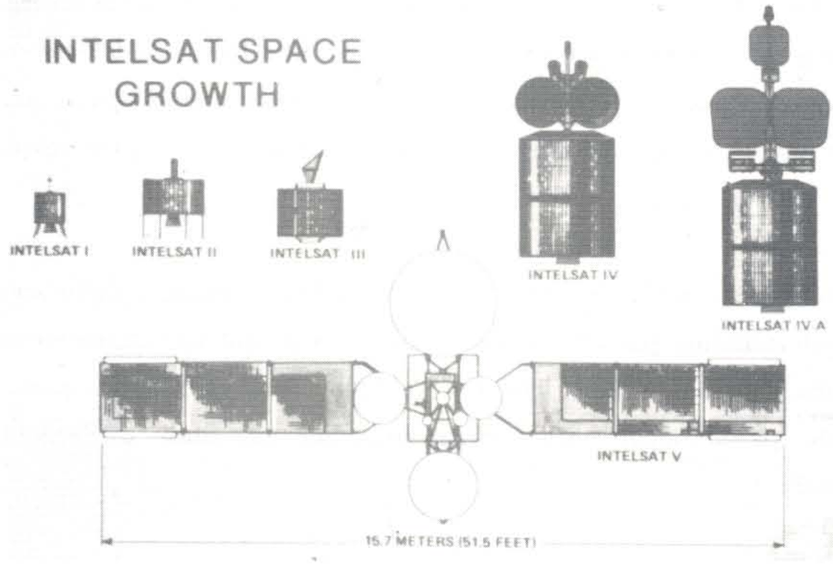
Over the past thirty years two very practical space applications have emerged: communications and remote sensing. Also, space has been kind to science and has provided research opportunities in a number of disciplines from astrophysics to zoology. Both automated spacecraft and manned space flight have been used to add the more glamorous and appealing term "exploration" to that of science.

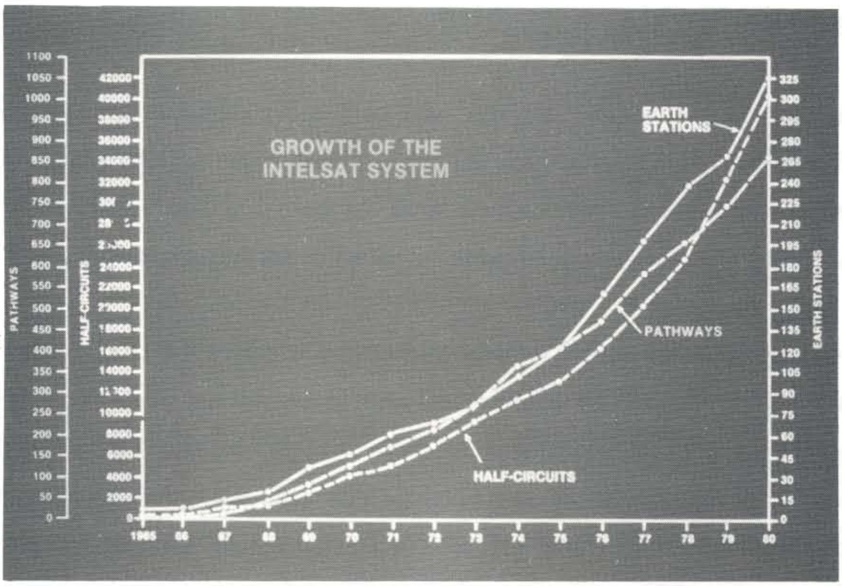
I would like to discuss the progress and opportunities in each of these areas, pointing out the great degree of international participation and cooperation that has characterized the development of space activities. Then I would like to highlight those space disciplines, technologies, or projects in which special opportunities might exist for the State of Israel and its R&D and industrial communities.

Satellite Communications

Communications via satellite was the first and most obvious practical benefit of the space program. In 1960, NASA conducted project "Echo" in which voice and television signals were bounced off an aluminum-covered plastic balloon and received by a big "ear" on Earth some distance away, thereby demonstrating the essential elements of satellite communications.

The following year, President Kennedy announced a policy for the commercial development of communications satellites with both commercial and international aspects. "I invite all nations," he said, "to participate in a communications satellite system, in the interest of world peace and closer brotherhood among peoples of the world." The U.S. Congress passed the Communications Satellite Act in 1962, which in turn led to the formation of Comsat Corporation in 1963, the Intelsat Organization in 1964, and the launch of the first commercial satellite "Early Bird" in 1965. Events proceeded swiftly in those days!





Since 1965, the international network of satellite communications has grown and improved enormously. Where Intelsat's first satellite carried some 240 telephone circuits over a single path, its present satellites each carry 15,000 circuits over hundreds of paths. Per circuit costs have been reduced 95%. An international maritime system has been formed, and many regional and domestic satellite systems are in operation. There are over 100 operating communications satellites in orbit.

Earth stations are located in every country and almost every community, on many islands and individual buildings, even private houses. Today, there are over one million small receiving terminals in operation, and 6,000 terminals aboard ships flying flags of every nautical nation. Satellites carry telephone, television and data traffic of all types, producing revenues exceeding $5 billion per year.

Now satellites are beginning to face competition from optical fiber cables, particularly over the heaviest intercontinental telephone trunks, such as between North America and Europe. However, satellites have advantages on smaller trunks over great distances, as between cities in distant countries, Washington and Tel Aviv, for example. Also, satellites have distinct advantages for distribution, networking and data collection services. And of course there's no competition at all for mobile or broadcast services. I believe that the future of satellite communications lies primarily in these latter services--and it appears to be a great future indeed!

Satellite communications is growing strongly in several areas. In Europe, there appears to be a great spurt in satellite television services. Mobile services are expanding rapidly, not only to ships at sea but to land vehicles and aircraft in flight as well. Satellites and computers work so well together that global distributed processing networks appear to be just around the corner!

Israel, with its university research and its industrial development and manufacturing capabilities, should find many opportunities for participation in the future growth and extensions of satellite communications. An Israeli communications satellite system might be considered, either using its own satellite or, as has been done successfully by other nations, using a shared satellite or leased capacity. Also, there will be many opportunities for development of new devices and equipment for the world market in satellite subsystems, in ground, shipboard, and airborne terminals, and in data transmission and processing equipment of all kinds. Let me suggest a few examples: solid state power amplifiers, high speed digital modems and coding equipment, antennas for aircraft and land vehicle use, microwave integrated circuits equipment, antenna feed networks. The list could go on, and the opportunities are significant and worth exploring.

Satellite Remote Sensing

Another important space application is that of satellite remote sensing--observing the Earth, its atmosphere, its land areas, oceans, and biosphere using space-based instruments of many types. NASA flew its first picture-taking satellite called "Tiros," in 1960. Its primitive images of cloud formation indicated that weather could be predicted on a worldwide basis. Its success led to the development of more advanced satellites: Nimbus, advanced Tiros, GOES, the Landsats, and Seasat, which introduced more sophisticated instruments and provided both scientific data and practical, even commercially valuable, knowledge of Planet Earth.

Today satellite images from low polar-orbiting NOAA satellites, and from GOES and other geostationary orbit satellites, routinely provide cloud cover and movement information--shown daily on television--for weather prediction. These same spacecraft, and others using more sophisticated sensors, provide oceanographers, climatologists, atmospheric scientists, even biologists and archeologists with data of great value for their specialized fields. We can, for example:

- assess the health of crops, the destruction of rainforests, or the extension of desert areas

- detect phyto-plankton in the ocean, and predict areas for good fishing

- measure the distribution of stratospheric ozone

- explore for oil or mineral deposits

- create maps for urban planning, or find paths for building roadways or bridges, or for laying pipelines

- detect underground rivers, buried roads, and ancient ruins

- provide media coverage of conflicts or disasters (e.g., the Chernobyl nuclear accident)

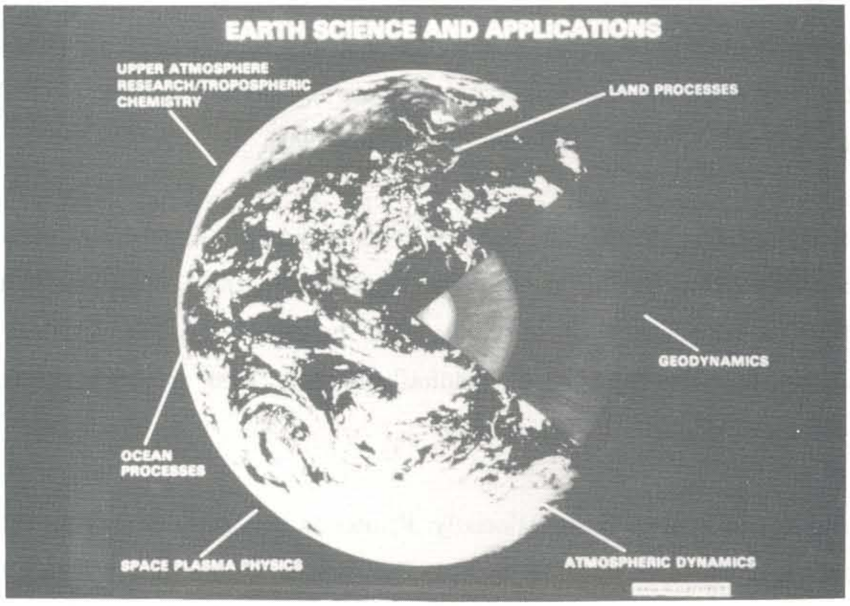
Today's satellites provide all of these services and many more. Spacecraft are planned in the next decade to increase greatly the scope and power of Earth remote sensing from space. The two U.S projects of greatest relevance are the Upper Atmosphere Research Satellite (UARS), to be launched in 1991, and the space Station polar platforms in the mid-90s.

In the United States an attempt has been made to "commercialize" remote sensing operations. The EOSat Corporation has been formed to take over and operate the Landsat satellites. However, since the satellites produce a mixture of scientific and practical data, and since one of the most practical applications, meteorology, has traditionally been a "free" government function, EOSat has met with little commercial success.

Remote sensing has spread internationally. France is currently operating the Spot system, with higher resolution than the Landsats. Recently, the Soviet Union has started to provide satellite images of even higher resolution on a commercial basis through its distribution organization, Soyuzkarta. The European Space Agency, India, and Japan also have their own remote sensing satellite programs.

The present problem of proliferation without coordination of satellite remote sensing technologies and systems may well be resolved in the 1990s because of three important developments:

(1) IGBP - The International Council of Scientific Unions has approved a program to be known as the International Geosphere- Biosphere Program (IGBP), sometimes referred to as "Mission to Planet Earth". This will be an attempt to gain an understanding of how the Earth works as a system--how the atmosphere, hydrosphere, geosphere, and biosphere all interact with each other. It will also involve a study of "Global Change," of how and to what extent the presence of mankind is affecting the health of our planet. It will shed light on the future biological productivity of our planet and its prospects for habitability of various life forms, including mankind. IGBP will require a massive coordinated international effort to observe the Earth from space (and from the ground and oceans too) over a period of a decade or so. It will require the best instruments and spacecraft and the best scientific and technological talent of many nations to be devoted to this project of such obvious importance to the future of mankind.



(2) EOS - The EOS project (EOS is the goddess of dawn, also the letters stand for "Earth Observing System") is an attempt to design the ultimate remote sensing system. EOS involves a set of passive and active instruments operating in the optical, infrared, ultraviolet, and microwave bands to give comprehensive, synoptic measurements of the Earth system. This set of instruments is being

developed to fly on large, polar-orbiting platforms, one of which will be provided by the U.S. and one by ESA as part of the International Space Station program. Someday, perhaps in the late 90s, EOS instruments may also fly on large platforms in geostationary orbit to track storms and observe other dynamic phenomena.

(3) Envirosat - A movement has been started, and is currently being considered by the International Astronautical Federation and other groups, to form an international organization, termed "Envirosat", patterned after Intelsat, to coordinate all civil remote sensing satellite systems. Envirosat, when it comes into existence, would be responsible for seeing that scientific data was properly distributed to universities and research centers throughout the world; that governments received meteorological and other desired data; and that private and business organizations received the data that they need for their use under commercial terms. The idea, of course is that, Envirosat would at first coordinate and distribute the data from several existing national systems, but would encourage the development of international systems, and eventually would process and distribute data from the EOS platforms.

Space Sciences

The world's investment in space over the past three decades has paid enormous dividends in scientific research, exploration and discovery. The first American satellite, Explorer I, launched in January 1958, performed a plasma physics experiment in space. It carried a Geiger counter, built by Dr. James Van Allen of the University of Iowa, to detect trapped particles in the Earth's magnetosphere in "belts" which now bear his name.

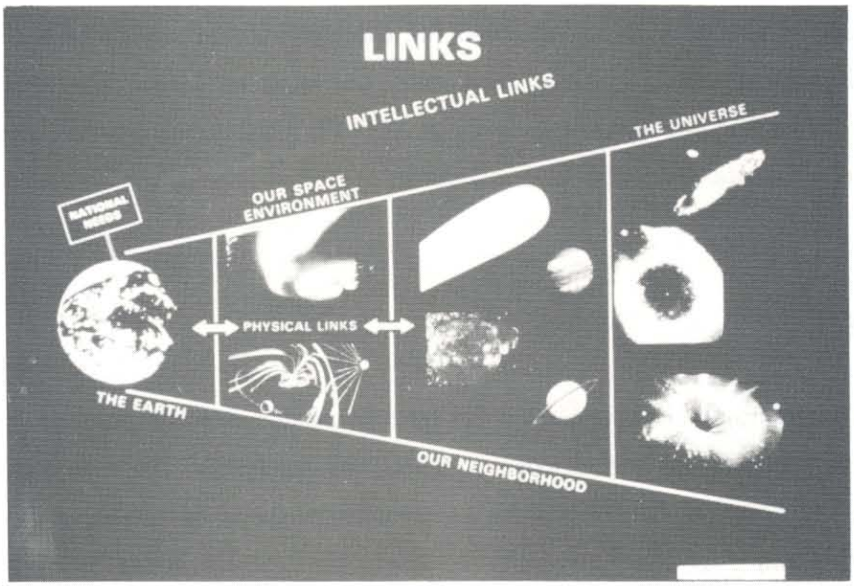
Now there are six recognized space science disciplines, each with its own grand history, intense current activity, and ambitious plans for the future:

Astrophysics
Planetary science
Solar and space physics
Earth system science

Microgravity science

Space biology and medicine

Astrophysics – In 1983, the joint US–UK–Dutch Infrared Astronomy Satellite (IRAS) conducted a complete sky survey, detecting, measuring and cataloging celestial objects large and small that appear far different or are invisible in the optical band. No comets were discovered by ground based astronomers that year; six were discovered by IRAS. And, to great excitement, IRAS provided the first hard evidence of planetary systems around suns other than our own.



Now, the astronomical community is awaiting the launch in 1989 of the Hubble Space Telescope, a joint NASA–ESA project, the finest optical instrument ever built--for ground or space. It will detect objects seven times farther, 50 times fainter, and with 10 times greater resolution, than the largest terrestrial telescope. One intriguing thought is that the Hubble Telescope should be able to detect and resolve planetary systems within twenty light years or so. Another is that it should be able to track and observe Comet Halley out to aphelion (its furthest point from the sun).

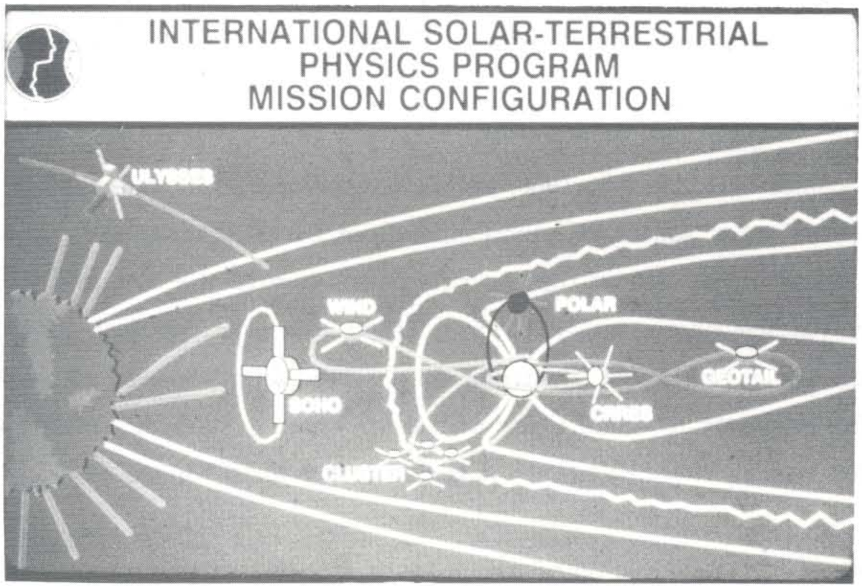
The Hubble Telescope will be followed by three other marvelous space-borne observatories operating in diverse parts of the electromagnetic spectrum: the Gamma Ray Observatory, the X-ray Astrophysics Facility, and the Space Infrared Telescope Facility--all constituting the "Great Observatory" program.

Planetary Science - In January 1986, the Voyager-2 spacecraft, launched 8-1/2 years earlier, sped past the planet Uranus, some two billion miles from Earth. It measured and observed that odd planet, which is tipped on its side so that its pole points toward the sun, and its magnetic pole is canted 60° away. Voyager photographed Uranus, its striated cloud pattern, its bizarre moons and discontinuous rings. Its complex set of instruments observed and measured all of these phenomena, providing data for scientists to analyze for a decade. Then it sped off toward the most distant planet of our solar system, Neptune, where it is due to arrive in August 1989.

March 1986 saw the culmination of five years of coordinated planning when an international armada of spacecraft went out to encounter Comet Halley. The four leading space agencies: ESA (Europe), ISAS (Japan), Intercosmos (USSR), and NASA (US), each made significant contributions to this effort. The result was a tremendous scientific and technological success and a great tribute to international cooperation.

The Soviet Union has announced plans for a major campaign to explore Mars over the next decade and has invited other nations to join it. Many share the hope that the Americans and Russians will agree to join in a cooperative endeavor to conduct first an unmanned rover sample return mission in the 1990s, and then early in the next century a manned landing on Mars!

Solar and Space Physics - The International Solar Terrestrial Physics Program (ISTP) is now being planned by the same group of four space agencies that coordinated the Comet Halley program. ISTP will involve as many as twenty spacecraft to observe the Sun, its radiative and particulate effluence, and its effect on the Earth's magnetosphere and atmosphere. Simultaneous measurements will be made in the Sun-Earth path, in various orbits around the Earth, and deep in the magneto-tail millions of miles on the "shady side" of the Earth.



Earth System Science - The line between "science" and "applications" in Earth remote sensing is a very indistinct one. In fact, the same spacecraft and instruments that have provided such practical benefits as weather prediction and resource assessment have also contributed greatly to our scientific knowledge of the Earth system. Scientists, engineers, and businessmen will all participate with enthusiasm in the IGBP, the program of Global Change, and the "Mission to Planet Earth."

Microgravity Science - This is a new name given to a field of research previously known as "Materials Processing" to indicate its wider scope and fundamental nature. Microgravity science addresses itself to an understanding of the basic physical and chemical processes and how they behave under low gravity conditions. Although some progress may be made by placing microgravity experiments on small rockets or unmanned spacecraft, advanced and difficult experimental work requires human presence and control. Much valuable experience was gained from Space Shuttle flights, particularly on the three joint ESA-NASA Spacelab missions and on the German D-1 mission. Some of the most interesting work is in growing large crystals of metals, polymers, and proteins. Such research is now being carried out aboard the Soviet Space Station, Mir. Microgravity science will also be a principal function of the International Space Station to be flown in the 90s.

Space Biology and Medicine – Research is being conducted in space biology to gain an understanding of how basic biological processes are affected by gravity, or the lack thereof. Some very interesting work was done on the Space Shuttle on how plants develop in low gravity, which way their roots grow and their leaves reach, and how lignin (which strengthens bark) is generated. A very promising experiment, designed by an Israeli, Professor Jacob Ishay, and built at the Israel Aircraft Industries, will be carried on a future Shuttle flight to determine how hornets build and orient their nests in low gravity.

In order for people to live and operate effectively in space for long periods of time such as would be required for a Mars mission (two years or longer), it is necessary to understand how low gravity affects human physiology and how this might be compensated for. Experiments have been done on animals and on humans to reduce space motion sickness and to measure calcium metabolism, fluid shifts, and cardio–vascular effects. Some good work in this area was done on the Space Shuttle, but in this area the Russians are far ahead. Cosmonaut Yuri Romanenko recently completed a record of 326 days on their space station, Mir, and brought back a wealth of scientific data and experience with him. There has been an excellent record of cooperation and sharing of data between East and West in the fields of space biology and medicine.

International Cooperation

What started as a race between two space powers thirty years ago has since become a unique arena for international cooperation. As space technology advanced, as more opportunities arose and more benefits became evident, other countries started space programs of their own. At first a few, then many countries became involved in joint and cooperative space projects.

Intelsat and Inmarsat are excellent examples of cooperative international management organizations established to provide fixed and maritime communications services, respectively. These two organizations might expand or new organizations might be formed to provide mobile, aeronautical, and broadcast services.

The Envirosat concept holds great promise for international cooperation in satellite remote sensing of the Earth.

The COSPAS/SARSAT system is a splendid example of cooperation in search and rescue services. Supported by four countries, Canada, France, the U.S. and the U.S.S.R, this system has been in full operation for four years and has saved over 1000 lives in rescuing people from airplane and boating accidents.

In science, almost all of the recent great missions (e.g., IRAS, Spacelab, Comet Halley), those under development now (e.g., Hubble Space Telescope, Galileo), and those planned for the future (e.g., ISTP, EOS, Mars rover) boast significant levels of international participation and cooperation. This participation can be in several forms--in building the spacecraft, in developing scientific instruments, in providing ground facilities, or in tracking and data processing; and cooperation can extend from planning, through development, to orbital operation, even management and of course, funding.

It is clear that international cooperation in space has been very successful, and will not only continue, but will become more important in the future.

International Space Year

One international space initiative now underway should be of special importance to Israel. The entire international space science and applications community is currently engaged in planning the International Space Year (ISY) - 1992. This will be a special period of recognition and promotion of space activities. It will also be an opportunity to initiate major new international space activities to last into the next century. There will be many projects incorporated into the ISY and a place in the ISY for every country, every space discipline, and every area of space competence and capability.

The centerpiece of the ISY is expected to be the "Mission to Planet Earth". It would incorporate the IGBP - Global Change program and other research programs, with a global network of data and education centers. Of all possible space programs, this Earth-oriented program, combining as it does elements of both science and applications, offers the greatest benefit to mankind, and the greatest opportunity for international cooperative participation.

The ISY offers an excellent opportunity for Israel to draw upon its own space capabilities and to join with the world space community in pursuing several of the peaceful and beneficial programs being planned for the ISY. Israel already possesses much advanced technology needed for future space missions as a result of its past R&D programs (several here at the Technion) in aeronautics, materials, electronics, and computers. It is appropriate now for Israel to prepare specific plans and start development of the space- and ground-based instruments and systems needed to participate in and benefit from the ISY.

A few Israelis are already aware of the ISY and are engaged in preliminary planning through the International Astronautical Federation (IAF) and the International Council of Scientific Unions (ICSU). The Israel Space Agency and its supporting industrial and academic communities might well start planning now for this country's contributions to and participation in the ISY.

International Space University

The International Space University (ISU) is a new graduate school just being organized to train young people for careers in space science, engineering, and management. The ISU will have its first summer session in 1988 at the Massachusetts Institute of Technology with 100 students from all over the world. Summer sessions will be held each year in a different country for the next five years. Starting with the ISY in 1992, the ISU is considering a year-round program. Israel might well consider sending several students to the ISU.

Opportunities for Israel

There are many opportunities for Israel to engage in space activities and many reasons to do so. Space represents the high technology frontier; there are practical benefits in telecommunications, weather prediction, and resource assessment to be gained; and space stimulates science and education. On the other hand, the stakes are very high. Space is an expensive game to play; space activities are competitive; and they drain human and technical resources from other tasks. Careful consideration must therefore be given by any country, or for that matter any company or university, to the relative risks and rewards before it plunges into space activities.

For Israel, a high technology country but a late starter in the space game, it would seem appropriate to engage in space science and applications missions, rather than building space infrastructure; and to join in cooperative programs with other countries rather than to start an independent Israeli space program.

Israel, already a member of Intelsat, might involve itself more deeply in satellite communications by designing and developing new transmission and processing systems. The emerging technologies of satellite networking and distributed processing and the new world of ISDN (integrated system digital network) would seem fertile territory. In satellite remote sensing Israel might consider such advanced developments as detectors for satellite sensing instruments and the application of artificial intelligence to satellite image processing. These are examples of course, but they are growth areas in space technology where this country has the requisite scientific and technical skills to contribute.

Fortunately, there are many international bilateral and multi-lateral cooperative programs just being formed at the present time. The grandest program of all, the International Space Year, with its emphasis on Earth science and applications would seem perfectly oriented to Israel's interests.

An appropriate entry point might be Israel's, and particularly the Technion's, advanced technological capabilities in aeronautics, materials, electronics, computers and instrumentation. These technologies could then be applied to develop space science and applications instruments, spacecraft subsystems, and space- and ground-based computer processing systems. These instruments and systems in turn could be applied to space programs to contribute to the ISY and provide evidence of Israel's capabilities, competence and cooperative spirit.

Burton I. Edelson

Dr. Edelson received his B.S. degree from the U.S. Naval Academy in 1947 and his Ph.D. from Yale University in 1960. He is a Registered Professional Engineer and a Fellow of AIAA and IEEE.

From 1968 to 1982, Dr. Edelson held executive positions at the Communications Satellite Corporation including Director of COMSAT Laboratories, the Corporation's central R&D facility; Vice President for Systems and engineering; and Senior Vice President.

Prior to joining Johns Hopkins, from 1982 to 1987, he was Associate Administrator for Space Science and Applications of NASA. He was responsible for the direction of all NASA scientific efforts, development of communications satellites and other applications projects; and for institutional management of the Goddard Space Flight Center and the Jet Propulsion Laboratory.

Burton I. Edelson is a Fellow of the Foreign Policy Institute of the School of Advanced International Studies, the Johns Hopkins University. His field of interest is International Science and Technology Policy.

SMALL APPLICATION SATELLITES

D. L. Brown
European Space Agency
The Netherlands

Why Small Satellites?

Small satellites provide rapid flight opportunities for modest scientific and application missions due to the fact that the

* Required resources are limited
* Number of parts are limited and can be procured from high grade industrial or Mil-Spec stocks
* Satellite can be built in a single facility
* Satellite can be launched as a piggy back payload on a large launcher

How Small is Small?

* Geo mission range - 12 to 18 channels of 5 to 10 watts RF, C or KU band
* Payload mass range 50-100 kg
* Payload power range 200 - 600 watts DC
* Antenna diameter up to 2+ meters to allow shaped beams over coverage zone

* Pointing accuracy target < 0.1 degree

* Spacecraft mass range 300–800 kg dependent on v and eclipse requirements

* To be studied in 2nd half of 1988

Design, Build, and Test Philosophy

Standard bus tuning involves variation of

  * Diameter/volume to accommodate antennas/sensors and payload instrumentation

  * Area of solar arrays and choice of silicon or gallium arsenide solar cells

  * Stabilization system, choice of 3 axis, spin, or gravity gradient dependant on mission requirements

  * Reaction control system, choice of propellant expulsion system, magnetorquers, or solar sailing or a combination of these

* Keep it simple – design to meet the task and do not gold plate

* Avoid the "nice to have" traps

* Use simple interfaces – this will minimize interface documentation and assembly and ease "trouble shooting"

* Develop a standard bus which can be tuned to support a range of typical missions, this reduces the non–recurring investment per programme

* Use extended test sequences to "burn out" the infant mortalities of components and sub-systems

* Reduce the cost and shorten the schedule by minimizing the amount of hardware constructed in the programme

* Payload performance should always be evaluated at an early stage by constructing an engineering model and evaluating its performance

* Using the standard bus concept the flight spacecraft can then be constructed and tested on a protoflight basis

Launch Strategy

* A multiplicity of launchers in the market place

* A lively competition is possible with benefits for the client on price, schedule, and insurance

* STS (shuttle) started the get-away special (GAS) launches for very small satellites

* Ariane and Delta have launched piggy back satellites for AMSAT, UOSAT, and other clier ;s

* Small commercial launchers are being developed (CONESTOGA, AMROC) for low Earth orbit missions

* Choice of piggy back launches for small satellites in the range or

* Shared launches on a commercial launch cost basis for the large satellites

* Piggy back launches to be paid for on a get-away special basis

* Shared launches to be paid for on a commercial basis e.g., 20–40 K$ per kilogram dependent on the competition and the mission profile

How Small is Small?

* HEO mission – navigation payload in Molniya orbit
  39.105 km x 1.250 km x 63.45° with argument of perigee 90/270 degrees

* Antenna diameter 2 meters

* Payload mass 60 kg

* Payload power 150 watts. DC

* Pointing accuracy $\leqslant$ 1 degree

* Lifetime 3 years

* Spacecraft mass ~ 250 kg

* Studied by University of Surrey and Institut fur Raumfahrtelektronik during 1987

The subject of this study is to examine the feasibility of using a low cost design approach for satellite navigation missions. This study includes the analysis of a small cost–effective satellite bus for highly elliptical earth orbits. Since satellite–based navigation systems require many satellites, the use of low–cost spacecraft in such systems results in considerable cost savings, and improves the overall system feasibility.

A key factor in keeping the overall cost of the spacecraft to a minimum whilst maintaining acceptable reliability is the adoption of the ground rules listed below for the design of the bus and payload sub-systems:

* Keep it simple. Examine thoroughly the task and environment of each sub-system and specify components/techniques that will accommodate the task with a suitable, realistic safety margin. Unless the function or environment demands it, do not simply go for the highest rated/quality approach as this will generally increase cost dramatically.

* Essential houskeeping modules should use standard, proven designs and hardware wherever possible.

* Where possible, use flexible design to provide functional redundancy, rather than by duplication.

* Use easily defined, simple interfaces between sub-systems wherever possible. Sub-systems should run independently of each other even if that entails duplicate hardware.

* Design sub-systems around established, industrial highgrade, volume production components. If a component has been in volume production it is likely that any 'bugs' have been removed. If possible, use high-reliability or Mil-Spec screened versions of these volume production devices.

Space navigation systems like GPS/NAVSTAR, GLONASS, and system concepts like GRANAS or NAVSAT all use the time-of-arrival principle to determine the precise location of the user; even for highly dynamic applications like aircraft.

For the measurement of 3-dimensional position, signals from four satellites must be received simultaneously in order to calculate X, Y, Z coordinates and the time bias. In the NAVSTAR configuration, 18 operational satellites are required in high circular orbits (20,000 km) to provide an operational system with continuous global coverage. Since so many satellites are involved in such a system, any decrease in the cost of each satellite will greatly decrease the overall cost of the system. This feasibility study determines whether the satellites in a satellite-based navigation network could be built using cost-effective engineering methods.

The study builds on the results of previous ESA studies such as the GRANAS/NAVSAT comparisons and ITALSPAZIO studies; these identify efficient satellite constellations. This study determines whether low-cost satellites can be made compatible with these proposed space navigation systems.

STUDY TASKS

Task 1:

Trade-off studies are performed of alterative system design concepts for the satellite and the launch system. After making a study of the specified mission requirements including the orbit scenario, for service availability, a trade-off study is prepared of the spin, three axis, and gravity gradient stabilized satellite solutions against the following criteria:

* System performance - measured as the predicted mission lifetime over which the payload requirements can be sustained.

* Mechanical complexity including launcher compatibility.

* Electrical complexity, where complexity is measured by the relative quantity of mechanical parts or electrical units and factored by deployment sequences etc. which may be required for mission success.

* Relative costs, both non-recurring and recurring.

* Contractor experience and/or other relative experience of possible sub-contractors.

Task 2:

A system design study is performed to sub-system level on the selected satellite concept. A synthesis is made of the space-craft design against the system performance specification which incorporates the following items:

* Drawings of the spacecraft configuration including all the major structural elements. The compatibility of the structure with the reaction control, the attitude control, the electrical and the payload sub-system is demonstrated. A launch configuration is shown.

* An outline design and analysis of the Thermal sub-system for the principal phases of the mission assuming a payload dissipation of 70% of the d.c. input power.

* An outline design and analysis of the Electrical sub-system including estimates of the solar array characteristics for all phases of the mission and a typical battery operating profile.

* A mass budget analysis.

* An outline Reaction Control sub-system design and analysis for the required mission lifetime.

* An Attitude Control sub-system design and analysis including budgetary estimates of the satellite pointing errors.

* An outline design of the Telemetry and Telecommand sub-system required for satellite control and operation.

* An overall drawing of the operational configuration of the satellite.

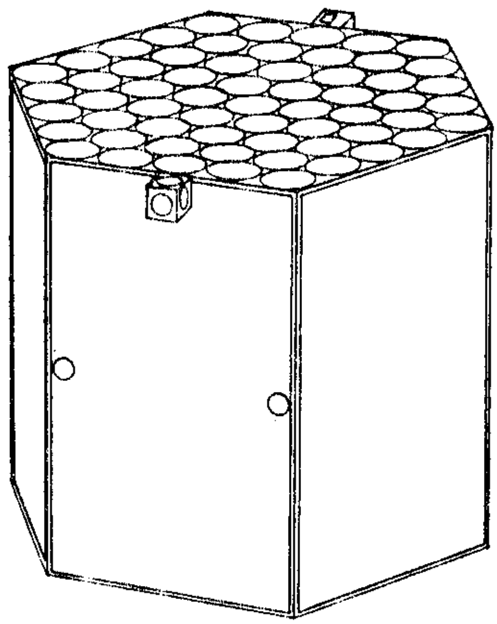
Task 3:

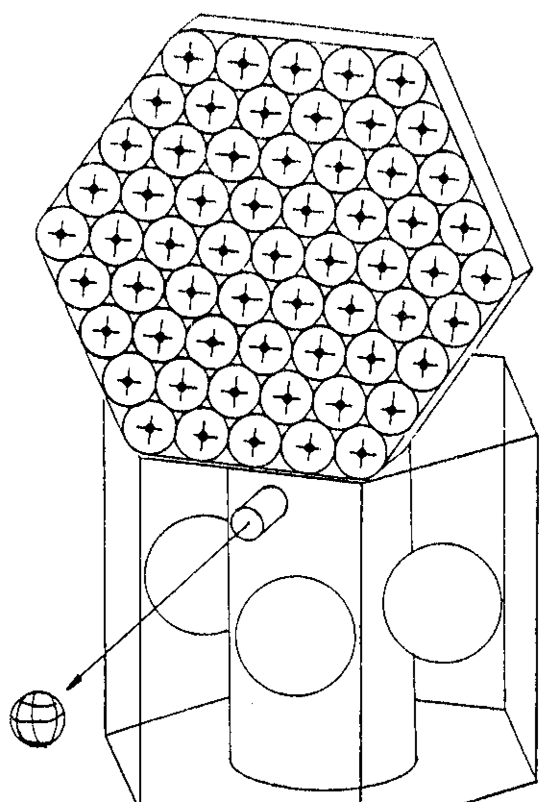
System design to sub-system level is performed on the selected launch concept. A synthesis is made of the launch scenario by means of a selection of a multiple launch configuration arising from Task 1 and followed by a sequenced mission description which is presented pictorially and incorporates the following phases:

* Launch
* Orbit injection
* Orbit maneuver and control
* In-orbit storage and reactivation.

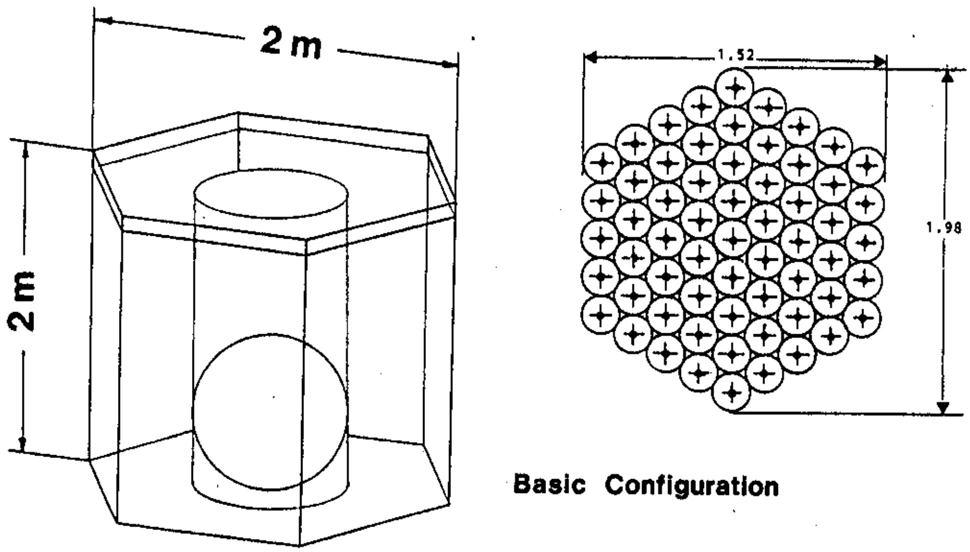
D. L. Brown

Mr. Brown is currently a Senior Systems Engineer in the Satellite Systems Division of the Communications Satellites Department in ESTEC. He is responsible for performing ESA studies on advanced communication satellites and systems. He was the system architect responsible for the initial definition for ESA's data relay satellite space segment and also served as manager of the ESA Consultancy for the Canadian Department of Communications of their M-SAT programme. Prior to this, he managed the consultancy to the Australian OTC on the AUSSAT Programme, he was earlier responsible for a number of promotional experiments on the orbital test satellite, OTS. Mr. Brown also served as Payload Manager on ESA's Aeronautical Communications Satellite studies.

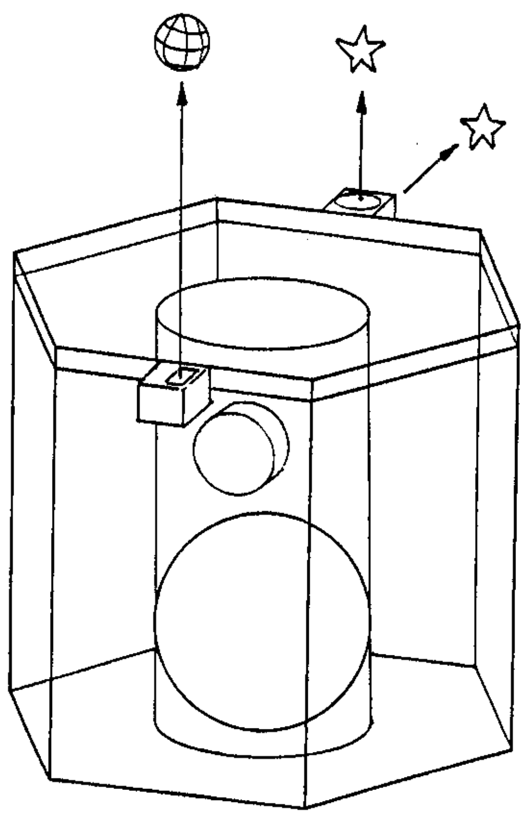




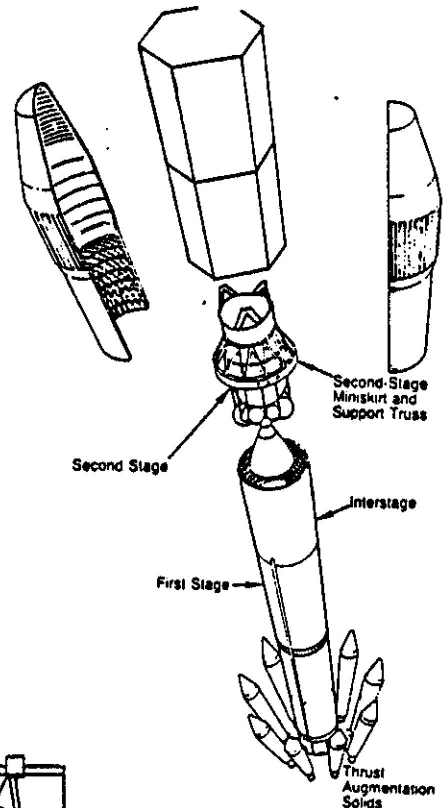
Dual Spin



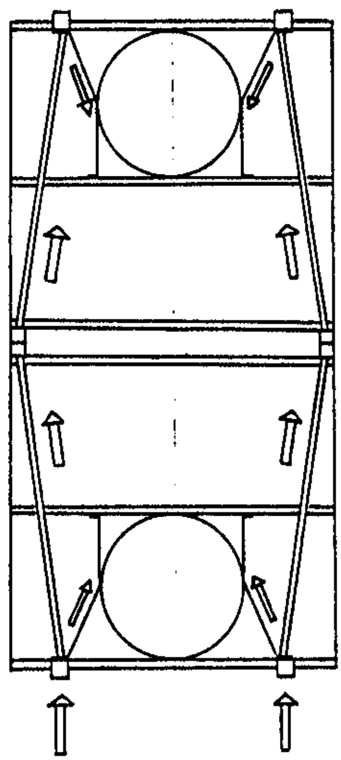
Basic Configuration



Three Axis

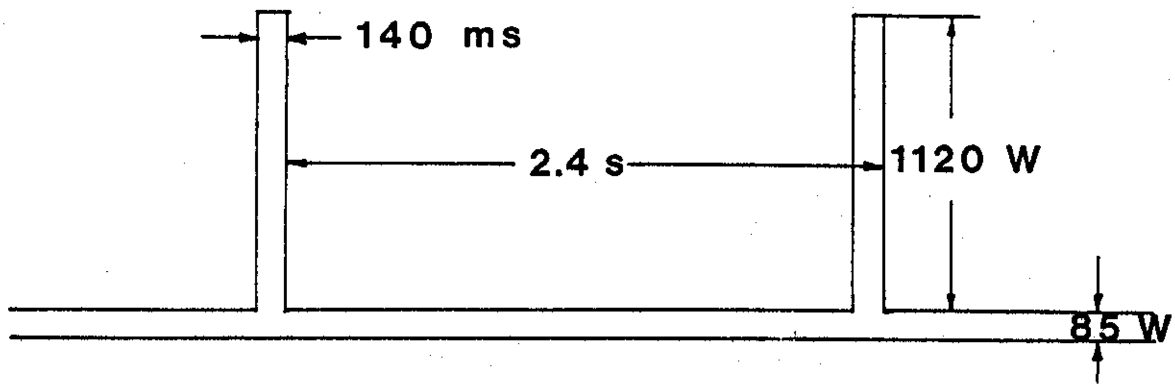


Launch (1)



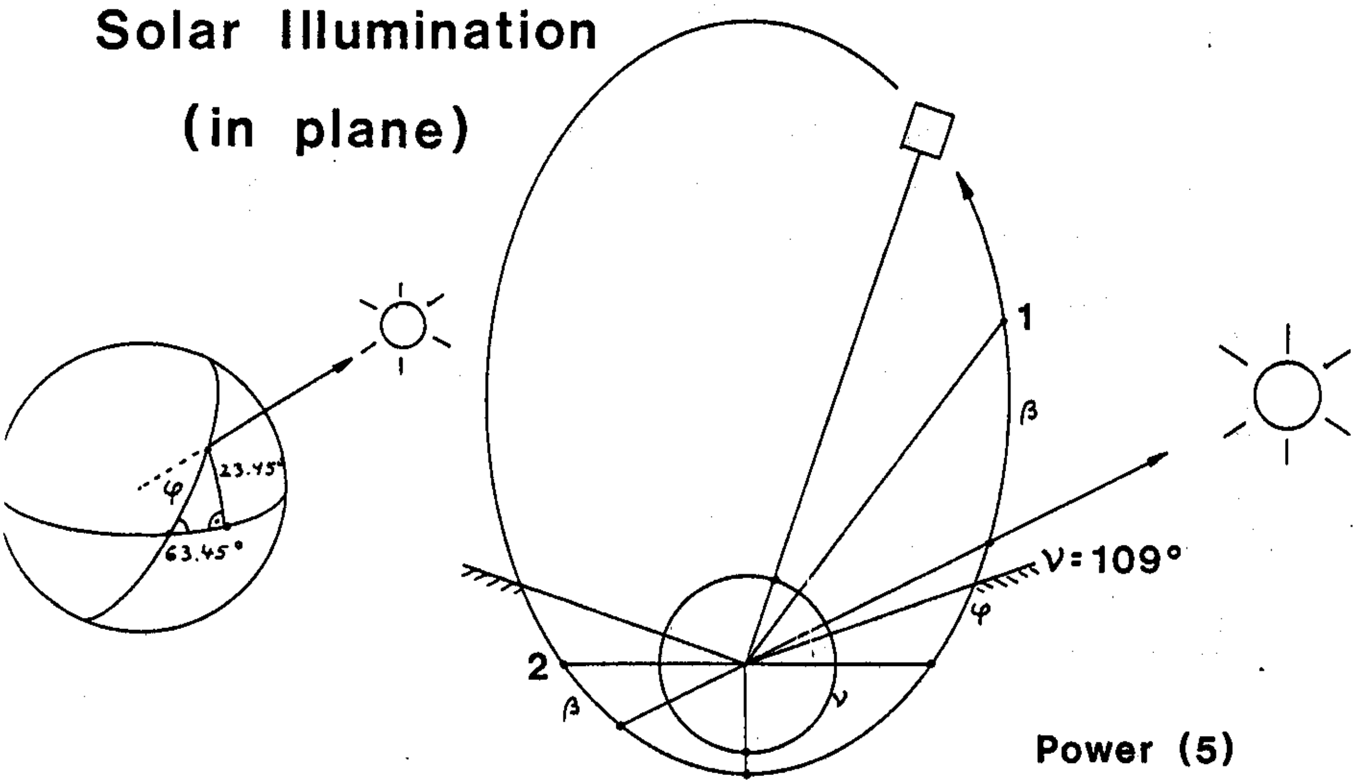
Double Launch Concept

Payload Power Profile

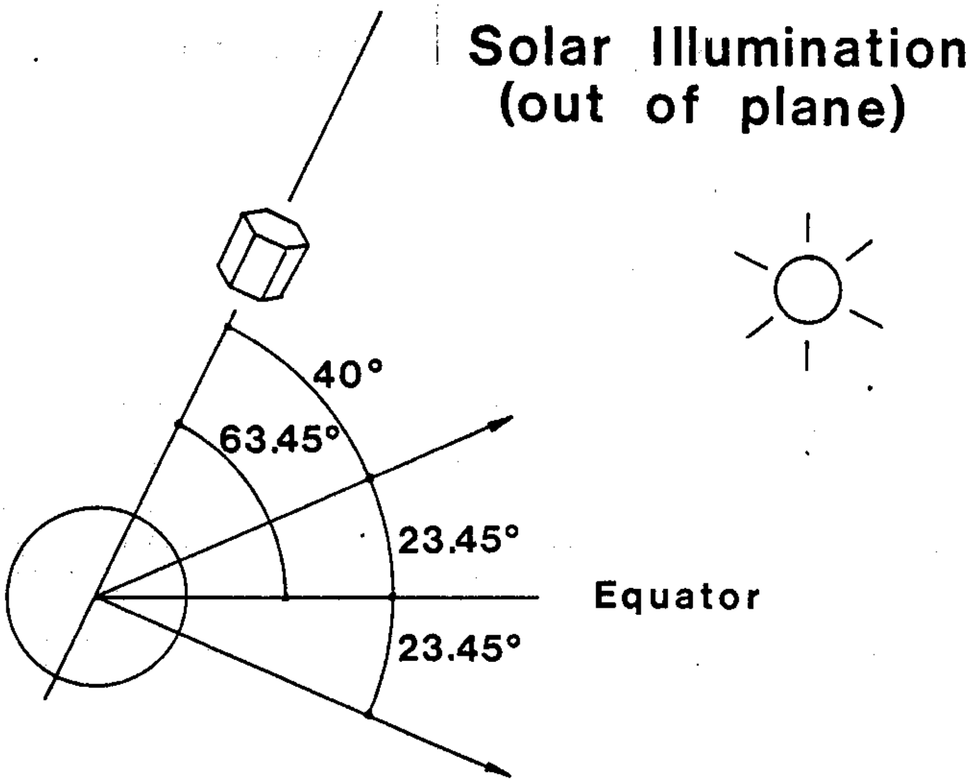


Power (1)

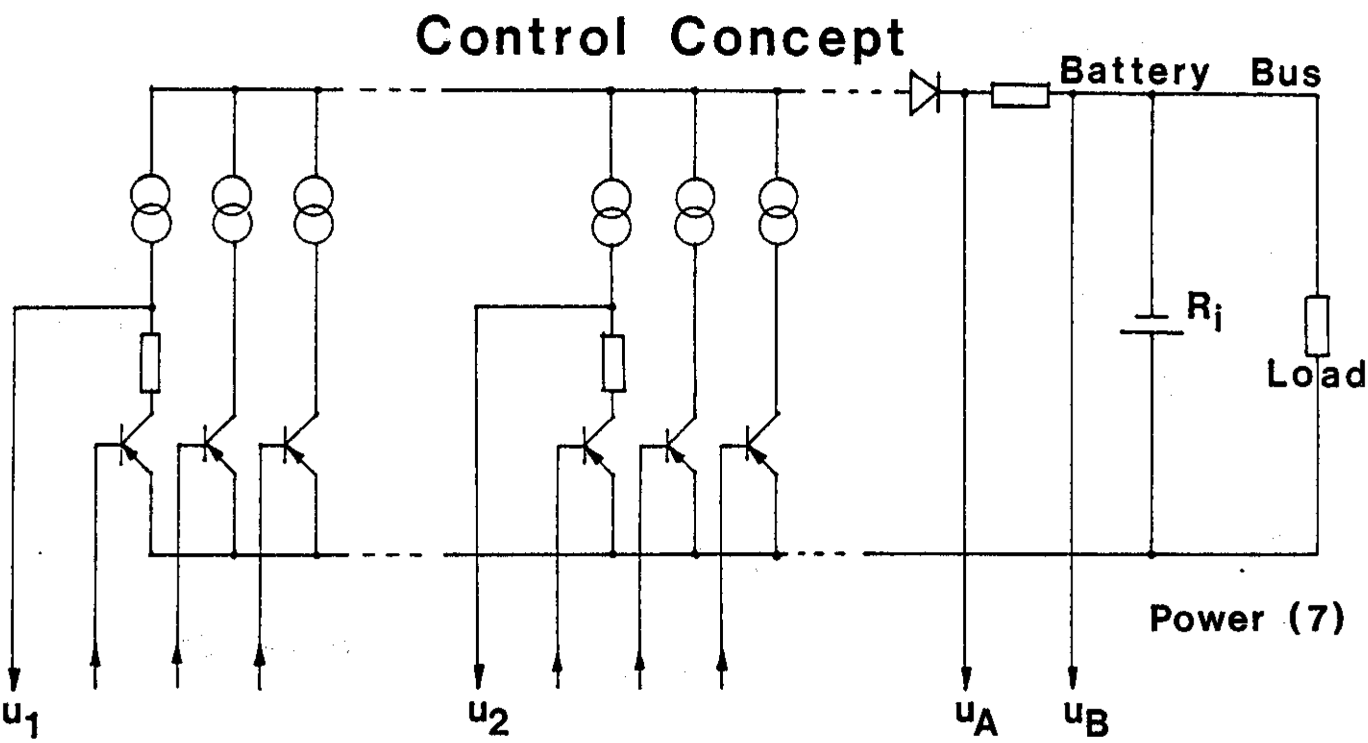
Solar Illumination (in plane)



Power (5)

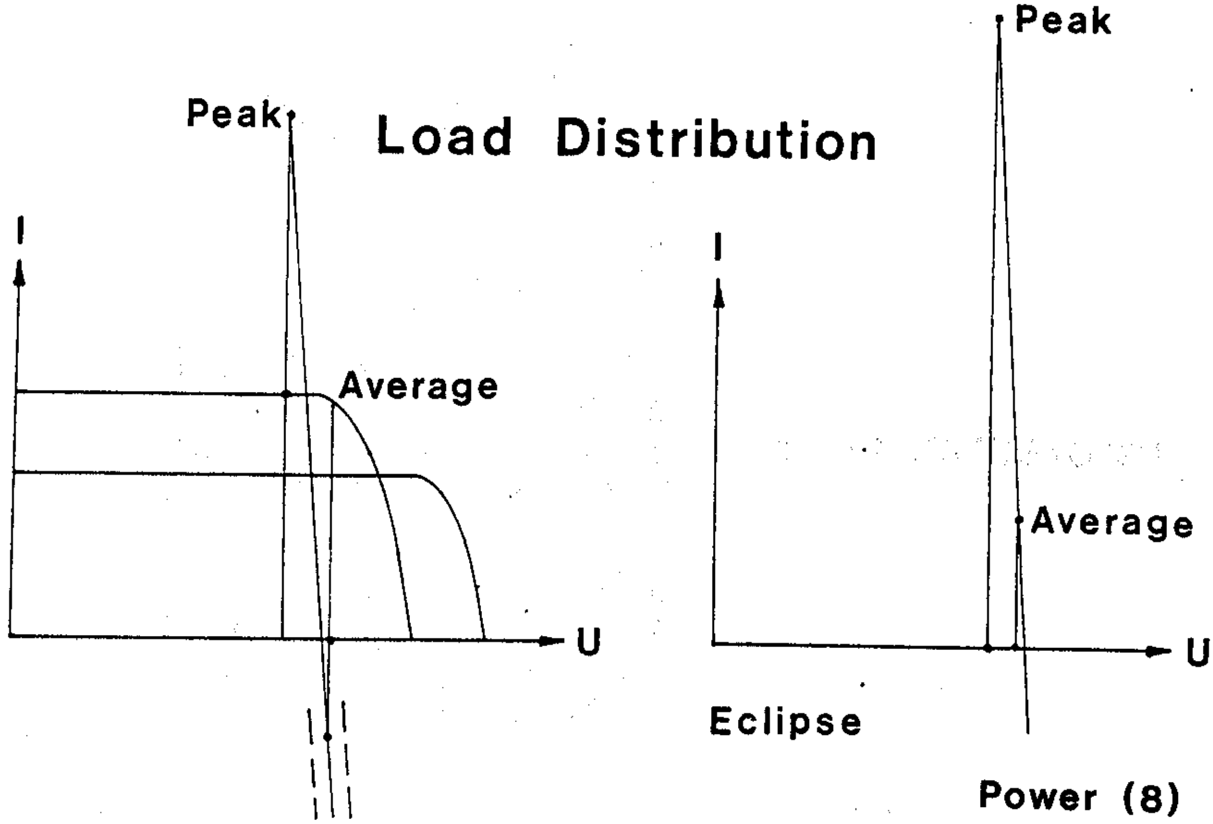

Solar Illumination
(out of plane)
40°
63.45°
23.45°
Equator
23.45°

(4)


Control Concept
Battery Bus
R_i
Load
u_1
u_2
u_A
u_B

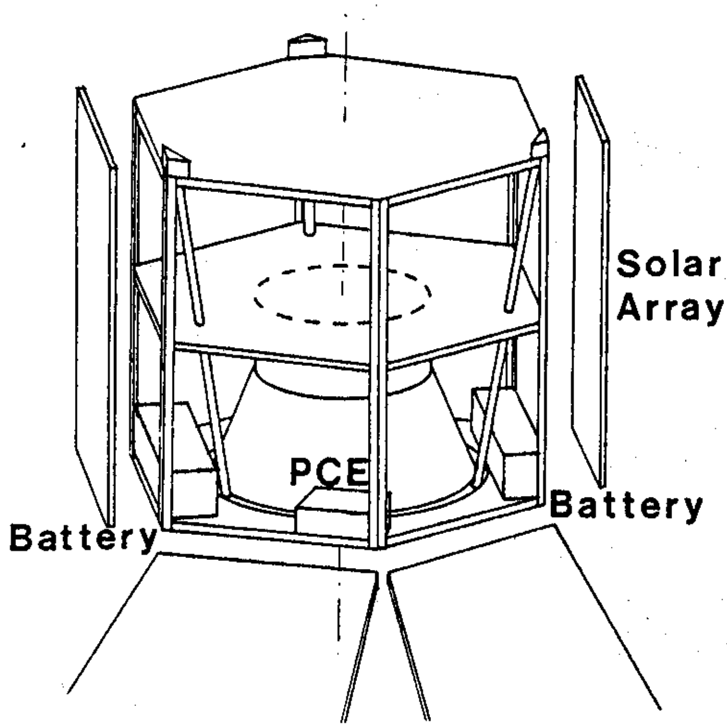
Power (7)

Load Distribution



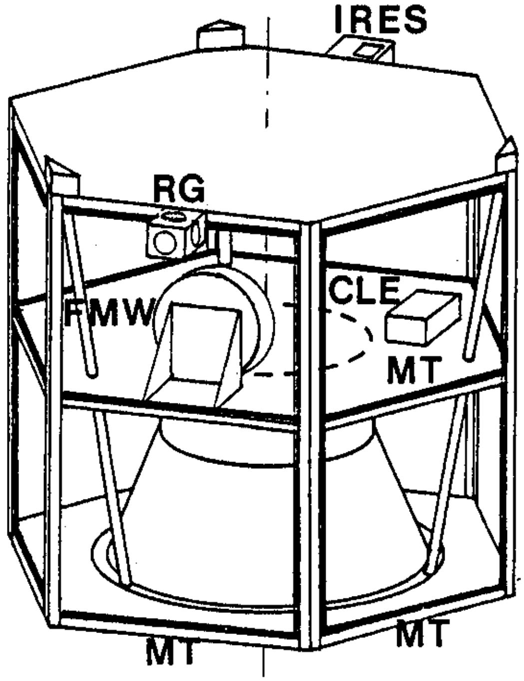
Power (8)

Implementation

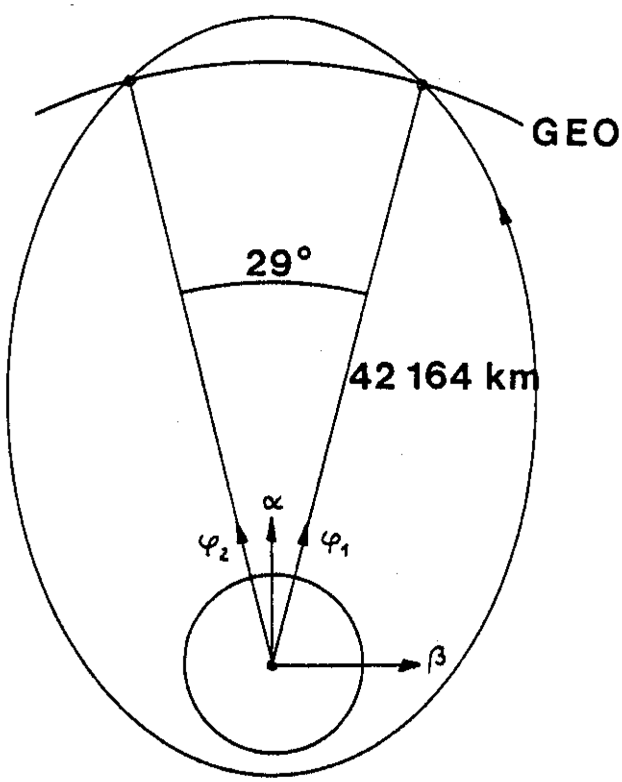


Power (9)

Implementation



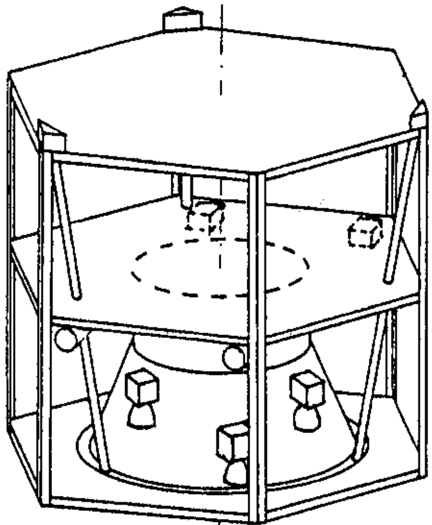
AOCS (1)

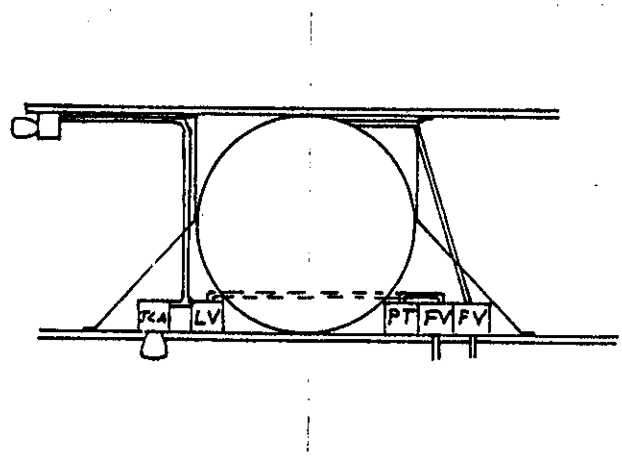


Attitude Reconstitution

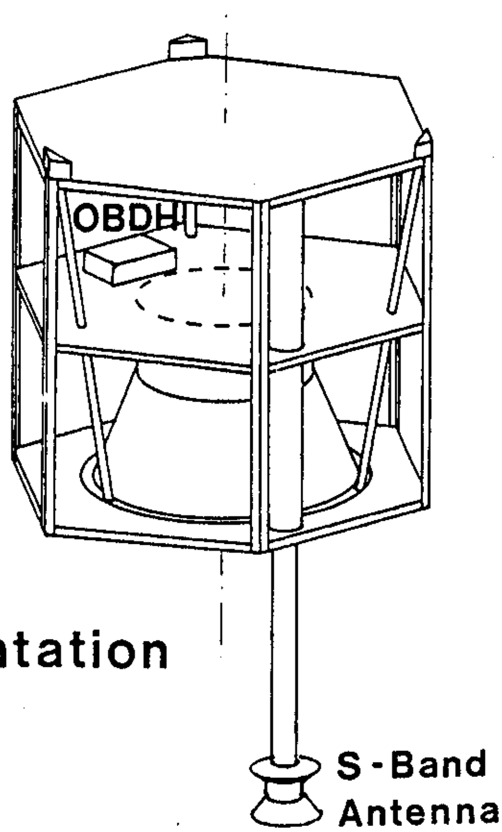
AOCS (2)

Implementation





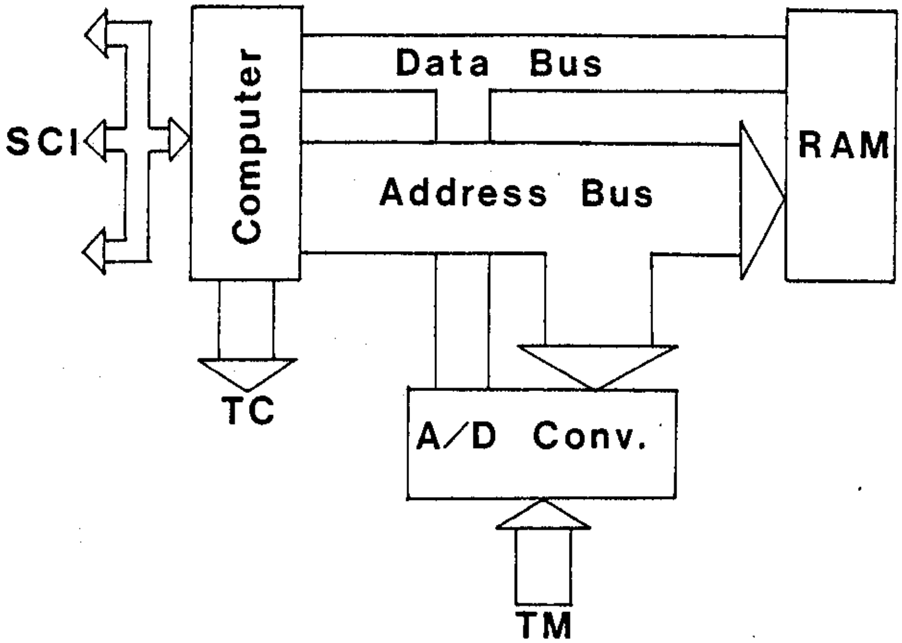
RCS (7)



Implementation

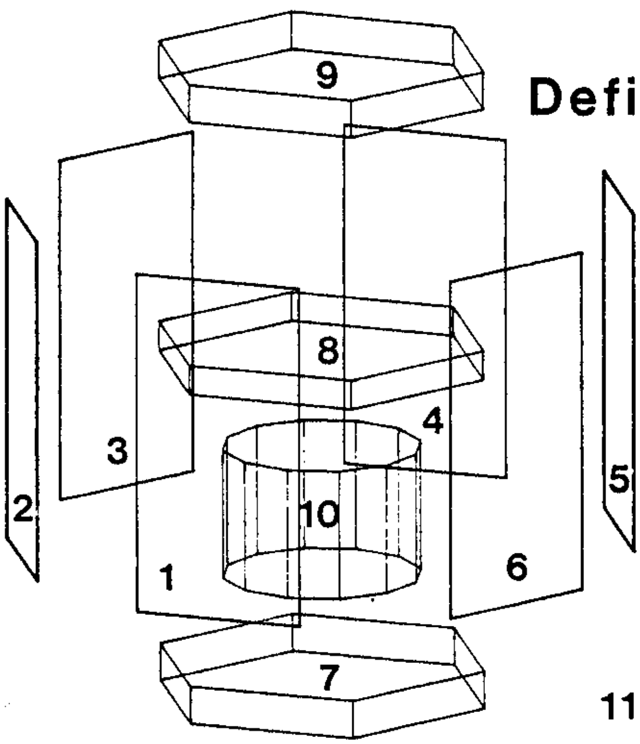
OBDH (5)

Functional Diagram



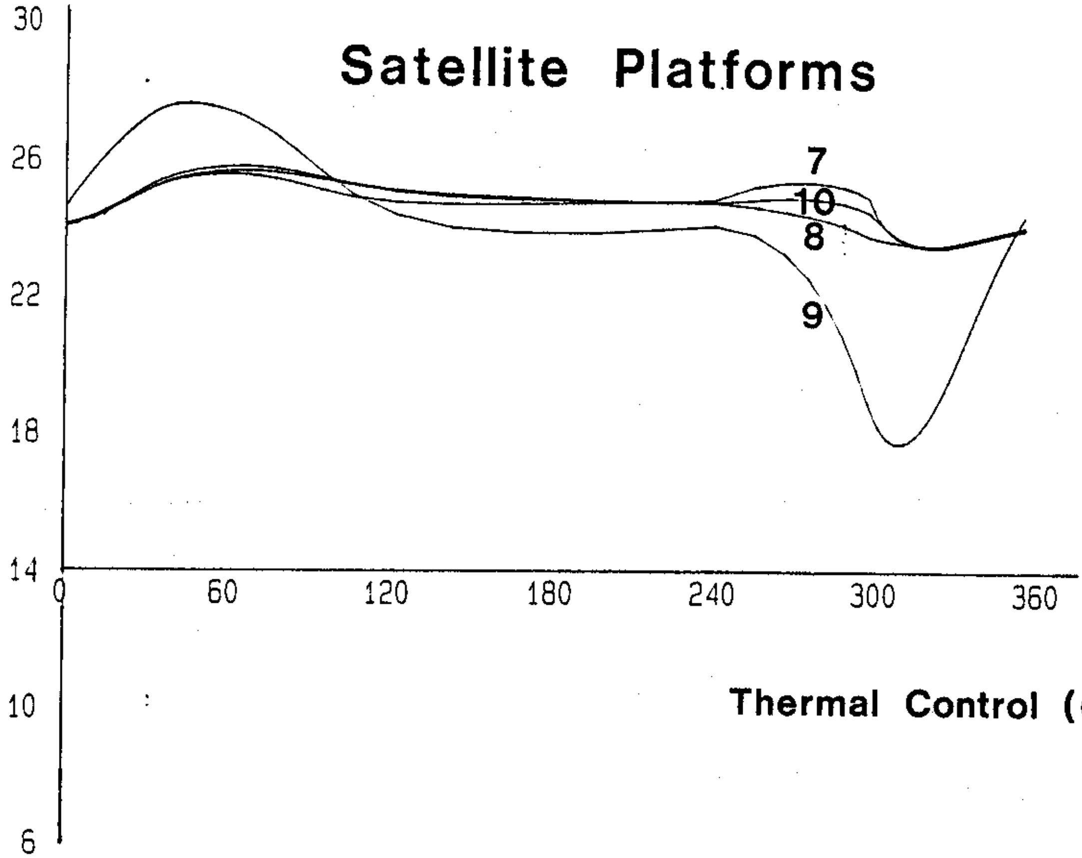
OBDH (6)

Definition of Nodes



Thermal Control (2)

Satellite Platforms



Thermal Control (6)

Mass Budget

Payload	60
Structure	55
Power	55
RCS	25
AOCS	20
OBDH	5
Dry S/C	220
Contingency	96
Propellant	184
Total Mass	500 kg

LOW COST SATELLITE STUDY

* **AIM** - 'TO EXAMINE THE FEASIBILITY OF USING A LOW COST DESIGN APPROACH FOR SATELLITE NAVIGATION SYSTEMS'

* **STUDY** - ANALYSIS OF COST EFFECTIVE SATELLITE BUS FOR HIGHLY ELLIPTICAL EARTH ORBIT

* **TIME** - 28 WEEKS

* **COST** - 50 KAU

WORK UNDERTAKEN DURING STUDY

TASK 1 TRADE-OFF OF ALTERNATIVE SYSTEM DESIGN CONCEPTS FOR SATELLITE AND LAUNCHER

TASK 2 DESIGN SELECTED SPACECRAFT TO SUB-SYSTEM
- Structure
- Thermal
- Electrical
- Reaction control (RCS)
- Attitude control (ACS)
- Telemetry & telecommand (TT&C)
- Mass budget

TASK 3 DEVELOP LAUNCH CONCEPT TO SUB-SYSTEM

TASK 4 FINAL REPORT

SYSTEM SPECIFICATIONS

* ORBIT	-	Molniya Inclination 63.45 degrees Apogee 39105 km Perigee 1250 km Arg of perigee 90 /270 degrees
* SPACECRAFT	-	To support C/L band transponder Operational at altitudes > 10635 km 150W (av) payload 60 kg payload Pointing accuracy +/- 1 degree 3 year lifetime (minimum) L-band - 61 element, ~2m dia array C-band horn - 0.07m dia x 0.17m

FOR MINIMUM COST

LAUNCH OPTIONS

1. ARIANE IV

Circular or elliptic transfer orbit
Spacecraft must carry ABM*
Possible range safety problems

2. DELTA

Can carry 640kg direct into final orbit
No spacecraft ABM
Range safety acceptable

Can carry more mass with PAM-D option

3. LONG MARCH - require spacecraft ABM

4. CONESTOGA ETC - Unproven

* Apogee Boost Motor

SPACECRAFT OPTIONS

OPTION A 3 Axis Stabilised, boresight maintained
Deployed solar arrays

OPTION B 3 Axis Stabilised, boresight maintained
Body mounted solar arrays

OPTION C Dual Spin
C1 : Spin axis normal to orbit plane
C2 : Spin axis in orbit plane

OPTION D Gravity Gradient Stabilised

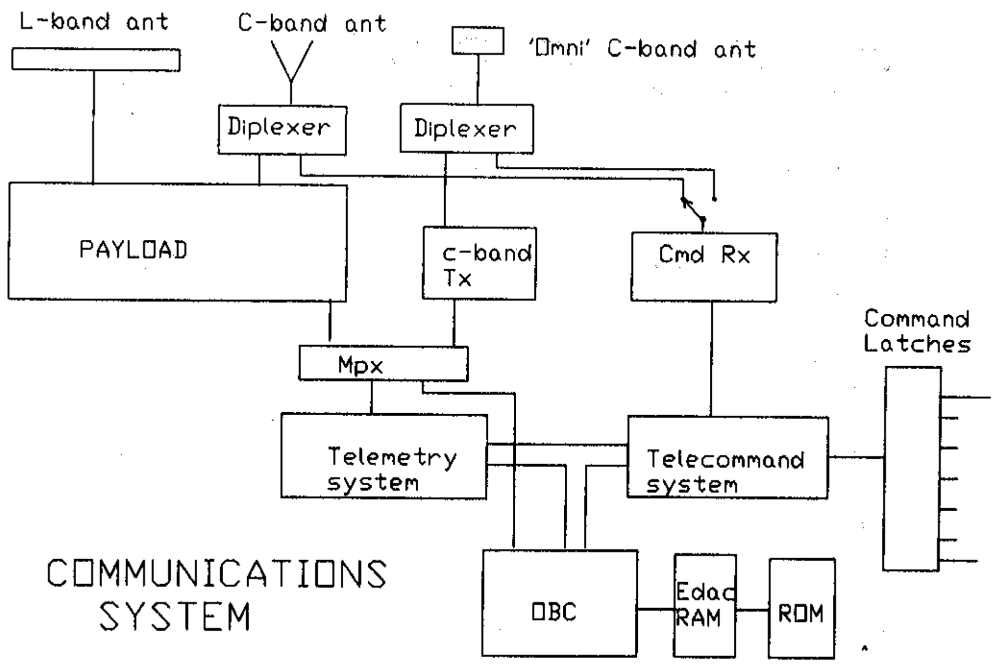
OPTION E Spin Stabilised - inertial pointing of boresight

PROPOSED SPACECRAFT OPTION

OPTION B
3 Axis Stabilised, boresight maintained, body mounted arrays

- simple geometry and construction
- no deployable mechanisms
- can fit two in dual Delta launch
- only small mass disadvantage
- simple Attitude determination and control

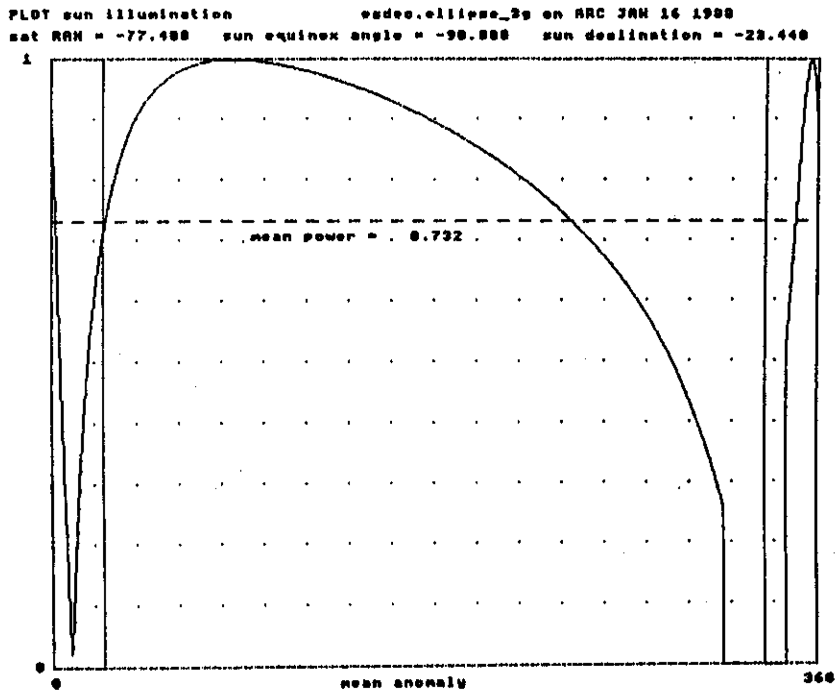
Hence minimum cost satellite and groundstation control

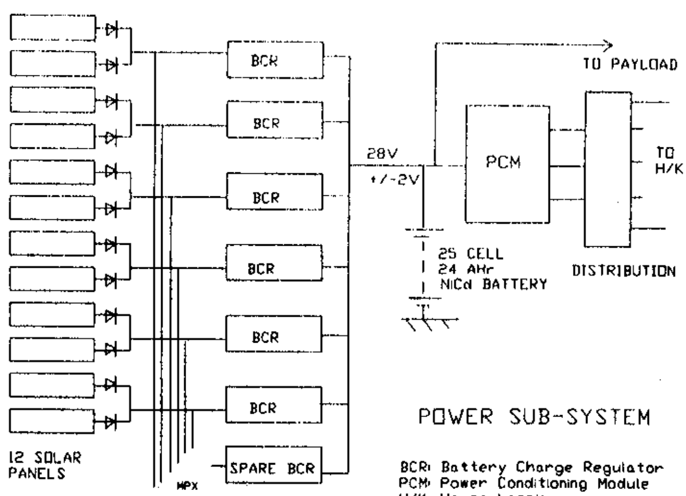


COMMUNICATIONS SYSTEM

POWER BUDGET

PAYLOAD	85W (cont)	65W av pulsed (224W RF)
ACS - EARTH SENSOR	1W	
MAGNETORQUERS	140W	(occasionally around perigee)
MOMENTUM WHEEL	8W	
GYROSCOPE	3W	
MAGNETOMETER	0.5W	
RCS - LATCHING VALVES	<50W	for 50ms at 28V
THRUSTERS	6W	+ 1W for heaters
PRESSURE T'DUCER	1W	
OBDH (OBC/TT&C ETC)	7W	
THERMAL	5W	
POWER	5W	
TT&C EMERGENCY RF	8W	(4W RF)
TOTAL	180 W average	

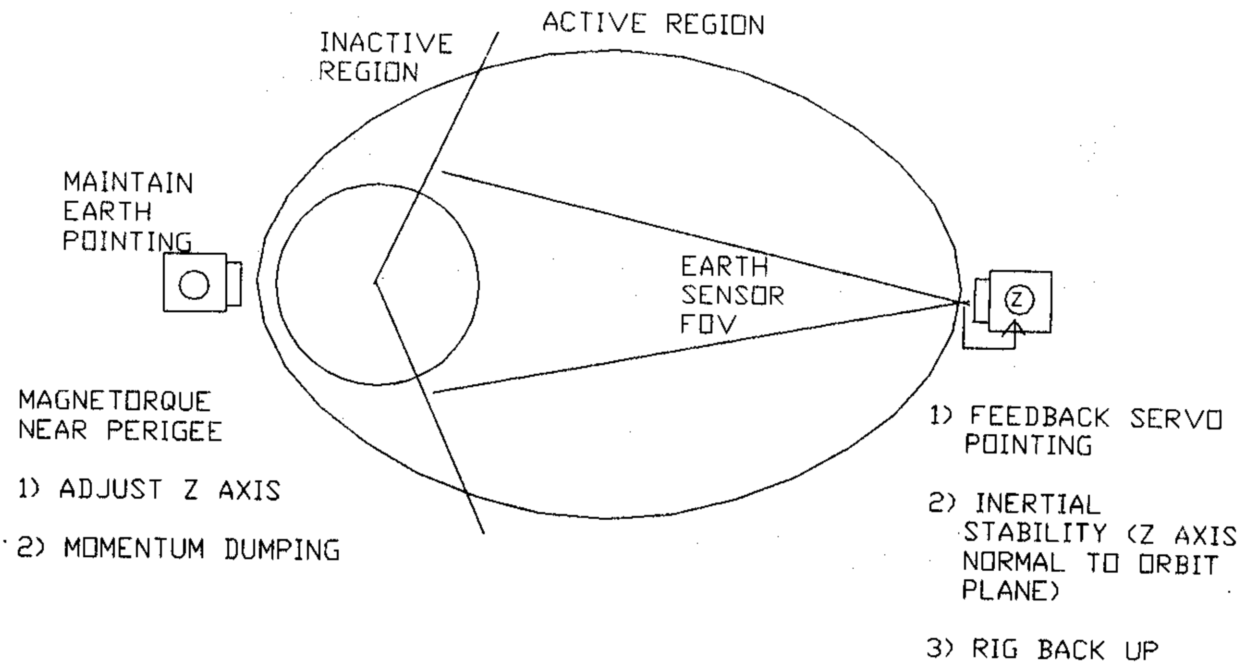




POWER SUB-SYSTEM

BCR: Battery Charge Regulator
PCM: Power Conditioning Module
H/K: House keeping

ATTITUDE MAINTENANCE



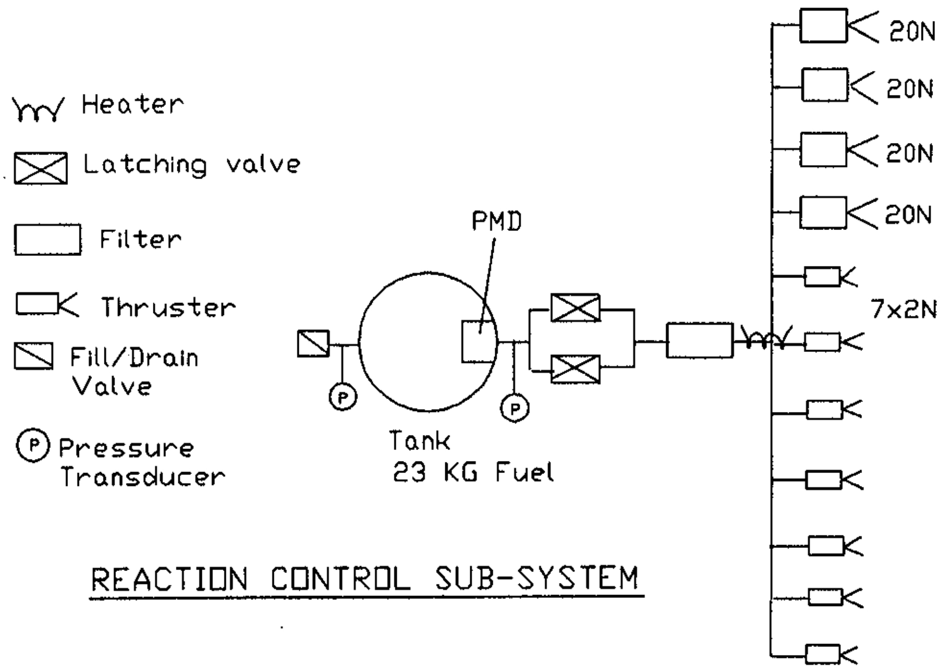
REACTION CONTROL SYSTEM - FUNCTIONS & OPTIONS

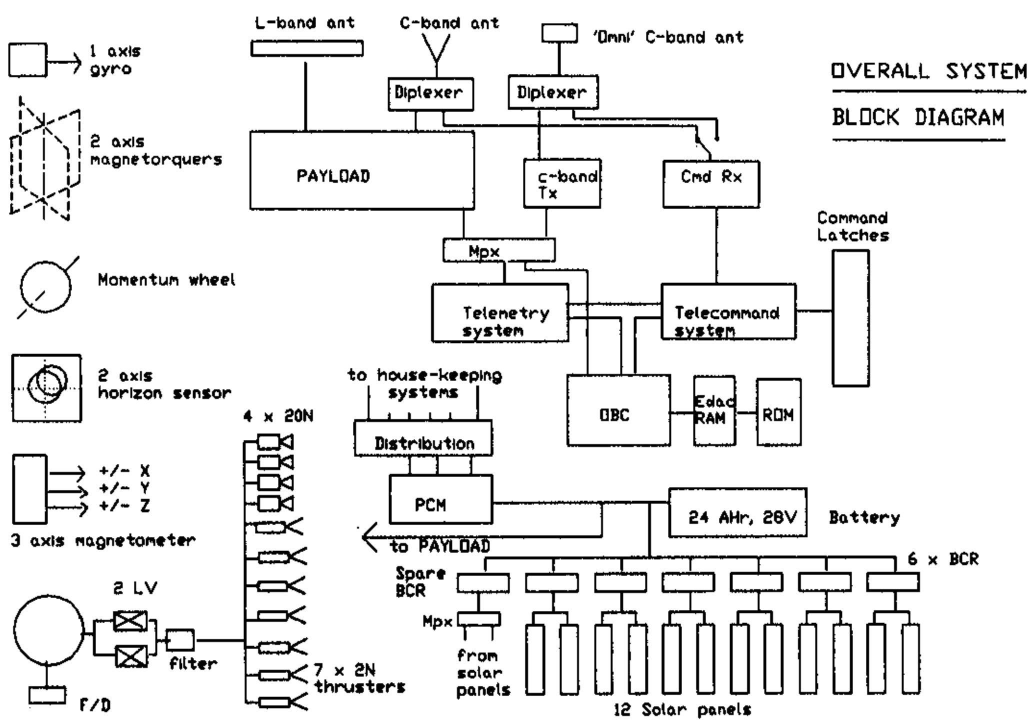
FUNCTIONS:

	maintain ground track	50m/s per year
	initial orbit change	50m/s (negotiable)

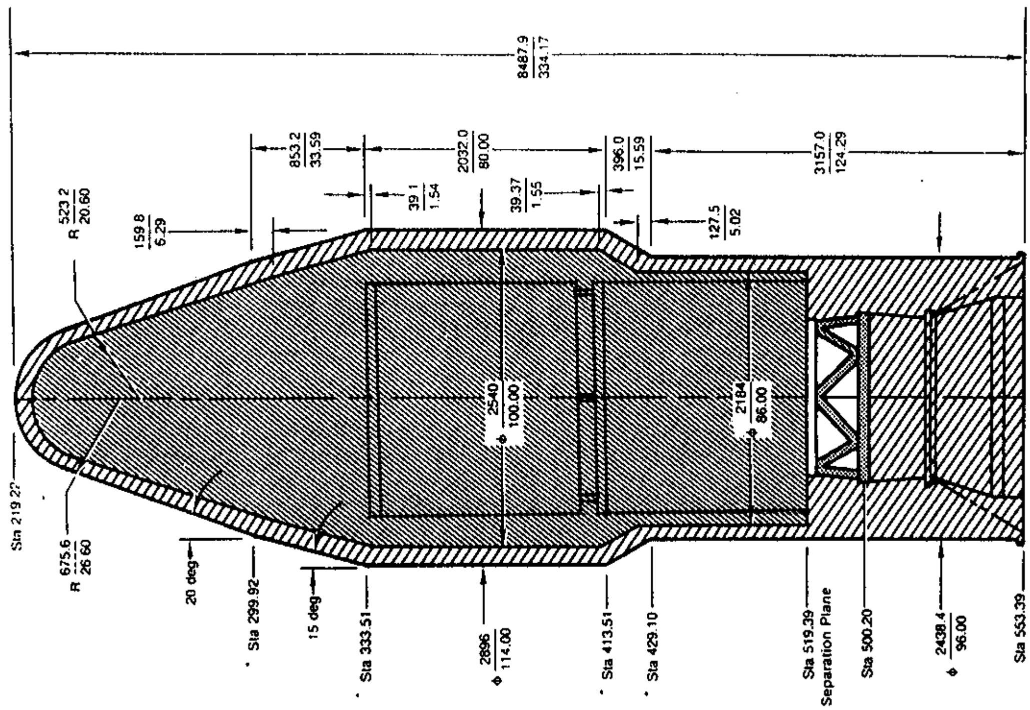
OPTIONS:

* FUEL	Cold Gas	- Isp too low, mass penalty inhibitive
	Hydrazine	- Isp=210s, acceptable performance proven technology, proposed option
	Bi-propellant	- complex, high cost, extra performance not required
* TANKS	Bladder	- bladder decomposition, redundant thrusters
	Surface Tension	- no bladder, 1 set thrusters small cost disadvantage Proposed option


Heater
Latching valve
Filter
Thruster
Fill/Drain Valve
Pressure Transducer
PMD
Tank
23 KG Fuel
20N
20N
20N
20N
7x2N
REACTION CONTROL SUB-SYSTEM


OVERALL SYSTEM
BLOCK DIAGRAM
1 axis gyro
2 axis magnetorquers
Momentum wheel
2 axis horizon sensor
+/- X
+/- Y
+/- Z
3 axis magnetometer
2 LV
Filter
F/D
4 x 20N
7 x 2N thrusters
L-band ant
C-band ant
'Omni' C-band ant
Diplexer
Diplexer
PAYLOAD
c-band Tx
Cmd Rx
Command Latches
Mpx
Telemetry system
Telecommand system
to house-keeping systems
Distribution
OBC
Edac RAM
ROM
PCM
24 AHr, 28V
Battery
to PAYLOAD
6 x BCR
Spare BCR
Mpx
from solar panels
12 Solar panels

CYLINDER THRUST COLUMN OPTION



Payload Envelope, Two-Stage Configuration (6019 Attach Fitting)

MASS BUDGET

PAYLOAD	60
SOLAR ARRAYS (Si)	40
BATTERIES (NiCd)	25
POWER SS	12
MOMENTUM WHEEL	6
GYRO	3
SENSORS	1
MAGNETORQUERS (x2)	8
7 x 2N THRUSTERS	2
3 x 20N THRUSTERS	1
TANK	4
PLUMBING	3
FILTERS/VALVES	2
ELECTRONIC PCB'S	10
'OMNI' C-BAND ANTENNA	3
TOTAL (excl Structure)	180
STRUCTURE	39
TOTAL DRY MASS	219
FUEL	23
WET TOTAL	242
TWO SPACECRAFT	484
ADAPTER	60
TOTAL	544 kg

THE FRENCH SPACE PROGRAM

The Main Trends in the Fields of Space Sciences, Earth Observations, Life Sciences and Physics in Microgravity

I. Revah
Centre National d'Etudes Spatiales
France

France initiated its space activities 25 years ago by the creation of CNES which aimed its initial efforts at building a launch vehicle, Diamant. The civilian French space agency, CNES, established in 1962, was given the following main responsibilities:

- Identify the future trends in space activities and propose future orientations to the government for national and cooperative programmes.

- Take the responsibility of the technical management of large programmes conducted on a national, bilateral or multilateral basis within ESA.

- Define and support space research activities within the scientific community.

- Support the space industry at the technical level through research and technology programmes.

- Interface with space systems users including public service authorities.

- Promote and support space technologies applications through the establishment of and participation in commercialization subsidiaries.

The French space programme is currently characterized by balanced activities in four main domains:

- Basic studies involving research and technology efforts are the core of CNES programmes and the foundation of future successes in space sciences and applications. Present ambitious scientific missions in astronomy or planetary exploration, the Ariane launchers programme or the operational systems and the competitive area activities such as SPOT, in earth observations, and Telecom 1, in telecommunications, have been prepared by the basic studies initiated in 1970. Similarly, current technical efforts prepare the space missions of the end of this century.

- Scientific programmes and the quest for knowledge stay at the heart of space activities. The challenge of research in space provides the impetus for large international cooperative projects and advanced technological developments.

- Practical uses of space technologies are directly connected to commercial applications satellites in telecommunications, earth resources survey, direct broadcasting, search and rescue.

- Development of space transportation systems: autonomous access to space is the key of an independant programme able to reap economic and strategic benefits from large-scale investments.

Space activities will be dominated, during the coming twenty years by a multiplication of manned flights and by the efforts aiming the occupation and exploration of Outer Space by Man. This direction which involves political, commercial, technological and scientific challenges is strongly linked to the mastering of key technologies in various fields: robotics, complex software and simulation, artificial intelligence, new materials, hypersonic aerodynamics and aerothermodynamics, etc.

In addition to the American and Soviet space station programs and orbital infrastructures, one must take into consideration a similar European effort. The ESA councils at ministerial levels in Rome (1985) and La Haye (1987) have strongly endorsed the objective of autonomy for manned space flights before the year 2000. This fundamental decision has been taken considering that:

- New space applications using the presence of man will open up an important field for technical and economic ambitions of countries in space exploitation.

- Human intervention in space may have a considerable impact for technical and scientific programmes (tendable observatories, in-orbit assembly of heavy spacecrafts, deployment of large structures, etc. ...).

- Discovery, exploitation and utilization of space by human beings will be one of the prime undertakings of major powers in the 21st century.

Space Sciences

Scientific research has been among the first activities to benefit from the space effort. Space platforms and sensors have significantly transformed observational methods in all the disciplines of Cosmology and Space Sciences, and have allowed major progress in our understanding of the Universe, its origin and evolution.

These scientific activities are generally operated in cooperation either in the framework of ESA's scientific mandatory programme or in bilateral cooperation mainly with the USA and the USSR.

Space platforms have enabled carrying astronomy sensors above the screen formed by atmosphere and have opened the way to important discoveries. One has thus progressively observed, since 1965, that the image of a calm Universe of stars and galaxies must be replaced by that of a Universe in which occur continually severe phenomena as star collapses and explosions, or shocks following the formation and disappearance of celestial objects. The corresponding studies use the radiation emitted by these objects in a wide range of wavelengths in the electromagnetic spectrum. In the field of high energy astronomy, two projects are conducted with the USSR:

- The French Sigma telescope (1 ton, 3.5 m high telescope) has been included in the Soviet gamma/X-ray astronomy satellite Granat (1988) to map gamma-ray sources in the range 30 keV to 2 MeV with an angular accuracy of 1 arc-min.

- French astronomy sensors are mounted on the Soviet Gamma 1 satellite (1988) observing sources of energies above 50 MeV.

In the framework of the ESA programmes, France participates in the 1 ton geostationary astrometry satellite Hyparcos (1988) which will measure the motions and positions of over 100,000 stars with a very high accuracy (2.10^3 arc-sec) and to the Infrared Space Observatory (1992) with its 60 cm cooled telescope devoted to the observation of infrared galactic and extragalactic sources.

In the field of solar system exploration the research effort concerns mainly the study of the sun and its physical properties and the observation of planets: the Soviet Vega mission towards Venus and the Halley Comet, 1985, also carried a set of French instruments; the French scientific teams participated in the Giotto mission of ESA (1986) which flew by the Halley Comet at a distance from the nucleus of 500 km.

In this field the main projects in preparation for the future concern on the one hand, participation in the Soviet programme for the exploration of Mars:

- Participation in the Phobos mission in 1988 (fly-by of Phobos at a distance of 50 m in order to study its surface properties, and study Mars and its atmosphere).

- Provision of remote sensing and in situ sensors for the Soviet 1994 Mars Mission which will be composed of a Mars orbiter and a balloon for the measurement of atmospheric parameters and surface properties.

On the other hand, participation in the framework of ESA to the solar terrestrial physics cornerstone of Horizon 2000 programme (Soho for the study of heating processes in the solar corona and Cluster for the study of the spatial and temporal variations of the Earth's magnetosphere and the interplanetary medium).

CNES is also engaged in an active scientific cooperation with the USA in the field of atmospheric sciences (Windi experiment on the American UARS satellite, 1992) and in the field of Space Oceanography. In the latter field an American satellite with American and French instruments (radar altimeters, microwave radiometer, precision locating systems) will be launched by the Ariane rocket in 1991. This project, Topex-Poseidon, will provide a global view for the ocean circulation whose knowledge is essential for the understanding of climatic changes of the planet Earth.

Microgravity research: life sciences and material sciences

The conditions of reduced gravity which exist in a spacecraft on orbit, provide long-term scientific and technological perspectives and new possibilities for space applications.

In the field of life sciences fundamental research efforts concern the fields of human and animal physiology and the field of radiobiology. This gave rise to experiments involving French astronauts on board the Soviet Salyut Station (J.L. Chretien, 1982) and the American shuttle (P. Baudry, 1985). In the near future (1988) a long duration flight is planned in the MIR station and will involve new cardiovascular and neurophysiology experiments. Concerning the applications field an important effort is devoted to techniques of purification (electrophoresis) and crystal growth of macromolecules (proteins) which would open the way to major industrial challenges.

Concerning material sciences, directional solidification and crystal growth (vapour phase and solution) have proven to be fields of excellence for the French teams (results obtained during the Spacelab flights, 1983 and 1985; building of the Mephisto facility for solidification studies on board the shuttle in cooperation with NASA.

Applications satellites: telecommunications

CNES takes part in cooperation with the French PTT in the development of a wide range of telecommunication services oriented by the needs arising for digital telecommunication service, conventional telephone traffic between France and the overseas territories, video communication links, governmental and military links. In France, considerable progress has occurred since the launch of the two geo- stationary satellites of the Symphony programme in 1974 and 1975, in cooperation with Germany. The perfect success of this project allowed to take up current programmes under good conditions:

* The Telecom 1 programme which started in 1979, is a three satellite system, Telecom 1A (1984), Telecom 1B (1985) and Telecom 1C (1988). Continuity of service will call for a system replacement beyond 1990 (studies for second generation systems are now underway).

* The Franco-German cooperative Direct Broadcasting Satellite programme with four high power channels(230W) on each satellite TV-SAT and TDF1. The German satellite TV-SAT was launched in 1987 and the French TDF1 is scheduled for 1988.

Earth Observations

France has developed (with Belgian and Swedish participation of 4% each) an ambitious Remote Sensing of Earth resources programme: the SPOT System. SPOT 1, the first of a series of 3 identical satellites was launched in February 1986.

The SPOT programme is characterized by high resolution instruments and new capabilities putting it in a strong position compared to the other competitors in Earth observations. A private corporation SPOT IMAGE, a subsidiary of CNES, assures the commercialization of SPOT data, within the framework of continuity of operations for at least 10 years, which has recently been decided by the French government.

Endeavours to observe our planet Earth from above were undertaken long before the advent of remote sensing space platforms. Aerial photography was already being used for many years in various fields of applications when the first satellites for earth observations were launched. Two main fields of applications, meteorology and remote sensing of Earth resources, took advantage of the unrivalled capabilities of space systems: global coverage, wide extent of the instantaneous field of view, repetitivity and permanence of the observations, efficiency of the data collection and dissemination techniques.

As regards remote observation of the Earth's surface, the implemented sensors involve specific functions and complex techniques aiming at the acquisition, the analysis, the selection and the processing of extremely large amounts of information contained in the observed images.

Remote sensing images and images provided by the French SPOT system contain valuable information for a wide range of applications in the economic sectors:

* For the renewable resources field, current SPOT data, appear to be an important complementary information to other traditional sets of parameters for the management and exploitation of these resources; this information by its geographical accuracy and the updating possibility will very probably lead to substantial economic benefits.

* For the cartography field SPOT represents the first genuine topographic satellite by its stereoscopic capability and geometric quality of the images (altimetric maps at scales in the range of $^{1}/_{50000}$ to $^{1}/_{25000}$).

* Mining and oil exploration which have already integrated Landsat data in their usual engineering methods aiming at productivity gains, will benefit from the improved space resolution of SPOT data.

* Infrastructures and construction, land use, rural and urban planning will take advantage of the essential information yielded by the SPOT high resolution and 3D imagery, during the preparatory and feasibility phases of the projects.

In taking into account these industrial and economic features, CNES has undertaken a long-term effort as early as 1979 in order to prepare and promote the utilization of SPOT images and make potential users aware of the benefits of remote sensing and of the products and services which could be derived.

At that time, research studies aimed at the development of methodologies were carried out in cooperation with the main French institutes interested in remote sensing (BRGM, IGN, ORSTOM, IFREMER...). A simulation programme having the objectives to familiarize users with the future SPOT data and evaluate the contribution of these data in main applications areas was also undertaken.

In 1984, after this first phase of research activities, CNES in conjunction with SPOT IMAGE has focused its support on the development of operational applications. In that framework the main effort concerned the PEPS programme (Programme International d'Evaluation Preliminaire de SPOT) which evaluates the usefulness, the quality of SPOT data and their contribution to the users needs:

130 projects have been selected from 31 different countries and their results presented at a symposium in Paris (November 1987).

In parallel, the French institutes cited above have undertaken training programmes for their personnel, established remote sensing centers in their organisations and promoted remote sensing techniques through seminars or with specific assistance.

From the industrial point of view, that period is also characterized by the development of equipment (ground receiving stations, data processing systems) specific to the SPOT system.

Following the launch of SPOT 1 in 1986, the preparatory programme is being completed by a wide range of actions with the objective of speeding up the development of commercial and operational utilization of SPOT data which could benefit identified user market.

This programme is progressing in three main directions:

* Sensitize and train users of SPOT data.
* Help emergence of appropriate systems for the reception and the processing of SPOT data.
* Help emergence of products and services derived from SPOT data (value added services).

Isaac Revah

Isaac Revah, born in 1934, obtained his Ph.D. at the University of Paris in 1968. From then on he was at the Centre de Recherches en Physique de l'Environnement Terrestre et Planetaire (CRPE).

Deputy Director of CRPE in 1979, a joint laboratory to the Centre National de la Recherche Scientifique and the Centre National d'Etudes des Telecommunications, he was nominated Director of this laboratory in 1982.

In 1984 he joined the Centre National d'Etudes Spatiales as Director of Programmes.

NEW DIRECTIONS IN LOW GRAVITY SCIENCE
Applications And Commercialization

S. Ostrach

Case Western Reserve University

U.S.A.

Before talking about new developments in micro-gravity science applications and commercialization, I will tell you about the current program. The long-term goals of this program, as outlined by NASA are to develop advanced fundamental understanding of processes on Earth, in the solar system, and in the universe. More specifically, to increase understanding of the influence of gravity on earth-based processes that can lead to better control strategies for such processes; to develop limited production of exotic high value materials with enhanced properties; to serve as bench marks for comparison with earth based technologies for highly specialized applications; to

evolve processes for the eventual commercial production of certain high value added products in space; and, to explore the possibility of processing extra terrestrial materials for the support of space or lunar colonies and for long duration manned exploration missions.

What are the potential advantages of a low gravity environment? Well, there is the reduction of buoyancy-driven convection, reduction of phase separations and particle settling, and levitation and isolation of large samples in materials processing. The NASA program includes aspects of each of these, or applications involved in each, but primary emphasis has been given to the reduction of buoyancy-driven convection in the hopes of obtaining enhanced crystal quality. There are some programs on directional solidification and multi-phase composite materials and biological separations and there has been some work done on levitation and isolation of large samples with the ultimate application being for containerless processing of materials.

The present program is broken up into six disciplines. I am going to describe each of these, more or less, to give you an idea of the scope and the objectives of both scientific and applied tests.

For the most part, the effort has been directed to materials processing. The interesting thing is that in the early days, fluids and transport aspects were sort of considered to be ancillary to the program--not terribly important. Today the concept is that the fluids and transport part of the program is really the cornerstone. Because, after all, these advantages impinge very, very, significantly on the fluid phase. Also, one of the things that was developed in the early days is the idea, on the part of materials people, that what happens in the fluid phase very signifcantly influences the solid state structure. If nothing else, even if there were not a single bit of scientific information obtained, this program, put together in a very positive way, brought together people from many different disciplines. This has had a very direct and positive influence on many aspects of research in the United States in other fields.

Let us take these one at a time: the first of these is bio-technology and broadly defined, bio-technology includes any technique that uses living organisms or molecules from organisms to make or modify products and to develop new organisms in biological materials and to improve plants and animals through genetic manipulation. The objective of this program is to research, both on the ground and in space, to increase our understanding of the relevant phenomena that provide improved biological materials and processes.

The justification is that convection or sedimentation processes effect separation of biological properties or interaction of cells and therefore, you could gain a great deal more understanding by low-gravity research; and the applications are the fractionation of biological cells and proteins yielding higher purity and specifically resolved biological species.

Another very important aspect in which some rather interesting results have been obtained is the growth of protein and macro-molecular crystals that are larger and of higher quality than achievable on Earth. These can be studied by X-ray diffraction techniques to determine the molecular structures. Also included here is the culture of biological cells, to evaluate beneficial effects in the cell function metabolism or secretion of desirable products. The general overall goals of these areas is to produce large, high quality crystals of proteins, DNA and other biological macro-molecules; to improve methods of separating cells and biological macro-molecules; to investigate gravitational effects on the formation of complex, macro-molecular aggregates; to study the functional properties of cells in micro-gravity; and, to test formation and release of secretory products from cultured cells in micro-gravity. Experiments indicate that the space environment affects the secretion of cells with the pituitary and immune systems and therefore there is a need to understand the cellular functions for people working for long periods of time in space.

The second main category in the program is Metals and Alloys. Gravity influences the formation, structure and properties of metals at various length scales varying from atomic and molecular level to microscopic and macroscopic levels. So the goals of the metals and alloys program is: to arrive at an understanding of the relationship between the microstructure of metals and alloys and their properties; and also to see how process changes influence the microstructure. We want to gain understanding of and create a comprehensive scientific data base on solidification mechanisms of metals and alloys and their resultant properties and behavior. The reduction of the gravity force diminishes convection and permits more precise control of solidification processes, obviates the limitation of reactive melts and reduces body forces such as sedimentation, hydrostatic pressure, and defermation. There is interest in taking advantage of each of the three characteristics of a low-gravity environment and the applications would be improvement in processing control strategies;

the development of innovative new processes and perhaps getting some bench mark materials made in space.

We found that the priorities from a scientific point of view are the solidification, kinetics and under-cooling, micro-structural morphology prediction, process analysis and modelling interfacial phenomena and thermal-physical properties, and the key technological applications would be in containerless processing, directional solidification, crystal-growth and casting.

The third main category is glass and ceramics. And again, in glasses and ceramics low-gravity and modelling studies are used to gain improved scientific understanding of glass formation and the processing and the properties of vitreous and crystal ceramics. Some of the processes that need further consideration are containerless processing, single-crystal growth glass formation, glass processing, and so forth The topics of scientific interest are the nucleation phenomena, interfacial phenomena, bulk transport effects, bubble dynamics particularly when you are interesting in the fining aspects, and thermophysical properties.

The emerging technologies are low-loss optical glass fibers, high-strength and abrasion-resistant crystals and ceramics and so forth.

A very large part of the program has been directed to studying electronic materials and here again the objectives are to advance the science and technology of the preparation and crystal growth of electronic and opto-electronic materials by providing well-defined boundary conditions and controlled transport during the preparation or crystal-growth process. And, secondly, to try and determine the gravitational limitations on the preparation and crystal-growth processes and to determine what benefits there might be by growth in space. The justification of this, is again, based on the concept of reducing convective flows are expected to give you better compositional homogeneity and fewer defects. And, of course, the applications here would be that one could get electronic materials that perform much better, are more economical, and of course have tremendous importance both in commerce and national defence.

The convection phenomena are expected to influence the macro- and micro-segregation, the heat mass transfer, the interface shape, the morphology and stability, growth defects, stoichiometry, growth kinetics and nucleation and super-cooling. The body force related phenomena, induced mechanical stresses in some heavy crystals like mercury-iodide and the like, and the confinement related phenomena are of interest in the program.

Another one of the discipline areas is combustion science, and the primary interest here is to determine what is going to happen in case there is a fire onboard a spacecraft or a space station. So such things as ignition inflammability, pre-mixed flame behaviour, diffusion flames--how these all behave in a low-gravity environment is very much of interest and concern. There are other aspects such as droplets and spray combustion in particular that are being studied that give one some better ideas of the chemistry involved in these processes.

The fluid physics originally was sort of an ancillary thing. In the Skylab days there were a whole bunch of experiments on materials processing that were put in the Skylab on the premise that if you eliminate buoyancy driven convection, you get perfect crystals. And when that did not happen, a character like me was brought into the program to try and explain this. We realized very early on, that although the materials people had gained an understanding of the fact that what happened in the fluid state could be important for solid state, we really did not have a deep appreciation of the transport processes, even on Earth. And that even, the so-called hi-tech industries which are based on these crystals, had extremely crude and empirical methods of growing the vital elements in those processes--it was really quite a revelation.

So, the fluids physics program became very important. It was required to explain those phenomena involved in materials processing, and in fact it turns out that the low-gravity environment is not a benign environment in which nothing happens. Actually, such things as surface tension effects become very important and have led to some very fascinating flows driven by surface tension gradients due to either to temperature gradients or composition gradients, or a combination thereof. And that just simple astronaut movements and other things like that produce an environment that we call "g-ger" which gives you these random accelerations. The point that emerged is that it is not only low-gravity that is important, but also the direction; and, it is the random oscillations about some mean levels that are very, very important if one is going to do scientific experiments and particularly if one depends upon a benign environment to do "diffusion controlled materials processing". So, it readily became apparent that there were numerous questions in fluid physics that were of interest: new driving forces central to many of the processes and throughout this whole theme, I hope you have noticed that almost every one of these discipline working groups comes up to the matter of thermal-physical properties being crucial.

Thermo-physical properties of materials under some relatively interesting conditions such as at critical points, that have not been possible to be measured on Earth, even if we had wanted to, can in fact now be done at low-gravity environment.

Well, the kind of data you can get, or want to get, for the fluid physics and transport program would be the testing of fundamental hypotheses and theories. This is related to some of the questions in physics such as the Lambda point transition that was brought up by Prof. Abarbanel this morning, and the measurement of thermal-physical in these critical transistion regions. Then, related to materials processing, you saw that each of the other disciplines, metals and alloys, glasses and ceramics, electronic materials and bio-technology, all have transport processes going on, and it is important to be able to describe these. And then, with regard to dealing with the spacecraft operations, spacecraft fire safety, and of course, the fuel storage and management are other important issues.

Now in the science areas these are the topics of interest: First and second order phase phenomena, and if you take and consider what happens at the critical point of a fluid, on Earth, every factor goes to enhance buoyancy-driven convection becomes optimum, and every retarding factor becomes minimum. So that, for example, the volumetric expansion coefficient essentially goes to infinity. Viscosity becomes very low. And so it is very difficult, you get very strong convective flows in the vicinity of a critical point and it is very difficult to get thermo-physical properties. Well, you can do that in Space. And, in these second-order phase transitions such as the Curie points in magnetic systems, you have similar things happening. There are multi-component coupled transport flows, multi-phase flows driven by capillarity and all of these others are important scientific questions in the discipline of transport phenomena.

Up to now you have seen a broad-brush picture of the existing six discipline working groups, their objectives and goals, and part of the program that is covered.

In trying to consider what new directions there should be for this program, it is important to realize that transport phenomena mostly determine the nature of physical/chemical operations. And among such operations are heterogeneous transformations in liquids and gases. Heterogeneous transformations in liquids and gases are of particular importance--whereby, in heterogeneous I mean physical/chemical reactions and transformations that occur on surfaces such as: free surfaces, or in catalytic surfaces. And so, these operations include things like catelytic reactions, absorption de-sorption, dissolution, crystal precipatation, electro-chemical reactions, evaporation sublimation, and condensation. It is easy to realize that these phenomena are vital elements in industrial processes. So, I view materials processes as a subset of industrial processes. There are many of these processes in the chemical, pharmaceutical, food processing, bio-technology industries that have all of these aspects in them.

In these types of phenomena, phase separations and mixing are inherent to many of them. Clearly, these phase separations and mixing will be very much different in a low-gravity environment. In some processes it is desirable to keep a component in suspension for a longer period of time, possibly for some sort of chemical phenomenon like a catalytic reaction, for nucleation and growth. And clearly, these things will be different in a low-gravity environment.

Of course, the interfacial phenomena now become very much different. So, when you realize that most industrial processes were empirically derived around the turn of the century and made very little change in their processes as long as the companies were profitable and unchallenged. In effect, the situation in industrial processing is very much like the situation that prevailed back in the Skylab days in crystal growth. There was no scientific or technological base which gave any sort of understanding of what was happening in those processes and the same thing is very true in industrial processes. And so, when you consider, the global challenges to industrial competitiveness in the United States, the attention of industries has been gotten, and I think they are beginning to realize that perhaps we ought to give scientific scrutiny to their processes in order to enhance their competitive positions. We need to establish a scientific and technological base in order to do this. There has been an effort to identify limitations in industrial processes due to gravity. Gravity never was considered to be, or rarely ever has considered to be a variable in industrial processes. Recently some chemical industries have been looking to centrifuges where they use hi-g as a possible variable. So, through a better understanding of phenomena involved in industrial processes it may be possible to identify terrestrial processes and to indicate logical space experiments that will improve processes by economy, quality or purity and uniqueness of end products. Therefore I feel that some of the new directions ought to be along these lines; namely, to begin to give some scientific scrutiny to processes. I have identified a number of industrial processes which have some aspects that are influenced significantly by gravity or by surface tension. I do not mean that what I am going to show you here is a comprehensive list but I merely identified it to generate ideas and to identify the needs for these kinds of studies. At least it may be useful to point out in what ways the lower gravity environment would be helpful in leading to an understanding that could improve processing terrestrially and also perhaps lead to some novel processes aboard spacecrafts.

Some of these industrial processes which are influenced by gravity are multi-phase mixtures, which segregate and separate at normal gravities; and there are many ways in which you can break this down. I have chosen, just for purposes of discussion here, to break it down as gas-solid, gas-liquid and liquid-liquid. And so if we talk about gas-solid processes there are things like absorption, de-sorption, drying, fluidized beds, catalyst preparation, chemical vapor deposition, electro-chemistry separation.

Under gas-liquid systems you have gas-bubble and melt interactions, aerosols and foams, boiling, evaporation, distillation. You will notice that many of these things that I have identified are phenomena or unit operations, as the chemical engineers refer to them; but yet, I have also included such things as super-critical fluid extraction. This is a complete process which many industries are beginning to utilize. It depends upon putting a solvent and a solute together, close to the critical stage, and separating them. So you do the extraction and separation in one step. But remember what I told you what happens near the critical stage on Earth. The separation would perhaps get destroyed. The fact is that the method is made to work. How it works, why it works is yet unclear. There has been very little work done on that and in the low-gravity environment it will certainly be different. I think that if you look at each one of these unit operations, or processes, you will see that they will be different in space. I am not saying that it is going to be better, or anything, only that maybe we can gain some additional understanding. You know even on Earth, simple two-phase flows are essentially empirically defined and dealt with. So, these are some of the gas and liquid solid systems, coatings, polymerization, catalyst impregnation.

I just came to Israel from Washington where the National Science Foundation held a two day workshop on fluid mechanics applications and materials processing. We had some of the foremost polymer scientists saying that in the early days the United States could produce polymers and it did not really make a lot of difference how good these polymers were. They sold all they could produce. Now there are at least six countries that can make polymers. The polymer people are very well aware that the transport in the molten stage is very, very, crucial for the solid state. And if we can gain an understanding of the influence of the transport on the micro-structure polymers, the country that does that, and will be able to process polymers more quickly, and more precisely, is going to take that polymer business away. And the same could be said of many others. So these then are numerous phenomena which now open up wide avenues of research. This is only part of it. There are surface tension effects which, as I mentioned before, are very different in a low gravity environment. And thin films and coating, in space, for example, you may be able to make very thick coatings, which would be desirable; the fibers and filaments behaviours are quite different.

Let me say something about the whole business, again, from my own orientation as a fluid dynamicist specializing in thermal-capillary flows. In the early '70s when this was identified as a possible driving force, we thought it was a relatively simple phenomenon with a different kind of driving force. It turns out that these thermal- capillary flows, which are flows driven by surface tension gradients due to temperature gradients, are about as complicated a phenomenon as one can possibly imagine. There is a three-way coupling among the imposed thermal signatures that leads to the surface tension gradients. The surface flows and the return flows are due to the fact that the interface is deformable. And so you get fluid flows that look like perfect oscilators at times, and people jumped to conclusions that these were instabilities as fluid dynamicists are prone to do. But they are not, they are part of the inherent dynamics of the process.

Interface shapes are different, remember the interface shape in low gravity environment is not dominated by pressure (hydrostatic pressure) as it is on Earth. The damping characteristics of interfaces are very different. And this is just some indication of what we have learned regarding thermal-capillary flows. Now there is a great deal of interest and understanding thermal-capillary flows for container- less processes because free surfaces are inherent in containerless processing as are gradients of surface tension. But these have already been fed directly back into Earth processing. For example, the welders have found out that in many welding operations thermal-capillary flows are the dominant ones. A very interesting thing that was done by a German group in Freiburg: they grew a small silicon crystal with a containerless process float zone process aboard the German D-1 mission. They found exactly the same kind of defects. Then, reading some of these papers on thermal-capillary flow they put an oxide film on Earth on this float zone and got essentially a striationless silicon crystal, which shows that buoyancy driven convection is not the panacea. This is the kind of understanding required for this kind of physics. It is also a glaring example of how a little bit of, what I call, scaling analysis, could have saved millions of dollars in experimentation.

What I have tried to do today, is to give you a broad-brush picture of the existing U.S. program which is heavily directed toward materials processing. The ESA program and what you heard of the CNES program, are somewhat similar. I have tried to indicate to you that the emphasis has been merely on reducing buoyancy driven convection, but there are other aspects; namely, phase separations, or phase interactions and interfacial phenomena will be radically different. This opens up and should broaden the micro-gravity science research program. There is a lot of science that needs to be learned and if you do develop a greater scientific and technological base, along these lines, it should enhance any industrial involvement because you are not only dealing with such things as electronic materials or metals and alloys. I think in this sense, these represent some of the new and exciting directions.

Simon Ostrach

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He has a B.Sc. in Mechanical Engineering and a Professional Degree of M.E. from the University of Rhode Island, an Sc.M. and Ph.D. in Applied Mathematics from Brown University, and an honorary D.Sc. from the Technion.

He was at NACA and NASA until joining Case Western Reserve University. In 1960 he became Head of the Division of Fluid, Thermal, and Aerospace Sciences.

He is a member of the NASA Space Applications Advisory Committee and Chairman of its Microgravity Science, Applications, and Commercialization Subcommittee. He is also a member of the Board of Directors of the Universities of Space Research Association, and a Fellow of ASME, AIAA, and the American Academy of Mechanics. He is a member of the National Academy of Engineering and the Ohio Academy of Sciences.

A NATIONAL ISRAELI SPACE PROGRAM

Do We Need It, Can We Afford It, and What Should It Be?

M. Klajn
Infrastructure Committee
Israeli Space Agency

It has now been more than thirty years since man has effectively reached out from Earth and entered the space age, with the first Sputnik beeping at us from up there, and awakening us to new frontiers, new possibilities. In those years, mankind's activities in space, its related efforts and investments here on Earth, have expanded tremendously, and the effect of this activity on our culture, knowledge and even daily lives is considerable.

The solar system exploration is going on, and mankind's knowledge about it has grown many times over what we knew only thirty years ago. Our knowledge and views of the universe are being continuously transformed with the help of the data streaming down from space probes and instrumentation. Remote sensing satellites have given us a global view of our own planet and are more and more instrumental in helping us to manage the finite and precious Earth resources. Indeed, the very large progress made in understanding our own planet, understanding the global processes of weather, geology, agriculture and the global influences of man's activity would have been impossible without the present observation and sensing from space. Moreover, the only way of many third-world countries of remotely sensing and monitoring their own resources is through the use of the data provided constantly by satellites such as Landsat and Spot. Communications satellites, which were science-fiction thirty years ago, are being used now on a massive scale.

The communication satellites technology is now mature and has reached a commercial status. Its effects are being felt in almost every home. Indeed, the most economical way, and sometimes the only way for countries like Brazil and Indonesia to ensure a reliable communication and T.V. coverage on a national scale, is by means of a communications satellite. The industries and companies which take part in this field, and which are involved in space systems development, integration and services are being transformed by their very involvement. Space research and space technology have become an important part of the technology base of advanced Western countries. And one cannot think of European or American hi-tech industry without space technology being a characteristic part of it.

Now the question is: Is there, or should there be a part for Israel in this area? This is also the central theme of the present workshop.

In Israel, at first, the National Committee for Space Research was formed, more than twenty-five years ago, by the National Academy of Science, in response to a call by the International Council of Science Associations for the establishment of the international and interdisciplinary committee of space science (known as COSPAR).

The Israeli National Committee for Space Research, had initiated and encouraged space research related activity during those years, and organized the 1977 International congress for COSPAR, in Tel Aviv, which attracted more than 500 participants from over 30 countries. To encourage, support and accelerate the diffusion of space technology in the Israeli industry, and space related activities in the scientific and technical community, the Israel Space Agency was established in 1983 as a governmental organization within the framework of the Ministry of Science and Development.

The main goals and purpose of the Agency are:

(1) To support and encourage applied and theoretical space studies;

(2) To encourage industries in the development and production of space related products and the acquisition of the expertise and infrastructure;

(3) To formulate an Israeli space program and coordinate the related activities;

(4) To develop ties and cooperation especially with organizations abroad, and generally speaking;

(5) To promote and further interests in space related topics, in Israel.

We are indeed witnessing a growing and accelerating interest in those fields in Israel, within the scientific and academic community and within the industry.

In the Technion, the Norman and Ellen Asher Space Research Institute was founded in 1984 to promote interdisciplinary and interdepartmental ties among researchers in the space science and technology fields. Research topics in the Technion include: study of hydrazine sloshing under micro-gravity conditions, residual burning problems in space motors, x-ray astronomy, theoretical astrophysics, optimization problems in orbital maneuvering, aerothermodynamic and hypersonic flight, and bioregenerative life support systems. Courses in space science and space technology are being offered, such as: plasma physics, rarified gas dynamics, orbital mechanics, control and navigation of satellites and spacecraft technology.

In Tel Aviv University, research related to space sciences is conducted in several departments. The department of Geo-physics and planetary sciences deals with plasma physics of planetary atmospheres, interaction of spacecrafts and plasma, physics of asteroids and planetary atmospheres, and remote atmospheric and Earth surface sensing. In the department of Physics and Astronomy, the research subjects include comets, cosmic plasmas, gamma-ray asteroids. Work on satellite image processing is taking place in the faculty of engineering.

Space research topics at the Hebrew University include: astro-physics, planetary geology studies, use of laser radars for remote sensing of the atmosphere, and the study of various phenomena under micro-gravity conditions such as chemical driven convective patterns in liquid, embryo development and crystal growth from vapor phase.

Additional activities sponsored and supported by the Agency include an experimental study of the effect of gravity, or more exactly, the absence of gravity, on the behavior of hornets, which was due to fly in NASA'S "get-away special" aboard the space shuttle. The scientific investigators are faculty members of Tel Aviv University and the experimental hardware instrumentation and data collection package was designed and built by the Israeli Aircraft Industry.

Within industry, IAI has identified the space technology field as an important direction for future development and has expressed its desire to be the prime contractor for the design, development and integration of AMOS, an Israeli communications satellite promoted by General Satellites Corporation. A fuller description of AMOS appears in the presentation by P. Rosenbaum in this volume.

Accordingly, IAI decided to establish, in 1985, a Space Technology Center, within its Mabat plant in the Electronics Division, and to develop the necessary expertise and infrastructure and become the major space "house" in Israel.

Other companies within the hi-tech industries in Israel including: Tadiran, Elta, Elisra, Tamam, have followed, and have expressed a desire to take part in the development of communication, electronics, power, control and navigation subsystems in the space and in the ground segment and their electrical ground support equipment.

However, active participation in a space platform development is necessary to really enter the space field and acquire recognized competence. Israel's Space Agency has therefore included, as a part of the suggested Israeli space program, the design, construction and integration of a small scientific satellite. Such a program will on one hand provide the local industry a really effective opportunity to acquire firsthand knowledge and expertise in this field and at the same time provide the Israeli scientific community with an opportunity to perform direct experimental work in space.

I would like to elaborate some views about Israel's need to be actively and significantly involved in space activities, which have long been discussed within the Agency and the Ministry. About this subject I have been asked: "Why should Israel want to be in Space?" or more specifically, "Why should we invest a part of our scarce national resources into a space program when we are talking about cuts in education, in health care and in social services. "Can we afford it?", "What will it give us besides prestige, pride, a sense of involvement in Mankind's new frontier? These are wonderful things in themselves, but their attractiveness may well be tarnished if they are financed at the expense of our children's education, and social services for our elderly".

In the past Israel has embarked on national programs and major investment. For instance, in agricultural development, basic industries like textile, and lately, in an advanced technological and industrial base characteristic of developed countries. There was no doubt then as to the justification of such programs and investments, due to which we have achieved a respectable position and are now competitive in advanced technologies, even in the Western developed countries market. In these fields we have indeed made large yearly investments. But were those investments made at the expense of social education and defense budgets? One might argue that funds that went into hi-tech ventures could have been diverted into social services. But there was a national consensus, and rightly so, as to the need and justification for a national effort in those fields. Did education, social care and defense suffer? Far from it. Due to those programs and investments we have achieved a stronger economic base, are able to support a stronger army, and provide jobs for technical cadres and talents. I do not say that our economy now is brilliant, but where would we be now had we not developed our modern technological base with industries such as I mentioned before. And in the process, we have managed to form a local stock of talent and expertise which makes it attractive for international companies like Intel, National Semiconductors, and others, to come and set up research and development plants here.

Is a national space program - an investment in space technology - different? What are the advantages, what may we gain by actively entering the space technology field, and what may we lose if we do not?

All the Western technologically advanced nations, those that are on their way toward a post-industrial economy have a space technology base and this base was formed and developed by national space programs established for that purpose. For civilian space activities alone, in the western developed countries, about 10 billion dollars a year are now being spent. I do not have exact figures for this year, but I guess, we can show what was the partition of those budgets (civilian budgets not including military expenditures) in the year 1985. At that time the overall budget was about 8-9 billion dollars of which the major part was due to the US NASA program, and about a billion to European national cooperation programs. Japan entered massively with about 1/2 a billion dollars, India and Brazil having a smaller part. Look at the investment being made by the different countries we see that the national investment varies between .3 to .5% of the gross national product of the different nations. According to this figure, Israel should have a national program of about 20 - 25 million dollars, now.

In ten to fifteen years from now, the civilian space market will reach 25-30 billion dollars a year, at least. We can see that by looking at the trends developing in world expenditures.

All over the world, the picture is similar. I think the figure I quoted, about 25-30 billion dollars yearly, in the year 2000, may even be conservative.

Now, what should Israel's share in this market be? Assuming our technological, scientific and industrial profile stays as it is now, and assuming we have successfully entered the field and have a share of this market, either proportional to our industries relative importance; or to our population's relative importance, we arrive at space business activity of 100-200 million dollars a year, at this epoch.

Can we really achieve it? My opinion is, that if we invest wisely, if we act in that direction and succeed in establishing appropriate centers of excellence, we might, and we can. If we do not, there is just no chance. At most we might then provide kosher food for Jewish American astronauts.

Let us now take a look at the space industries business and the activities in this field.

In the space segment we have:

1. Development, production and integration of space platforms, satellites, space probes and now the growing activity of space stations and space labs;

2. Development and construction of space launchers and space propulsion;

3. Space scientific activities, instrumentation and payload development;

4. Life and biological support equipment;

5. Industrial production in space – now in research stages, but in the future I am sure on an industrial scale.

6. All subsystems from the component level with their high reliability and radiation requirements to complete subsystems including specifically communications equipment;

7. The growing field of automatic fault tolerant systems, bordering on robotics and in which expert systems and artificial intelligence are expected to have a growing role; and

8. Systems analysis activities, simulations and planning.

In the ground segments we have:

1. Ground stations;

2. Ground launch equipment and installation;

3. The ground infrastructure needed for space research, development, production and testing of the space equipment--and this includes all the various electrical ground support equipment and its software, environmental test facilities, simulators and simulation facilities.

4. Services linked to the use of space technology like satellite tele-communications, all applications of remote sensing, result processing and dissemination, insurance business, not to mention military applications which takes a very large part of the space activity of the superpowers.

How are these activities funded? Where does the money come from? From what I see there are three main sources: there are national programs, there are international programs (whether in conjunction with an international organization like ESA, or on a bilateral basis), and there are commercial or private ventures.

A long time ago, my Israeli colleagues tried to have help in funding our national efforts to go into space by seeking help from abroad, from other space organizations. If we look at what happens we see that the main goal of a national program is to develop that country's own space technology and allow its scientific and technical community to participate in space research and space activities. I, therefore, do not think we can expect to enter the space business through contracts funded by a foreign (even a very friendly) country's national program. The only national program which can really introduce us to space technology, is our own. International space organizations like Europe's space agency are tied by their very charters to return contracts to their member countries according to their financial participation in the program. They subcontract outside only if there is no alternative in the member countries, and in any case, the member country has first refusal rights. So, I do not think that there are good chances of having any significant business based on European (ESA) financing. Cooperations are possible, but they are always based on each side's supporting his activities within the cooperation program. On this basis, cooperation programs can be very fruitful and efficient in building our infrastructure base.

Now, the commercial activities ventures. I expect them to grow and become more and more important around the world. Here, the business is not entirely dependent on political and national considerations, but also on competition in which consideration of price, quality and previous experience is of primordial importance. In order that our industry can compete successfully in space technology, on a commercial basis, it must not only have acquired the adequate expertise and capability, but must have demonstrated and proven its competence in the field.

This competence, up to now, in all the space-faring countries has been reached by means of a national space program. In order for Israel to enter the space technology field, and develop expertise in space systems and subsystems, it is necessary to have a national space program which includes as a central goal, development and construction of a space platform, whether in the framework of a scientific program, or the development of a communications satellite technology system and subsystems. The Swedish national space program and their Viking satellite,is I think, a good model to look at.

Participation in the space business foreseen in the year 2000 will provide a tremendous technology driver in almost the whole breadth of the technology spectrum: Communications technology, very high speed data processing, computer technology, hi-reliability and fault tolerant distributed computer system, artificial intelligence, robotics, remote sensing, electro-optics, hi-reliability system design, implementation and philosophy, propulsion, power and energy conversion, receiving stations and real-time communications networks; not to mention material sciences. All these are the dominant industrial, scientific and technical fields through which the developed Western countries will reach, and are reaching, the post- industrial stage.

Being in or out of the space business in the coming generation, will have a much larger significance for Israel than the hundred million dollars a year business I mentioned before. Israel has built a quite successful and competitive hi-tech base, whose competitiveness we will depend on for our future economic well-being and security. Against whom do we compete? Against the most advanced technology of European and American companies and this competition takes place in all the markets: in Israel, in the developed countries, and in the Third World. The question is, in the next fifteen years, can a country with a hi-tech industry which is not involved in space business and space technology be expected to remain competitive, even in the non-space field, against those industries actively involved and participating in the space business and benefiting from the presence within them of the related technical expertise and excellence.

So, maybe the question is not can we afford it? But, can we afford not to be there. We have therefore to look upon our national space program as an investment, needed not only to get a share of the expected space business, but also to remain competitive even in non-space related business. This is being perceived by many countries around the world, and has been a factor in the launching of their space program. These include India, Brazil, Canada, Japan (which are entering this field massively); and many others are sure to follow.

There is no doubt in my mind, we must be there, and a well- structured space program is the only way. The question we have to answer is what level of yearly funding is optimal for Israel. This question is being raised within the space agency and ministry. The local economic climate, of which we are all aware, does not help us. But I think the subject must be looked at as part of the economic expansion and development of Israel.

As I have stressed before, involvement of our industry in the space segment technology, either on a bilateral program, or a commercial venture in the world market, is not realistic until the industries involved have qualified products, recognized experience and performance, and established contacts in the international space community.

The main goal of our space growth program is to help achieve that status by a two-phase long-range program.

The first phase is based on the development of a scientific space platform in which local industry will develop their expertise and which will serve the Israeli scientific community and be used to test experimental communications hardware.

The second phase, includes involvement in an international cooperation program on the basis of the experience, expertise and relative strengths gained in the first phase. This will help establish working contacts and integration with international space technology activity and therefore finding the natural niches which are best adapted to Israel's science and industry.

Is such a program within reasonable reach of Israel? Surprisingly for those who hear the enormous publicized cost of space programs, I think it is. Part of the investment in the basic infrastructure in the industries interested in taking part in the program will be supported by the industries themselves. The cost of design, development and integration of a small satellite depends strongly on the technical requirements, the design philosophy, and most of all, the development philosophy chosen. There are examples of satellite programs costing more than a hundred million dollars, and others like the Surrey University satellites of which we heard today, claiming to be in the hundreds of thousands of dollars range. In our case, with a budget reaching 15 million dollars in a peak year, it should be possible to complete such a project in 3–5 years. This includes the funding for the launch, by a European launcher, like was done with the Viking satellite; or with an American launchers like those appearing now on the scene.

In order to enable the space agency to define in detail such a program and coordinate its activities, the formation of a program directorate within the space agency was decided upon, which will take charge of program definitions and of setting up the framework of academic, scientific and industrial cooperation in this context. In addition, a program committee is being set up which will issue a call for proposals and opportunities for an orbital scientific experimentation. Two experiments will then be selected by the committee and submitted to the program directorate and space agency as candidate for the satellite program and payload development.

The basis of the selection will be a set of criteria taking into account:

1. The scientific return value of the proposed experiment and its contribution to science and technology as a whole, and to the Israeli scientific community in particular;

2. The overall expected contribution to Israeli technology;

3. The possibilities of integration in a space platform which is within the means of the Israeli space program, and technical requirements for that platform: like weight, orbit, attitude control requirements, power, communication requirements, etc.;

4. The budget and time–scale foreseen for the payload development, integration and testing, and the technical and uncertainty in building the payload in local laboratories and facilities;

5. The risk assessment with regard to proof of concept status, uncertainties of scientific or technical nature, and therefore uncertainties in keeping within constraints of budget, weight, and time to achieve the expected payload performance.

Marcel Klajn

Marcel Klajn, born France 1937, received his B.Sc. (1960) and M.Sc. (1968) from the Technion - Israel Institute of Technology, and his Ph.D. (1974) in Aeronautical Engineering M.I.T. From 1962 he divided his time between the Department of Aeronautical Engineering at the Technion and RAFAEL where he developed and headed the Propulsion Department until 1971. He was also Chief Research Engineer of the Aeromechanics Division until 1980, and presently holds the position of Chief Scientist. He is a member of the Infrastructure Committee of the Israel Space Agency and the Space Research Institute at the Technion.

THE AMOS PROJECT

Domestic Communication Satellite for Israel

P. Rosenbaum
MBT
Israel Aircraft Industries

1. GENERAL

Israel Aircraft Industries' (IAI) management has decided a few years ago to commit itself to space activities, and support the efforts made in Israel to promote space projects.

Accordingly, a three phases plan was implemented; this involved the following space related subjects : -

- Infra-structure buildup
- knowhow and Technology acquisition
- Projects development.

2. IMPLEMENTATION OF THE THREE PHASES PLAN

2.1 Space Related Infra-structure Build-Up

IAI/MBT was selected by Israel Space Agency (ISA) ISA to be the main contractor for all Israel made satellites. At this time a satellite integration and test center, as well as a ground control station is being built and operated within MBT's premises.

Electronic and thermal fabrication groups (Figures 1 and 2) have been formed in-order to implement ESA and NASA fabrication recommendations and standards. These groups are now operative, using test equipment such as thermal-vacuum chambers (Figure 3), built in Israel.

Figure 1. Electronic Fabrication Group in MBT

Figure 2. Thermal Fabrication Activity in MBT

2.2 Acquisition of Space Related Knowhow and Technologies

A system engineering group was formed, in-order to get acquainted with astrodynamics, satellite concepts, spacecraft control, operational analysis, and various sub-system components for attitude control and navigation, thermal control, power system, communication system in S-band, X-band and Ku-band, and electrical ground support equipment. In addition, mission planning and control was addressed, both from the analytical and operational aspects.

2.3 Space Related Projects

MBT, together with ISA and the Tel-Aviv University have developed a canister for the famous Hornets Experiment, to be flown on the shuttle.

Various subsystems are now being developed on a feasibility study basis. Those sub-systems, once tested and space qualified on a scientific platform, will represent the backbones of the future Israeli satellites.

Some years ago, Mr. Meir Amit, our former Minister for Communication and Dr. Moshe Bar-Lev, head of MBT/Space Technologies Division, have initiated the idea of a domestic communication satellite for Israel, named AMOS. It is this project that we shall describe hereforth.

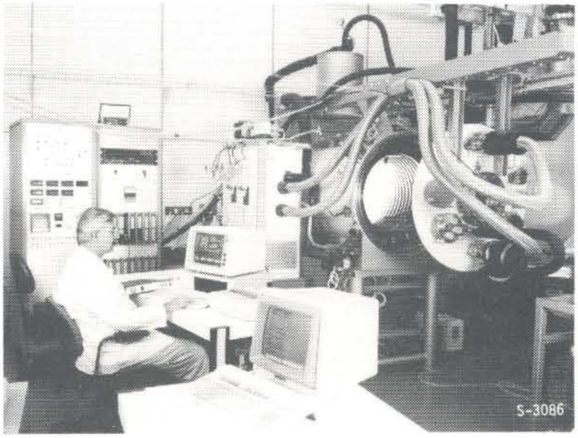

Figure 3. Activity at MBT's Thermal-Vacuum Chamber

3. BACKGROUND CONSIDERATIONS

Before describing AMOS, we should take a look at the revolution that has been accomplished in the satellite communication field, in the last three decades.

The first communication satellites were used for inter-continental telephone transmission, essentially over the atlantic route. Today, communication satellites have evolved from trans-continental use to regional and even domestic uses.

Direct broadcasting satellites are now in-existance, allowing the use of small (50 cm) dishes (Figure 4) for reception. This is due, in the main, to the following developments : -

- Increase of the frequency band from C-band to Ku-band and Ka-band

- Increase of transponder's power and reliability

- Increase of satellite expected life-span, from 2-3 years to 10-14 years.

This revolution allows us today to present the Affordable Modular Optimized Satellite (AMOS), a cost effective small satellite, tailored to the needs of a small country (Figure 5).

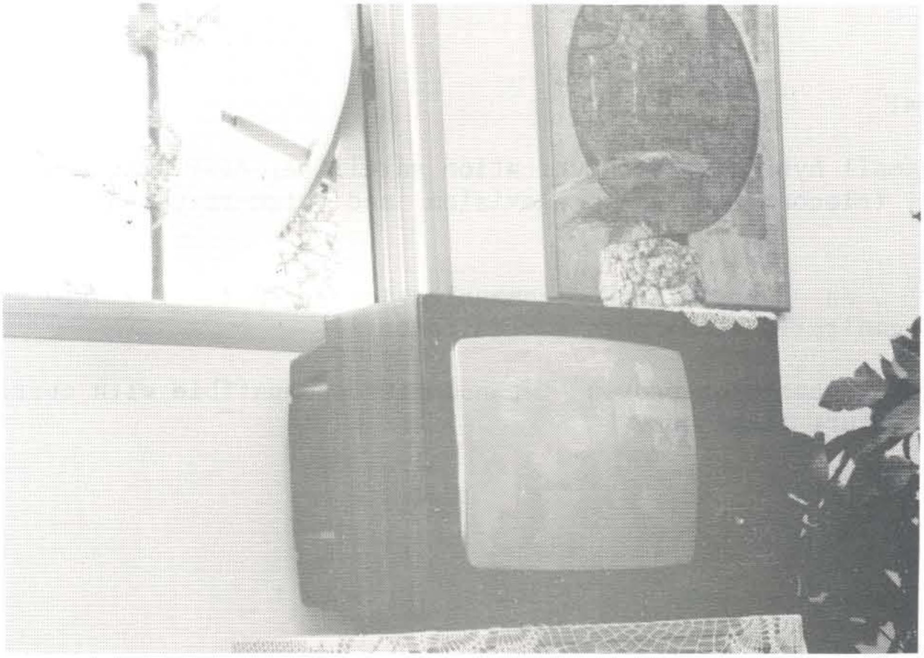

Figure 4. 50cm Dish in Domestic Broadcasting

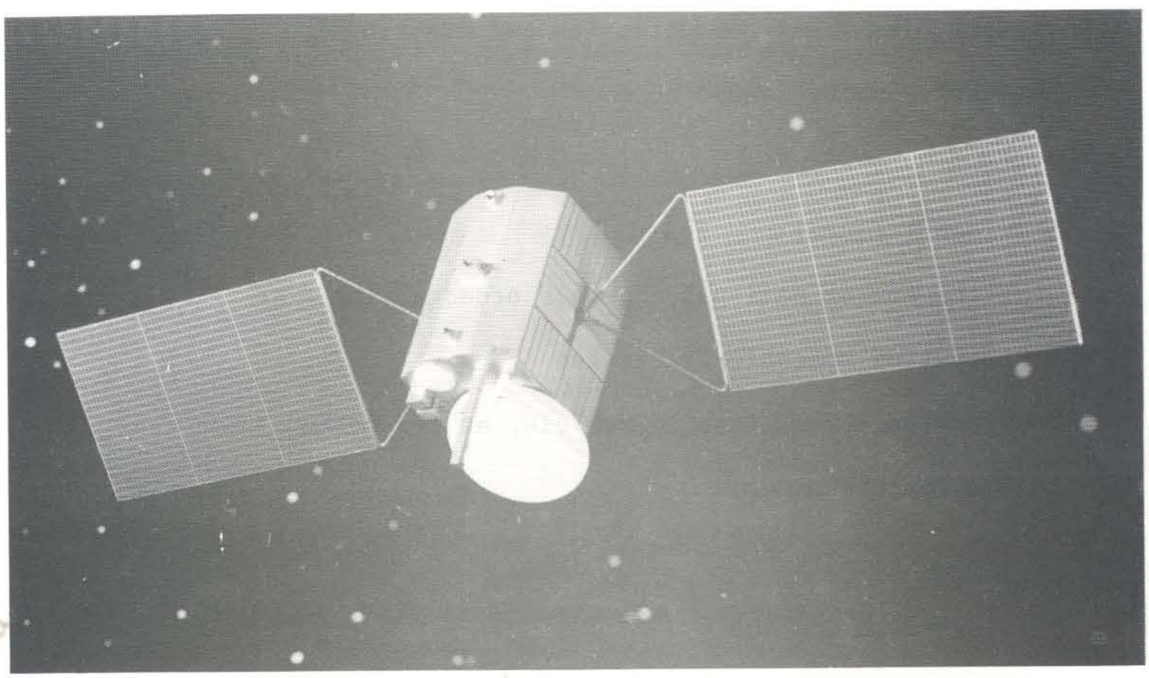

Figure 5. AMOS Satellite - General View

4. AMOS

4.1 General

AMOS is a small hybrid telecommunication satellite, providing advanced telephone, teleconferencing, television and high-rate transmission services.

AMOS is an optimized communication link, tailored to national/organizational corporate requirements.

AMOS design is based on proven technologies, compatible with current as well as future launchers.

4.2 Description of Services

The satellite will provide the following services : _

- Television broadcast
- Voice communication
- Digital data 2 way communication and distribution
- Backup for heavy loaded nodes.

a. Television

The services include:

- Distribution of national channels broadcasting
- Distribution to cable-TV centers
- Broadcasting from a mobile vehicle, at the scene
- Teleconference.

b. Voice Communication

The services will include:

- National telephone switching center
- Communication with mobile vehicles.

c. <u>Digital Data 2 Way Communication and Distribution</u>

The services will include:

- Private communication networks for large organizations
- Distribution of digital information to subscribers
- National Computer Network
- Remote Control of Distributed System.

AMOS System's general concept is shown in Figure 6 .

The communication system is based upon the launching of two satellites, one operative and another back-up redundant satellite, that shall replace the first satellite in case of a major failure.

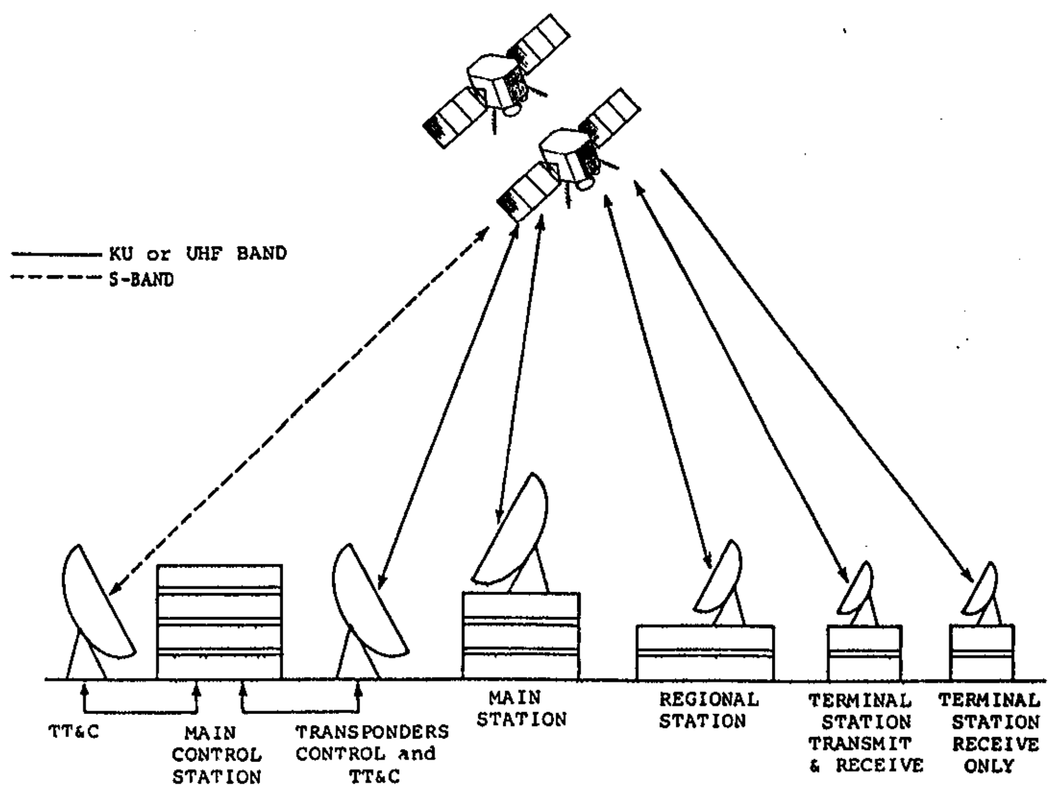

Figure 6. AMOS System - General Concept

4.3 Operational Concept

The satellite is to be launched by ARIANE IV or DELTA launchers, from an altitude of about 200 km into a Geosynchronous Transfer Orbit (GTO), with an apogee of 36,000 km. The propulsion system of the satellite will be activated at the apogee in order to bring the satellite into a circular orbit of 36,000 km altitude above the equator, at the assigned Israeli slot at a longitude of 15 degrees east.

At that altitude the satellite rotates at the same angular speed as the earth, thus the satellite will always be above a fixed point on the earth surface and is therefore fixed, relatively to the user.

The coverage areas of one satellite, as shown on Figure 7 consists of one Ku-band spot beam, illuminating Israel.

Each satellite will have 6 to 8 Ku active transponders and another 3 to 4 redundant ones, to be used in case of a transponder's failure.

The satellite is totally controlled by a ground Telemetry, Tracking and Command (TT&C) station, during all the satellite's life-span. However, the satellite has enough autonomous capability to handle all its subsystem as well as some system's major failures.

Table 1 lists AMOS' basic characters. Table 2 shows AMOS' mass allocation and Table 3 - electrical power allocation.

Table 1. General Characteristics

- Lifetime	10 years
- Stabilization	3 axis
- On-board power (Fully operative during eclipse)	1100 Watt
- Launchers	ARIANE-4, DELTA,
- Launch weights	1200 kg
- Dimensions	2.3 X 1.5 X 1.5 m
- Reliability	Enhanced by redundancy
- Frequencies	Ku band (14, 11 GHz)
- Transponders	6 - 8 active (3 - 4 redundant)
- RF power	20 - 40 Watt per channel.

Table 2. Mass Allocation

SUBSYSTEM	MASS [KG]
Payload KU	61
Payload UHF	20
Antennas	31
TTC + Clock	11
Control and Navigation	47
Propulsion	76
Electrical + Pyro	131
Thermal Control	16
Data Processing	26
Structure + BAPTA	82
Harness	20
Design Reserve	34
TOTAL	555

Table 3. Electrical Power Allocations
[Watts]

SUBSYSTEM	SOLSTICE	EQUINOX	
		DAY	NIGHT
KU Payload	450	450	450
UHF Payload	190	190	190
TTC + Clock	10	10	10
AOCS	58	58	48
Electrical	35	145	35
Thermal Control	47	106	22
Data Processing	40	40	40
TOTALS	830	999	795
Design Limit	930	1100	900
Design Margin	100	101	105

4.4 General Description

Figure 5 presents a general view of AMOS Satellite.

The satellite is composed of two main parts : The payload and the platform (or bus).

a. The Payload

The payload includes all the subsystems of the satellite that provide communication services for the various users. It includes the Ku-band antennas.

b. The Platform

The platform includes all the subsystems that are needed to operate and control the satellite in orbit. The platform is in-fact, the entire satellite, without its payload. It is comprised of the following : -

- Telemetry & command subsystem
- Electrical power subsystem
- Attitude and control subsystem
- Propulsion subsystem
- Thermal control subsystem
- Structural subsystem
- On-board data processing system.

5. CONCLUSION

It is our conviction that IAI/MBT has now the needed capability and infra-structure for designing a telecommunication satellite.

It is our desire to use the tremendous potential existing in the academic centers throughout the country and, more specifically, here in the Technion.

Patrick Rosenbaum

Patrick Rosenbaum was born in France, in 1947. He holds a B.Sc. (1967) and M.Sc. (1969) from Toulouse University, and a Ph.D. (1976) from the Weizman Institute of Science in Rehovot, Israel. Since 1976 he is with IAI/MBT, as Control and Navigation Department Manager and presently as Deputy Manager in IAI/MBT's Space Technology Department. He was a part time teacher at Tel-Aviv University, from 1979 to 1983.

THE SAMUEL NEAMAN INSTITUTE

FOR ADVANCED STUDIES IN

SCIENCE AND TECHNOLOGY

The Samuel Neaman Institute for Advanced Studies in Science and Technology is an independent public-policy research institute, established in 1978 to assist in the search for solutions to national problems in science and technology, education, and economic, health, and social development. An interdisciplinary think-tank, the Institute draws on faculty and staff of Technion, other institutions and scientists in Israel and specialists abroad. The Institute serves as a bridge between academia and decision makers through research, workshops, and publications.

The Institute pursues a policy of inquiry and analysis designed to identify significant public policy problems, to determine possible courses of action to deal with the problems, and to evaluate the consequences of the identified courses of action.

As an independent, not-for-profit research organization, the Institute does not advocate any specific policy or embrace any particular political philosophy. As befits a democratic society, the choices among policy alternatives are the prerogative and responsibility of the elected representatives of the citizenry. The Samuel Neaman Institute endeavors to contribute to a climate of informed choice.

The Institute undertakes sponsored advanced research, formulates invitational workshops, implements continuing education activities on topics of significance for the development of the State of Israel, and maintains a publication program for the dissemination of research and workshop findings.

Specific topics for research may be initiated by the Institute, researchers, government agencies, foundations, industry, or other concerned institutions. Each research program undertaken by the Institute is designed to be a significant scholarly study worthy of publication and public attention.

Origins

The initiative for establishing this Institute in Israel was undertaken by Mr. Samuel Neaman. He nurtured the concept to fruition with an agreement signed in 1975 between himself, the Noon Foundation, the American Society for Technion, and Technion, and with the ratification in 1978 by the Faculty Senate of Technion. Mr. Neaman, a prominent U.S. businessman noted for his insightful managerial concepts and innovative thinking, as well as for his success in bringing struggling enterprises to positions of fiscal and marketing strength, has devoted his time since retirement to the activities of the Institute.

Organization

The Director of the Neaman Institute, appointed jointly by the President of Technion and the Chairman of the Institute Board, is responsible for formulating and coordinating policies, recommending projects, and selecting staff. The five member Institute Board is chaired by Mr. Samuel Neaman and includes *ex officio* Technion Vice President for Development and Vice President for Research. The Board is responsible for general supervision of the Institute Including overall policy, approval of research programs, and overseeing financial affairs. An Advisory Council made up of members of the Techion Senate and distinguished public representatives reviews research proposals and consults on program development.

Funding

The Institute's activities are financed largely from the fruits of the Samuel Neaman Research Fund, located at the American Society for Technion. This ensures freedom and independence. At the same time, contract studies for government, public, and private organiations are also undertaken, provided they adhere to Institute goals and objectives.

Research Program

The activities of the Institute are carried out through a number of research programs, including:

* Issues of Technology, Science and Policy
* Education in Science and Technology and Universities
* Innovation, Engineering Design and Technology
* Environment, Health and Quality of Life

THE SAMUEL NEAMAN INSTITUTE

FOR ADVANCED STUDIES

IN SCIENCE AND TECHNOLOGY

SUMMARY OF WORKING GROUPS

REMOTE SENSING

Chairman: Chaim Eshed

In the remote sensing group we discussed the possibilities open for Israeli scientists and the industry in Israel in view of the latest developments, in the field of remote sensing around the world.

The Landsat digital data was an important cause for the development of specialized computer software and hardware for digital processing of multi-spectral imagery. As a result, applications of digital imagery were subject to extensive research on all possible aspects such as: identification, classification, and mapping; and we took part in all the aspects of these fields. In order to appreciate the number of remote sensing projects taking place in Israel I have made a short list of some of the important events that have been very significant for remote sensing in the last couple of years. For instance, the successful launch of Spot I; Japan launched the MOS-I, that is the Maritime Observation Satellite and is further planning to go on with their LOS, that is the Land Observation Satellite; SIRA and SIRB, the synthetic aperture radars, were flown on the space shuttle as were other new systems such as the MOMS (Modular Optoelectronic Multi-spectral Scanner), and of course NASA's LFC (Large Format Camera), which we heard about during these meetings; Brazil and India are developing their own remote sensing satellites; the Soviet Union has joined the commercial remote sensing market, offering several types of imagery including six bands and six meter resolution.

Further Spot launches are due, as we heard from Dr. Isaac Revah, and they are going to be planned with new capabilities. Landsat 6 has been approved and is being constructed with panchromatic 15-meter resolution, and Landsat 7 is being planned for a resolution of 5 meters. The new hi-resolution media-aimed acquisition system Newstar, is being considered; Canada is planning launch of Radarsat in 1994; and some new ultra-multi-spectral spectrometer systems are being developed, with all kinds of acronyms like JPLS, AVIRIS, SISIX and HIRIS. They are all advanced system developments and a great effort is being made to obtain hi-resolution and better response;

and last, but not least, the space station EOS. The Earth Observation System is under development. These developments were accompanied by dramatic developments in computer capabilities and reduced hardware costs. This made digital image processing possible even on desktop calculators.

The Israeli scene is quite sensitive to new developments, especially to hi-tech hardware, software type; and in this respect remote sensing activities started to take place a couple of years ago based on the following assumptions:

Assumption No. 1 - that we have in Israel the professional expertise necessary for developing civilian applications of remote sensing, both in the space segment and in the ground segment, including the data processing.

Assumption No. 2 - the development of this field in Israel is in line with national goals of developing hi-tech, and remote sensing is in this category of high-tech.

Assumption No. 3 - there are enough users in Israel and abroad who can use these technologies and products.

I will specify, briefly, some of the present and future uses, since Israel is a small country and anyone can propose to use a plane and fly from the Hermon to Eilat and make aerial surveys. But it does not work this way, and I am sure that you are well aware of the experience gathered in the remote sensing field - that it is quite different if you take a Landsat image or if you take an aerial image.

Institutions in Israel which are involved in remote sensing include the Tel-Aviv University, where the Faculty of Engineering offers courses in small-scale applications research and the Department of Geophysics gives courses for graduate students; the Hebrew University, Department of Computer Science, which engages some ten graduate students; Bar-Ilan University's Department of Geography offers research courses, for the time being - non-digital only; The Technion's Faculty of Aeronautics image processing laboratory, which is well developed and where some Ph.D's did their work; and the Ben-Gurion University, Department of Geography, which is engaged in extensive research. This is only a partial list, and I will not bother you with the full list.

Among public and Governmental institutions, the Ministry of Agriculture uses infrared aerial photography; the Geological Survey uses hardcopy imagery; the Jewish National Fund uses infrared aerial photography to monitor forests; the Hydrological Service uses hardcopy imagery; the Survey of Israel uses hardcopy imagery; and Tahal, Israel's water planning agency utilizes some space imagery for the planning of overseas projects. That is a breakthrough, I think. They do lots of projects in Africa and they take pictures from Spot and Landsat, from which they plan their projects; Israel Aircraft Industries has highly developed digital image processing capabilities at several of its subsidiaries; the Desert Research Institute is considering digital image processing for desert research applications from the Spot images; the Citrus Board, presently utilizing infrared aerial photography and the Archeological Survey, who are considering the use of digital imagery for sight mapping.

Some of the private sector companies that are working in the field are: Elpek 2000, image processing software development; Elisra, image processing capabilities; Scitex, which is a manufacturer of digital processing systems, hardware and software; Elop, digital image processing; and Intelligent Electronics, digital image processing, and I apologize if not all the remote sensing participants in Israel appear on this list.

The present situation of remote sensing in Israel can be summarized as follows: Promotion of remote sensing from space seems to have achieved its first goal of creating an awareness by all potential users, of the new capabilities in each field. As Dr. Issac Revah said, there is a lot to be done in this field. Still, not many institutions are aware of what can be done with digital images from space, and the initial cost of this technology is too high for each potential user to support his own facility. To sum up, transition from very good intentions to actual implementation has been slow. Too slow for my taste.

There are three areas of activity which should be developed in the future in Israel. These are: the use of applications inside the country, and I have mentioned a list of at least twenty participants in remote sensing activities (which is only a partial list). The use of remote sensing by Israeli companies such as Tahal, for projects being executed abroad, should be further developed, and the export of image processing projects to other countries should be started.

As some of you are well aware, the Israeli Space Agency and the industry have invested considerable amounts of money in infrastructure. It was suggested and emphasized by many of the speakers in these meetings that Israel should make its own satellite. This can be done either by building a small and not very expensive satellite, or by building a more advanced satellite within an Israeli- meaningful scientific experiment. Another way is by providing a scientific payload for a large, non-Israeli satellite, developed abroad. And finally, by joint ventures with other countries using some Israeli space hardware. This last option can be undertaken with French or German firms, or with others.

As to the recommendations: Recommendation number one is to encourage Israeli scientists and engineers to respond to the Israeli Space Agency RFP with relevant proposals to remote sensing, and to build a small Israeli satellite. Also, to encourage Israeli scientists to participate in international projects by providing instrumentation for remote sensing satellites.

Recommendation number two is that at this stage of the development, applied technology should be preferred to pure science. We know that science is very important, but at this stage hardware, and other space technologies, should be at the forefront.

The third recommendation is that bigger and more innovative proposals such as the Mados satellite proposed by Dr. Johnathan Mass, should be promoted through international cooperation. We are not big enough, we need some support from abroad, and we welcome it. Projects like the Mados need international cooperation.

And the fourth recommendation is that an extensive effort be made in market research, in order to identify the niche to which Israel can contribute in the remote sensing field.

Last, but not least, is education. Educational efforts should be made to prepare the technological and scientific manpower that we require for the future, coming, space effort. Thank you.

Chaim Eshed

Born 1939, received his B.Sc. in 1966, M.Sc. in 1969 from the Technion, and Ph.D. from Columbia Pacific University in 1988. He is Director of Projects and a member of the Executive Committee of the Israel Space Agency, and has been a guest professor of Space Technology in Tel–Aviv University and an adjunct at Technion's Asher Space Institute and Faculty of Aeronautical Engineering.

MATERIALS AND PROCESSES

Chairman: Zeev Löw

This was a relatively small group. There were no direct recommendations: there were, I would say, suggestions. Prof. Ostrach presented his research program over the last fifteen years, and the question related mainly to crystal growth--outside in space, where there is no gravity and you do not need crucibles. He made a very strong point, that most crystal-growing facilities on earth do not know very much about what they are doing. That is to say that the transport phenomena are not very well understood; therefore, most crystal-growing systems that are used in outer space are not very conclusive in their results. Before one should do that, one has to do simulation experiments here on earth in order to be able to come up to, I would say, considered experiments that you can do in outer space. Second, one really has to rethink his point of view, that in outer space, when you are dealing without any crucibles and without gravity, you have other problems such as: gravity-jitter and other phenomena which have not been properly studied, which may influence such processes including transport phenomena, not only for crystal production. Possibly the benefits of all that research will be at least as much, probably even more, on earth than in outer space--but that is a good way of probably getting started.

A second point of view that was presented by Prof. Zavistowsky, and I think it is a very strong point, is that any research on crystal goals or similar phenomena, need a directed, cooperative research program, you have heard this before. It cannot be done by one or two persons in a university. It has to be interdisciplinary, interdepartmental, it has to be directed somewhat from above--an atmosphere which is not necessarily conducive to a university, but an absolute necessity for such research. A minimum would be a group of six to eight, or ten people, possibly distributed over a number of departments. But certainly not a lone effort; this could not succeed. Unless such a suggestion is taken up, most of such research would be futile. We had no paper, and nothing was said about research in biological materials. Therefore, I cannot report about that although that would probably be more important than crystal-growing or materials research as such. There was a very strong suggestion by Dr. Charovi, and I think it is a very strong (important) point that could carve out a niche in materials research on the following respects. In the future, and even now, many of the materials will be polymer or polymer-composite materials. Out of space has a lot of radiation damage. The study of radiation damage on new materials is not being done extensively, or at least we do not know very much about it. One ought to establish a good research group on long-term radiation damage both on polymers, composite materials or ceramics, with the idea that with the basis of that study we can properly produce materials which would have much less radiation damage. So it is a combined research program, not in terms of crystal-growing or scientific materials or making first-class crystals, but rather using materials, particularly for structures and other artifacts in outer space. That can be done in this country, and there is probably the manpower here that can do that. And there is probably money for this too. In terms of radiation damage, it is suggested that one contact the producers to simply give us materials to be tested; there usually is not that much time and not so much interest so far in having these materials properly tested as far as radiation damage and we could fill here a considerable role. May I just suggest that as a side remark, if this is true, probably these materials would have other beneficial aspects and characteristics which would be important not only for space, and not only because of radiation damage.

Zeev Löw

William Zeev Löw received his B.A. in 1946 at Queen's University, Ontario, Canada; his M.A. and Ph.D. at Columbia University, New York in 1947 and 1950, respectively, and has been t the Hebrew University since 1980, becoming Professor of Physics in 1961. He has received the Israel Prize and the Rothschild Prize, and since 1970 has been President and Rector of the Jerusalem College of Technology. He has been President of the Israel Physical Society, and URSI - Israel, as well as Head of Research and Development at the Hebrew University.

ENERGY

Chairman: M. Bar-Lev

We thought that we would start such a session with a logical approach to the problem of what should be done in Israel in the field of mechanical energy. It was the opinion of almost all of us that the problem was not what to do, but what *not* to do. We examined what we thought should be done in industry, and what should be done in the academic world or in phases of basic research and development in industry which would lead, in the future, to subsystems or components etc. We started with the assumption that those recommendations should be based on the four topics below.

1. Predicted Technology Development

There is no use in developing something which already exists or would not be applicable in the future. Of course not neglecting in the process the marketing and business opportunities. We must take into account the technological and industrial spinoffs which are always important (system subsystems-wise or components. Nobody has yet mentioned here that space programs as a whole are not as a whole very profitable. So there should be technological spinoffs coming from the items that we would spend our money and time on, based on existing relevant experience. Well, good intentions they were, but I think that the basic recommendation (and I will give the other technical recommendation as well) is that we are not directed. We have heard here sessions on what has been done in the world. It seems like we don't know exactly what to do and there is no directed activity in Israel. It is partially true, much to my regret, and I think that ISA should take the role of directing the activity in Israel, not only in industry, because industry is sometimes independent and sometimes will go its own way.

The recommendations of these sessions will not direct the industry because they will do whatever is the profitable, other direction according to their interest. But there is a definite need for directed, centralized activity in Israel and I think the only body in Israel that can fill this role today is ISA. I think that everyone in the session agreed with that and the following topics should be thought about.

First of all one needs to point out what are the subjects and technologies that should be, or are recommended to be acquired in Israel. Now, it is obvious that we want to do everything. There are some things that are more beneficial from the point of view of technology. There should be a centralized body who will at least recommend and try to direct in this area. Of course, there is another problem. We know that there is a lot of information, RFP's and so on, that are going around from NASA, ESA and other bodies that are not being distributed to all the bodies that are interested. There should be again a centralized office to which technical information should flow in and should be redistributed in Israel to industry and to the academy. But if you need to have funds in order to direct and control activities--either in the industry or the academic world Through allocation of funds you can at least direct work to the subjects you decide are the most beneficial. Of course, we also need the fertilizing of the inner group in Israel who want to be, and are involved in space programs. It is almost outrageous that we do not know what each group is doing, or what its intentions are. And we will not volunteer information, I can tell you that. If there will be somebody who will direct us, I assume we will do it. If we will have workshops, technical meetings, it will be done; otherwise, it will not be done. This is the entire group's most important recommendation.

Returning to the technical topics. Of course there was no intention of getting too deep into the subjects; they were just preliminary discussions to test the ground and to get the ideas. These recommendations should not be obligatory. On the subject of structures, we came to the conclusion that there is a place to work on large structures especially in the field of active control (or non-linear control). A small scientific satellite like Amos would not fit into this description. There is a place for such work to be performed we think in one of the universities and for that there should be established connections with those that will use these big structures. I am referring to the space stations, to the projects of ESA (the European Space Agency) and so on. Connections should be made, and universities can work on that and should work on that. The structure itself for a small satellite will be done within industry with some help of course of the academic world. On materials, I am afraid we did not have enough experience or exposure. Our recommendation is to continue working on the existing composite materials, basically carbon-epoxy based and it seems like, at least to some of us who were subjected to this area, that metal-matrix seems to be very beneficial for the future. It is not very developed as yet, and maybe we have a niche here in which our research and also industry can get and get some leverage in this area.

We examined the energy systems and discussed the different subsystems that compose an energy system in a satellite. As far as solar cells are concerned, it seems that the silicon based solar cell is here to stay. There was a lot of work done until now on solar cells and we cannot contribute much to this subject. But, as somebody said: "The good researchers in the university can come up with some improvement to èxisting substract such as--coating, plating, different glass windows and so on, that can enhance the properties of existing solar cells." Maybe there is some place for such research. Maybe! But, there is a new solar cell material--gallium arsenide with all its disadvantages and advantages we have discussed. It seems, from our knowledge there was no real advance in the world. By advancement I am not speaking about making a solar cell and checking it; but also getting into low production costs. And that is the name of the game. Because this is the state-of-art in the world. It seems to us that if somebody will take the lead in gallium arsenide cells, with the purpose of directing the effort into low production costs--we think there is an opportunity and we recommend this. Especially we think that university researchers should do the preliminary studies, and maybe even Tadiran (on solar cells) should get involved.

On batteries, nickel-cadmium and nickel-hydrogen are here and the technology is more or less mature. There are some gaps in nickel-hydrogen technology, especially in optimal charging and discharging, but it is not in such a state that we can come in and fill a gap. But there was a suggestion: of producing special purpose integral nickel-hydrogen batteries. By that I mean, putting them in one pressure vessel. That might be a possibility. The second item we discussed is much more far reaching. These are exotic batteries in which the energy density is very high, maybe tenfold or more than existing batteries are promising and the rewards that can be reaped from that are overwhelming so there is an opportunity there. We recommend very much that such an investigation will be done, Lithium is just one of them. There are other batteries that should be investigated. If we will have a breakthrough here, we think that it will be worth it.

On converters: that is an interesting topic because that ties up with our experience in electronics. Existing converters are somewhat, handicapped. They are of low efficiency (75-80%). The weight of such a converter is usually very high and this is because they are not standardized and usually the manufacturer does converters not only for space, but for other systems and he is using the same technology to put it into space systems. We think there might be an opportunity here. Both by offering a standardized converter or by pushing the market into standardized converters, by offering different stabilized voltages that can be standardized. Today, in my experience, every subsystem has its own voltage, and we cannot even standardize that. And, we recommend developing a better convertor by increasing the efficiency by higher switching frequencies and the use of hybrid components for example, and by decreasing the weight by designing the convertors by space thermal control engineers, that will take into account the thermal design that is basic for space and also the sophisticated packaging which is part of space design.

Moshe Bar-Lev

Moshe Bar-Lev was born in Israel, in 1944. He holds a B.Sc. (1966) from the Technion, Faculty of Aeronautical Engineering, and an M.Sc. (1973) and Ph.D. (1975) from the University of Southern California, U.S.A. Since 1976 has been with IAI/MBT. He is presently the Manager of IAI/MBT's Space Technology Department. He was a part time teacher at Tel-Aviv University and at the Technion, from 1976 to 1987.

SATELITE COMMUNICATION

Chairman: A. Livneh

We had a very fruitful, interesting and animated session on Satellite Communication. We had a very interesting presentation in particular describing the state of satellite communication services, in Israel. We had a presentation by Dr. Barkana about control problems in large flat surface antennas, we had an interesting and innovative proposal description by Dr. Gavan from Holon College on quasi-satellites for communications, and we had, as I said, quite stimulating discussions about several topics, I will mention briefly most of them. We also had some recommendations and some conclusions which I would like to formulate later carefully. I will now give only the main contents. Satellite communication in Israel consists of the domestic satellite communication and international satellite communication. International satellite communication has been here for a long time, more than 15 years, although it has been constantly upgraded and enlarged. Now they are going into the digitalization stage, installing new techniques. This was not described in detail; What was of special interest was the domestic satellite communication. It is now based on three Intelsat transponders which Israel purchased two years ago at a bargain price. They work in the KU band and have a spot beam with a very narrow footprint on Israel, having a hi-powered density. It is planned to be used mainly for T.V. broadcasting. Actually it is now being used for that purpose, i.e., distribution of the second channel and will be used for Pay T.V., for data communication, and for mobile satellite electronic news gathering. This involvement of Israeli communication-administration, and service-providing organizations in domestic satellite communications gave rise to a recommendation from the participants which briefly says that: "We think and recommend that this step should be a turning point in supporting Israeli industry in the earth segment: namely, in developing and providing small earth stations for data communication and for T.V. reception." Another question which was heatedly discussed was how, if and why, (it was not stated this way - but this was the intention), should we go into developing our own space segments - namely, a satellite. An advice was given that we should do it carefully, and in steps starting first with a small venture, actually a scientific satellite and then only in the last third stage should we go into a full size, commercial satellite development and manufacturing. It was an opinion both expressed and challenged by several speakers and we did not draw any conclusions. The other question was: Are communication satellites still a good business? As far as I understood the answers were: it could be, but it is risky, and it requires a very large investment. If it is done by private money then it is O.K, but if it is done using public money it should be considered very carefully. The question in this approach was if we do not do it, we will be out of the space business. This is correct. One bit of advice was that Israeli industry should concentrate on the earth segment--there is roughly ten times more business in the earth segment than in the space segment, so it certainly should not be neglected. This was not a unanimous conclusion of the forum; but it was discussed. At the beginning of the session we suggested some topics to be discussed. Some of them were discussed during the presentation, some of them were discussed at the end. There were some remarks, some recommendations and some advice for universities. I am speaking about education: graduate courses, seminars, in particular--graduate courses in satellite communications, the lack of which especially at the Technion, which should be leading in this subject is evident. There is also a remarkable lack of involvement in research in communication sciences related to satellite communications. We will later formalize the recommendation and send them to the universities, hoping that something would be done about it.

In the following are attached the future trends in satellite communications, presented in the Satellite Communications Workshop.

FUTURE TRENDS IN SATELLITE COMMUNICATIONS

SERVICES:

* DIRECT BROADCAST TV
* MOBILE - AERO, MARINE, LAND
* VSAT - BUSINESS, DATA, PERSONAL
* VIDEOCONFERENCING

TECHNOLOGY:

* ON BOARD PROCESSING
* MULTIBEAM
* LARGE PLATFORMS
* HIGHER FREQUENCY
* HIGHER POWER
* MICROSTATIONS

SUGGESTED DISCUSSION TOPICS

WHAT SHOULD BE DONE IN:

Communication Services

DOMESTIC
INTERNATIONAL
MOBILE

Industry

SPACE SEGMENT
EARTH SEGMENT

R & D

SIGNAL PROCESSING
NETWORK TECHNIQUES
MICROWAVE DEVICES
ANTENNAS

Education

GRADUATE COURSES
SEMINARS

Adam Livne

Adam Livne received his B.Sc. and M.Sc. degrees from the Technion, Haifa, and his Ph.D. degree in 1976 from the Polytechnic Institute of Brooklyn, all in Electrical engineering. At present Dr. Livne is Chief Scientist of the Ministry of Communications. He worked for many years at RAFAEL, participating and leading many advanced R&D projects. He was a Visiting Scientist at Lockheed Electronics Co., M/A-COM Research Center, Stanford Research Institute and COMSAT Laboratories. He is the Chairman of the Communications Chapter of the IEEE-Israel.

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