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A SEARCH FOR EXPERIMENTS TO EXPLOIT THE SPACE SHUTTLE ENVIRONMENT

VOLUME TWO

(NASA-CR-163031) A SEARCH FOR EXPERIMENTS TO EXPLOIT THE SPACE SHUTTLE ENVIRONMENT, VOLUME 2 Final Report (Relay Development Corp., Branford, Conn.) 32 p HC A03/MF A01 N80-26338
CSCL 22A G3/12 Unclas 22354

Relay Development Corporation

BRANFORD, CONNECTICUT 06405

A SEARCH FOR EXPERIMENTS TO EXPLOIT THE SPACE SHUTTLE ENVIRONMENT

by

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Final Report on Contract #955578 between

Relay Development Corporation and NASA-JPL

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"This work was performed for the Jet Propulsion Laboratory, California Institute of Technology sponsored by the National Aeronautics and Space Administration under Contract NAS7-100."

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15 December 1979

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<u>Second of Two Volumes</u>

A SEARCH FOR EXPERIMENTS TO EXPLOIT THE SPACE SHUTTLE ENVIRONMENT

Volume II - Places Visited

In this volume I will enumerate and describe briefly those laboratories and institutions which I was fortunate enough to visit during my travels. The spectrum of their activities and objectives covered a very wide range. Many of them were preoccupied with problems and projects having little or nothing to do with prospective experiments in the Space Shuttle Environment. Their interest in such a venture was merely polite. Consequently, I will here simply indicate some characteristics of each place, something about its mission, noting any particular items which I found interesting even though they may have little or no relation to Space Shuttle Experiments. Although I will mention some people in passing, I have left to the Appendix in Volume I the complete catalog of the names and addresses of the scientists with whom I had conversations. The body of Volume I is concerned with ideas for experiments which emerged.

The order in which the following places are described is simply chronological in the sense that it is the order in which I visited them (my first arrival in those cases where I had an extended stay.) As an overall guide I note that I went first to India, then to Japan and then to Western Europe including in order Italy, France, Belgium, The Netherlands, West Germany, Switzerland, West Germany, and France.

1. Indian Institute of Science, Bangalore, India. This venerable institution was founded in 1911 and has become the most prestigious bastion of science in all of India. Certainly it is the best known and most familiar to scientists outside of India because of its vigorous policy of encouraging visits, for both short terms and extended periods, by scientists and engineers in many fields from all over the world. Another reason for its renown is that it has been a source of select young scholars who have gone abroad

for further education and experience. Indeed, throughout the world there are many university faculty members and research scientists who began their careers at IISc, Bangalore. The present Director is Professor Satish Dhawan who received his Ph.D. from Cal. Tech. He is also Secretary of the national government's Department of Space and Chairman of the Indian Space Research Organization (ISRO). In sum, he is a very busy man.

IISc comprises twenty-one Departments distributed over the four divisions of Physics and Mathematical Sciences, Chemical and Biological Sciences, Electrical Sciences and Mechanical Sciences. In general, the science departments concentrate on research but carry out some instruction incidental to the research. The engineering departments undertake both teaching and research. All teaching is at the graduate level except in the Departments of Electrical Communication Engineering, Electrical Engineering and Metallurgy which offer curricula leading to a bachelor's degree. There are nearly 600 people engaged full time in research. The total number of students is also about 600. The annual operating budget is thirty million rupees, roughly equivalent to the same number of dollars in this country eventhough the official rate of exchange is about eight rupees to the dollar.

IISc was my home base during the two months I remained in India. Its extremely pleasant and efficient Guest House provided food and lodging. Professor R. Narasimha of the Department of Aeronautical Engineering, who received his Ph.D. from Cal. Tech., was one of my two official hosts and provided me with an office and various services in his Department. My other official host was Professor C. N. R. Rao, a chemist of international reputation (Ph.D. from Purdue). He came to Bangalore from the Indian Institute of Technology at Kanpur to start a new Solid State and Structural Chemistry Unit at IISc. In three short years it has already become a thriving research group, functioning effectively in temporary quarters while waiting for completion of its handsome new building. Professor Rao organized a schedule of seminars on Molecular Beams which I presented on an average of one per week during my stay. In addition, I gave some additional talks including a seminar on isotope enrichment to the Department of Chemical Engineering and a general lecture on Molecular Beams to a meeting of the Indian Academy of Science. IISc is quite a large place and I did not by any means become familiar with all of its people and activities. I did have numerous informal discussions with individual students and faculty in the three Departments mentioned and I paid more-or-less formal visits to other departments including Metallurgy, High Voltage Engineering, Physics, Mechanical Engineering and Applied Mathematics.

2. Raman Institute, Bangalore. When he was approaching retirement as Director of IISc, Professor C. V. Raman, who received the Nobel Prize in 1930 for discovery of the effect which bears his name, organized this institute as an arena for his post-retirement activities. The present director is Professor S. Radhakrishnan, son of the founder. Relatively small with perhaps twenty scientists, it houses two research groups. One of them, which includes the Director, pursues radio astronomy and operates a radio telescope in the hills at Ooty some 300 kilometers from Bangalore. The other under Chandrashekar pays attention to the chemistry and physics of liquid crystals. Housed on the Institute grounds is a museum which includes a remarkable collection of gems and minerals gathered by its founder.

3. ISRO Satellite Center, Bangalore. One of four Centers which house the activities of ISRO, the Indian Space Research Organization, ISAC is located in Peenya, a suburb of Bangalore. It is responsible for the design and construction of the satellites which have been and will be launched as part

of India's space program. A description of that program and its component centers is set forth in Appendix -A so that no further details on ISAC will be presented here.

4. University of Hyderabad. This brand new university, sixth in line of national universities, is being carved out of near desert on the Deccan Plateau in south central India. Because it will emphasize science and research and because it was to me an exciting place to visit, I have included in Appendix -B a somewhat extended accont of my visit there even though its connection with any space activity is presently remote.

5. Vikram Sarabhai Space Center (VSSC), Trivandrum. Located on the southernmost west coast of India, VSSC is the main center for research and development in technology relating to sounding rockets, satellite launching vehicles, payloads, ground-based and flight instruments, and production methods for propellants and rocket motors. A more detailed description of VSSC and its activities is included in Appendix -A .

6. National Chemical Laboratory, Poona. Upon achieving independence India under the leadership of Pandit Nehru began to realize the important role scientific research could play in solving many of its problems, especially those relating to economic growth and improvements in the general standard of living. This realization led to the establishment of a number of national laboratories and research institutions under the Council of Scientific and Industrial Research. The National Chemical Laboratory was the first of these establishments, now numbering about 30. Located on a tract of 475 acres outside of Poona, some 120 miles southeast of Bombay, it was inaugurated by Nehru in January 1950. It boasts a staff of about 1000 workers including 120 Ph.D.'s, 83 M. Sc's and 120 or so with Bachelor degrees in science and

engineering who are engaged in basic and applied research. There is a definite bias toward the latter as is evidenced by the fact that the present director is a chemical engineer, Dr. L. K. Doreseamy, newly appointed last year to succeed the retiring Dr. B. D. Tilak who was a chemist. NCL's mission is "to advance knowledge and to apply chemical science for the good of the people". It carries on research in areas such as: applications of plant tissue culture, development and use of immobilized enzymes as industrial catalysts, controlled-release systems for agrochemicals, use of solar energy, catalysis and catalystic processes, development of fluidized-bed chemical processes and polymer science and engineering.

7. Indian Institute of Technology (IIT), Madras. As part of the move after independence to strengthen education, especially in engineering and science, India established five new institutes of technology. Each of them enjoyed assistance and sponsorship by a foreign country or international organization. The United Kingdom was involved in the one at Delhi, the United States at Kanpur, Soviet Russia at Bombay,UNESCO at Kharagpur and West Germany at Madras. The German flavor and influence is clearly evident at IIT Madras which now has about 2800 students of which nearly 20 per cent are engaged in graduate study. The faculty numbers something over 300. Director of the Institute is Dr. K. A. V. Pandalai who received his Ph.D. in solid mechanics under Professor Nicholas Hoff when he was at Brooklyn Polytechnic Institute. My host was Professor T. K. Bose who is head of the Department of Aeronautical Engineering. He is interested in solid propellant combustion and is carrying out some experiment on rocket motor quenching by pressure dumping. His colleague, Professor A. K. Srikante, is building a beautiful stainless steel low density windtunnel with the intention of studying drag in rarefied flows.

8. University of Malaya, Kuala Lumpur, Malaysia. Professor Soon Ng, Chairman of the Department of Chemistry had arranged for my visit to this beautiful campus with striking modern architecture. School was not in session so there were no students around but some twenty-five faculty members assembled for my talk on molecular beams. There are very few graduate students and relatively little research activity.

9. The Chinese University of Hong Kong. Professor Hon-Ming Lai of the Physics Department had invited me to give a seminar. This newer of the two universities in Hong Kong is in the town of Shatin in the New Territories. Built on the top and sides of a rocky hill, its very modern buildings are themselves picturesque and provide dramatic views of both mountains and sea. Because the buildings are at greatly differing elevations, one needs wheels or the constitution of a mountain goat to get around. Indeed, this institution seems to offer education by the method of steepest ascents. Here, as elsewhere in the world, the number of graduate students seems to be declining so that maintenance of a viable research activity is difficult. I was somewhat surprised to find in a physics department a fairly extensive program on the physical properties of polymers with emphasis on measuring the speed and dispersion of sound waves and their dependence upon direction, composition and temperature. In addition, there is some experimental work on fluorescence in solids. Professor Lai is a theorist and is at the moment interested in the interaction between liquids and high intensity fields associated with laser photons.

10. Institute of Space and Aeronautical Sciences, University of Tokyo. ISAS is located at Komaba, Meguro-ku, Tokyo, about 10 kilometers southwest of the Hongo (main) Campus of the university. It occupies a site of about

25 acres with some 30 buildings having a combined floor area of 380,000 square feet. The staff includes about 70 professors and 120 graduate students most of whom are working toward a masters degree. (Essentially all of the undergraduate instruction in the University of Tokyo is carried out at the nearby College of General Education where all students go for the first two years, and the main Hongo campus where they spend their junior and senior years.) The total staff, including assistants, technicians, research associates, administrative personnel, etc. numbers nearly 600. The annual budget is of the order 35 million dollars. There are six departments: Aerodynamics and Structures, Propulsion, Electronics and Instrumentation Physics, Materials, Space Science and Space Technology. In addition there are three off-campus facilities: the Kagoshima Space Center, the Sanriko Balloon Center and the Noshiro Testing Center. It should be understood that all of these space activities are sponsored by the Ministry of Education for the purpose of basic research. There is an entirely independent, sometimes collaborative and sometimes competitive, National Space Development Agency under the aegis of the Ministry of Science and Technology which is charged with developing space technology for practical applications, e.g., satellite communication.

During my three months stay at ISAS the faculty was engaging in an agonizing reappraisal of its objectives and mission. Somewhat encouraged by the Ministry of Education, as I understood it, one faction wanted to forge ahead with large scale programs involving satellites and probes in a "big space science" effort. The other wanted to maintain the status quo or even retreat from the present independence to a much closer association with the parent university. It was not clear when I left what the resolution of this schism might be. Nor did anybody seem to know just how much influence the faculty would have on a decision which would ultimately be taken by the Ministry and the University Administration. The situation is aggrevated by the fact that the number of students interested in graduate education is continuously decreasing. In Japan as in America and all other countries I visited, university faculties are not expanding and industry is more interested in bachelors and masters than in doctors. Consequently, candidates for research degrees are becoming an endangered species.

The man who had invited me to ISAS and made all the arrangements for my stay was Professor Koichi Oshima. Designated a thermophysicist he has done research in supersonic aerodynamics, shock tube physics and rarefied gas dynamics. He has been interested in some fundamental problems of condensation and evaporation kinetics and is putting together a free jet molecular beam system based on liquid nitrogen cryopumping with which he intends to do experiments with water vapor and other readily condensible gases. There is also an active program in heat transfer in his laboratory with emphasis on heat pipe technology for satellite applications. Professor Oshima and his wife, who teaches at a private university for girls and does research on natural convection at ISAS, spent two years at the University of Southern California some years ago. His very able assistant, Dr. M. Murakami spent five years at NASA-Ames. They all like America and understand Americans so they were most kind in helping us to accommodate to life in Japan.

I also got to know Professor Hakuro Oguchi fairly well and became acquainted with his group. He is well known for his work in rarefied gas dynamics, both theoretical and experimental, and has been much concerned with the structure and behavior of shock waves. He is pursuing a fairly elaborate experimental study of the mixing of adjacent supersonic streams, a problem of interest in connection with gas dynamic lasers. My most active participation was in the group of Professor Susumu Kotake. Along with Professor Takeo Sano and Masamichi Yamashita, I got very much involved in a mass spectrometric study of dimer formation and destruction in free jets of gas mixtures. The result was a paper which was presented at the Molecular Beam Symposium at Riva del Garda. On the next to my last day at ISAS, I was invited to talk to the assembled faculty of the ISAS at their monthly luncheon meeting. Much of the talk was devoted to a discussion of the possibilities for experiments on the Space Shuttle Environment in which they had registered an interest.

11. University of Tokyo, Department of Chemistry, Hongo Campus. This is a vigorous department of the Division of Science in an ancient building on the central campus of the University. My host was Kozo Kuchitsu, Professor of Physical Chemistry, whose group studies collision processes of electronically excited atoms with other atoms, molecules and surfaces. Both beam and flowing afterglow techniques are employed. He is also interested in electron scattering from various molecules containing the NC group. I was shown through the laboratory of Kenji Tamaru who is Professor of Chemical Kinetics and was just finishing a tour of duty as Chairman of the Division of Science. Professor Tamaru spent several years in Princeton with Sir Hugh Taylor and is well known for his work in catalysis and surface chemistry. The Department as a whole has 25 professors and 16 associate professors.

12. University of Tokyo, College of General Education Department of Pure and Applied Science. Although the College of General Education is primarily concerned with providing the first two years of undergraduate education, it does have some graduate students and members of its faculty engage in research. Professor Soji Tsuchiya is the leader of a group of six faculty members whose interests center around molecular energy exchange and relaxation rates. They make use

of spectroscopic and interferometric methods to follow the decay of species excited by resonance radiation or by laser pulses. In addition, they do some molecular beam scattering experiments. They have been particularly interested in small molecules such as CO_2 and have been collaborating with Kazuo Takayanagi at the nearby Institute of Space and Aeronautical Sciences in theoretical studies of the inelastic molecular collisions involved in energy exchange and relaxation. Recently, Professor Mikio Katayama in this group has been studying the laser induced photoreactions of ethylene and the chlorinated derivatives of both ethylene and ethane.

13. The National Aerospace Laboratory, Mitaka (western suburb of Tokyo). Formerly known as the National Aeronautical Laboratory, NAS is analogous to NASA in the United States. Originally concerned with aerodynamics research, it has lots of windtunnels scattered over the premises. I was there to attend the annual meeting of JIAA (the Japanese counterpart of AIAA) but I did visit Dr. Onji's laboratory, which has a molecular beam machine using nozzle sources for the study of molecule scattering from surfaces.

14. University of Tsukuba, Institute of Applied Physics. Tsukuba is a new town about 60 kilometers northeast of downtown Tokyo. It started from scratch in 1972, designed according to a master plan as a city dedicated to science, research and engineering, with a target population of 200,000. Part of general strategy to disperse population and activities from overcrowded Tokyo, it will ultimately house 43 research and educational institutions, the core institution being the new University of Tsukuba. Boasting about 600 acres, it is by far the largest and most elegant university campus in the country. The general plan for the university is reminiscent of Santa Cruz and Rensselaer in that the distribution and assignment of faculty for instructional purposes is largely independent of the distribution of their research efforts. For the latter, there are 26 research institutes. For the

former there are three "College Clusters," each comprising three or four colleges covering a group of similar disciplines organized from among the human social and natural sciences. In addition to these clusters are more specialized schools with somewhat more intensive curricula in Medicine, Physical Education and Art and Design. The success of this marked departure from the traditional organization of Japanese Universities is yet to be measured. Construction is about half finished. Housing in the immediate vicinity is limited so that many of the faculty and students commute from as far away as central Tokyo. The established universities still attract many more applicants so that enrollments are below capacity. The occasion for my visit was an invitation by Professor Yasunori Kobayashi to give a lecture to a group of people interested in all phases of fluid mechanics who meet informally once a month or so at various places around Tokyo. Kobayashi had worked with Professor Oshima at ISAS on an experimental study of hypersonic rarefied flow over flat plates and around cylinders.

15. National Institute for Research in Inorganic Materials, Tsukuba. The first of the anticipated 43 institutions to start functioning in the new city of Tsukuba, NIRIM was moved there in 1972 from the temporary buildings in Tokyo which it had occupied since its founding in 1966. Its organization is unique and somewhat startling. Most of its 200 people are distributed among 15 research groups each comprising 8 or 9 scientists and engineers from various disciplines. Each of these groups is devoted to the study of a particular material, e.g., titanium dioxide, diamond, boron nitride, zirconium carbide, etc. A group is commissioned to study a particular material for five years. At the end of that time, its commission is renewed or a new assignment is given, depending upon results which have been obtained and the prospective scientific and technological importance of the material at the time. Among other bits of impressive apparatus is the electron microscope built to

order by Hitachi which has the highest resolving power of any such microscope in the world. (Hitachi will supply reproductions for about a million dollars each.)

16. Kyoto University, Department of Engineering Physics. Professor Kuniya Fukuda leads a group concerned with spectroscopy of plasmas and ion collision processes at low energies. In fairly close association with Fukuda's group is Professor T. Akamatsu of the Department of Mechanical Engineering who studies ionization and plasma formation by shock tubes. In addition, he has recently been applying shock tube techniques to the study of cavitation in liquids. Also at Kyoto but retired from the Faculty of Chemistry is Professor Kumasaburo Kodera, who is well known in America as Japan's foremost exponent of molecular beam methods for scattering studies of interest in chemistry. He was a student of Professor N. Sasaki who built the first molecular beam apparatus in Japan back in the mid-1930's.

17. Kyoto University, Department of Aeronautical Engineering. Its Research Institute for Chemical Kinetics is located at Uji about 20 km southeast of Kyoto. The former director was Professor G. Kamimoto, now emeritus from the Department of Aeronautical Engineering, who hosted the 10th International Shock Tube Symposium in 1975. Professor Kamimoto has not yet been replaced and Dr. Koji Teshima is running a fairly modest program with the objective of developing a shock tube driven molecular beam source to be used in studying the scattering of high energy molecules by surfaces. In that same institute Professor Michio Nishida is using spectroscopy to study the structure and composition of a plasma jet.

18. Institute for Molecular Science, Okazaki. Founded in 1975, this institute, some 40 kilometers east of Nagoya, is one of a new type of research institutes sponsored by the Ministry of Education. These "inter-university"

enterprises have no instructional responsibilities. The "chairs" in five of the fifteen research laboratories are reserved for "visiting professors" from other universities who hold temporary appointments. They will supplement and collaborate with the permanent staff. Brand new and still under construction, the laboratories are beautifully equipped with apparatus and supporting facilities but tomb-like in their lack of people because they are only a little over half manned. Budget constraints on personnel seem to be out of phase with construction budgets. IMS is to promote basic and exploratory research in molecular science with due concern for applications. A wide range of subjects in physical, organic-inorganic chemistry as well as in biochemistry and chemical physics, will be objects of study.

19. Nagoya University, Department of Aeronautical Engineering. Professor Toji Fujiwara was my host. He is developing Raman scattering techniques for the study of combustion phenomena. In addition, he is trying to obtain information on the chemical kinetic processes in detonation waves by making careful measurements of the dependence of detonation velocity on tube diameter. Together with his colleague Takeo Soga, he has also done some theoretical analysis of the evaporation rate problem by numerical solutions of the Boltzmann equation with special attention to "strong" evaporation, i.e., into low pressure regions.

20. Nagoya University, Institute of Plasma Physics. This large and elaborate laboratory is one of the main centers for fusion research in Japan. It has several machines embodying variations on the magnetic confinement theme. Its particular "bag" is the use of high frequency fields to improve the reflection in magnetic mirror machines, i.e., to "plug" the leaks.

21. Toyota Central Research and Development Laboratories. An extensive installation with nearly 500 employees, this separate and wholly owned subsidiary of Toyota Motors Corporation carries out all kinds of research and development

relevant to the automotive industry. I went there to visit the laboratory of Dr. Satoshi Yamazaki who has built a beautiful, elaborate and clearly expensive shock-tube driven nozzle beam machine. The ultimate objective is to be able to sample from the cylinder of an internal combustion engine directly into a mass spectrometer, in order to probe the details of engine combustion processes. The shock tube is simply a convenient intermittent high temperature source for use in studying and understanding the sampling process and will be ultimately replaced by an engine cylinder.

22. University of Kanazawa, Faculty of Pharmaceutical Sciences. In a city on the mid-west coast of Japan, which was untouched during the war and retains therefore the flavor of old Japan, this university is divided between a down-town campus of 1000 students in arts and sciences and a campus on the outskirts with 600 students in medicine and another 400 in Pharmaceutical Sciences. The latter discipline is much broader than "pharmacology" as understood in American and covers most fields of physical and biological science even remotely related to the manufacture, characterization and use of medicinal materials. I was there at the invitation of Professor Itoh who does research in laser spectroscopy.

23. Toyama University of Medical and Pharmaceutical Sciences. Little more than an hour's train ride north of Kanazawa, the city of Toyama has a whole university devoted to medical and pharmaceutical sciences which split off from its parent University of Toyama a few years ago and became an independent entity. Unlike its neighbor to the south, it offers a doctoral program leading to the Ph.D. in Pharmaceutical Science. My host was Professor Taiji Kitagawa who had been a student of Professor Kodera at Kyoto and did postdoctoral research with Dudley Herschbach at Harvard. His group at Toyama has built a nozzle beam system in which they are doing absorption and emission spectroscopy of complex molecules, e.g., naphthalene, in the ultraviolet region of the spectrum. They

are attempting to take advantage of internal cooling during the free jet expansion in order to improve the resolution. They indeed do see much more structural detail than can be obtained with room temperature vapors.

24. Tsukuba Space Center, National Space Development Agency. One of the 43 research institutions which will occupy the new academic city of Tsukuba (see paragraphs 14 and 15 above), this NASDA establishment houses the design, assembly and testing facilities for Japan's family of satellites. The most imposing feature of the installation and its pride and joy is the largest space simulation chamber in Japan. Made entirely of 304 stainless steel it has an inside diameter of 8.5 and a height of 25 m. A combination of rotary roughing pumps, cryopumps, titanium sublimation pumps and ion pumps can achieve a vacuum of 10^{-9} torr in 8 hours. The thermal environment simulation of space is achieved by a shroud cooled to 100K and an off-axis solar simulator comprising nineteen 30 KW Xenon arc lamps.

25. University of Trento, Faculty of Science (Povo), Italy. This relatively new faculty maintains a strong research effort in atomic and molecular physics. Its molecular beam laboratory is almost a colony of the well known molecular beam group at the University of Genoa. Both of these groups have been strongly influenced by Professor G. Scoles now at Waterloo University in Ontario. In the Scoles tradition, they are taking advantage of the characteristics of bolometer detectors in surface scattering and laser spectroscopy experiments. Another group under A. Zecca measures total cross sections for the elastic scattering of electrons from various molecules. Recently organized and now housed in university facilities is the Institute for Scientific and Technological Research which is supported by industry (FIAT) and government. Concerned with more applied problems, this Institute is mounting a major effort in the surface

treatment of metals by ion bombardment. For example, steel surfaces exposed to 100 KeV nitrogen ions become much more resistant to abrasion and high temperature corrosion than the substrate metal.

26. Space Science Department, European Space Agency, ESTEC, Noordwijk, The Netherlands. ESTEC, as it is commonly known, is part of the cooperative venture supported by a number of Western European countries. Its primary responsibility is for space technology as it applies to the design and construction of satellites, mostly for communication purposes. It does maintain a small but apparently dwindling activity in basic laboratory research and does have overall responsibility for coordinating the European Space Lab project. My host was Berndt Feuerbacher, a surface physicist who has done a lot of work on the scattering of electrons and photons from surfaces and is now starting some experiments on surface scattering of molecular beams. Because he is at present director of the Space Lab project, he has very little time for his own research.

27. Max Planck Institut für Strömungsforschung, Göttingen, West Germany. One of the outstanding centers for molecular beam research in the entire world this institute was Prandtl's home and now houses the groups of H. Pauli and J. P. Toennies, both of which maintain very active and well financed research programs in various aspects of beam scattering studies. Also at the institute is a group concerned with more conventional fluid mechanics and one on chemical kinetics and combustion under Professor H. G. Wagner who also holds Jost's old chair at the University of Göttingen. Professor Toennies is chairman of a German committee with members from university, industry and government communities whose responsibility is to plan and coordinate German participation in Space Lab and associated efforts, e.g., OSV (Orbitaler Stromungsversuchsstand), an orbital research facility for rarefied, reactive and plasma flows.

28. Deutsche Forschungs und Versuchsanstalt für Luft and Raumfahrt, Aerodynamische Versuchsanstalt (DFVLR-AVA). Also at Göttingen, in the same compound with the Max Planck Institute for Fluid Mechanics, this large installation of the German counterpart of NASA operates a number of windtunnels, large Ludwig tubes and low density gas dynamic facilities. My host was G. Koppenwallner who is active in the promotion and planning of OSV mentioned in the previous paragraph.

29. Institute for Physical Chemistry, University of Bern. In a new laboratory at an old university in the capital of Switzerland, Professor Ernst Schumacher has a group which is doing some of the most elegant work on metal clusters which is going on anywhere. A student of Clusius, Professor Schumacher had been in industry for many years and got into his cluster beam studies because of his longstanding interest in the chemistry and physics of photography. He generates clusters by the free jet expansion of alkali metal vapors, ionizes them with a tuned dye laser and detects the ions with a mass spectrometer. In a landmark study reported at the International Molecular Beam Symposium, he has determined ionization potential of sodium and potassium clusters containing from two to twenty atoms. The results provide some challenging problems to theorists. I was fascinated by the fact that his group operates continuously a Clusius thermal diffusion apparatus which produces most of the world's supply of argon 36. The "profits" from this operation amount to several tens of thousands of dollars per year and help to pay for the research program!

30. Institut für Physikalische Chemie, University of Karlsruhe. Professor Ulrich Franck is director of this very fine institute which he in fact organized back about 1955. He had been Professor Wilhelm Jost's number one assistant at Göttingen when he was invited to take the chair at Karlsruhe which was then a Technische Hochschule. A few years ago upon Jost's retirement, Franck was

invited to succeed his former mentor but finally decided to remain in Karlsruhe. The main theme of this laboratory is the study of properties and processes of systems at very high pressure and relatively high temperatures. As an example, they have measured the conductance of supercritical mercury vapor and followed its transition with increasing density from a dielectric to a metallic conductor. A very careful investigation of the high pressure polymerization of ethylene has just been carried out which revealed the very large accelerating effect of traces of oxygen.

31. Institut für Kernverfahrenstechnik, Kernforschungszentrum Karlsruhe, West Germany. This institute is the central research and development establishment for the German atomic energy program relating to fission systems. The headquarters for plasma and fusion research and development is near Munich at Garching. Here at Karlsruhe is where Professor E. W. Becker (who holds a chair at the nearby University of Karlsruhe) and his colleagues have developed the nozzle separation process for uranium enrichment. This process became famous when it turned out to be the basis for an enrichment plant that West Germany had agreed to build for Brazil. The political repercussions of that announcement have not yet died away and the final permit to build the plant has not yet been issued. Next to the barrier diffusion process, which has been the mainstay source of enriched uranium, for both power plants and weapons, and the gas centrifuge, which is now being evaluated in demonstration plants, the separation nozzle is the only other known process which has reached the demonstration plant stage, except for the South African process which is more highly classified than the diffusion and centrifuge processes in that even the principle has not been revealed. Becker's nozzle process is a textbook example of an unexpected fruit of basic research. He discovered the

separation effect quite accidentally during his development of free jet sources for molecular beams at the University of Marburg. His group at Karlsruhe has been very active for many years in rarefied gas dynamics and in cluster beam formation by free jet expansion. They regard hydrogen clusters as a promising method of fuelling magnetic fusion reactors.

APPENDIX - A *

FROM SACRED COWS TO SATELLITES — INDIA'S GREAT LEAP UPWARD

John B. Fenn

After Leslie Kovasznay's report two years ago, it will come as no surprise to readers of this *Bulletin* that India has a space program. I would guess that many of those readers might have shared my skepticism about the wisdom of such an endeavor and wondered why a nation which seems hard put to feed itself should squander any of its resources on such a "way-out" venture. But after visiting two major centers of the Indian Space Research Organization (ISRO) and talking with a number of thoughtful observers, having come to scoff I remained to pray. Indeed, I am about persuaded that India's motives in pursuing space technology are at least as sound as those of the U.S. or the U.S.S.R. Certainly national pride is involved, but, in India's case, there is even more practical justification.

It all began in 1961 when responsibility for a program of space research and development of peaceful uses for space technology was assigned to the Department of Atomic Energy (DAE). In the following year, DAE established the Indian National Committee for Space Research (INCOSPAR) to organize the program. In 1969, INCOSPAR was reconstituted as an advisory body under the aegis of the Indian National Academy of Science. At the same time ISRO was established under DAE to carry out the space research program and to pursue its commitment to peaceful purposes. By 1972 space had become important enough to rate a department of its own which the national government created in order to assume responsibility for the program as a whole. As do other departments of the government, the Department of Space (DOS) reports directly to the Prime Minister. Its policies are formulated by the space commission, a body of distinguished advisers. The secretary of the DOS is also chairman of the Space Commission and chairman of ISRO, which became the operating arm of the department Since 1972 these leading roles have been performed by Professor Satish Dhawan, a California Institute of Technology Ph.D. who is also director of the prestigious Indian Institute of Science (ISS) at Bangalore, where the ISRO administrative headquarters are located. Operating responsibilities are divided among four centers, each with its own theme or mission. I will sketch the activities of each center, with more details about the two I was fortunate enough to visit, the Vikram Sarabh Space Centre (VSSC) and the ISRO Satellite Centre (ISAC).

THE SRIHARIKOTA RANGE (SHAR) CENTRE

SHAR is on Sriharikota island off India's east coast about 100 km north of Madras. It is being developed as the major launching site for multistage sounding rockets and satellite launch vehicles. Sounding rockets up to 560 mm in diameter can be accommodated by present facilities. Preparations are being made to handle still larger motors in order to test various stage combinations for the SLV-3, India's first satellite launch vehicle. Also at SHAR is the Solid Propellant Space Booster Plant (SPROB), one of the largest propellant plants in the world. Its present capacity is for an annual production of 250 tons of composite propellants. There is provision for further expansion. The design and construction of this plant is based entirely on know-how and skills developed in India and is a source of great pride, understandable to anyone who knows something about the range of technologies and the complexity of their interaction which underlie the modern solid propellant rocket motor. The main ground station for Aryabhata, India's first satellite, launched on 19 April 1975 by the Soviets, is at SHAR. The mission control center for all future spacecraft will be located there as well.

THE SPACE APPLICATIONS CENTRE (SAC)

The only center not in the southernmost part of the country, SAC is at Ahmedabad in the state of Gujarat, some 400 miles almost due north of Bombay. Its mission is to apply the fruits of activity in space science and technology to practical ends which will be of more or less direct benefit to the people of India in their everyday lives. It concerns itself with telecommunication and television broadcasting via satellites, the use of remote (satellite) sensing for surveying and evaluating resources, and the application of space technology to meteorology

* This article is reprinted from the ONR Tokyo Scientific Bulletin (Volume 4, Number 2, 1979)

and geodesy. Also at Ahmedabad is the Physical Research Laboratory (PRL), which devotes its efforts to the more basic aspects of space science such as studies of the structure and dynamics of the upper atmosphere, earth-sun interactions, analysis of lunar samples and meteorites, laboratory studies of plasma behavior relevant to the ionosphere, climatology, and hydrology.

THE ISRO SATELLITE CENTRE (ISAC)

Located in Peenya, a suburb of Bangalore, ISAC is responsible for the design and fabrication of the satellites which are the star performers in the ISRO show. Greater Bangalore is also the home of the National Aeronautical Laboratory, the Hindustan Aircraft Company, the Indian Institute of Science, and a number of machine tool and electrical equipment companies as well as industrial research laboratories. Thus it is an appropriate home for ISAC, which sometimes requires "higher technology" in executing its assignments than do other centers. Managing director is Dr. U. R. Rao, who is interested in X-ray and UV astronomy and who has spent a number of years in the United States, first at Massachusetts Institute of Technology and then at the Southwest Research Institute. About half of the thousand or so employees are scientists and engineers. To date there have been four satellite programs undertaken.

- Aryabhata, named after a famous ancient Indian astronomer and mathematician, was launched from the Soviet Union into a near-circular orbit at an inclination of 50.7 degrees relative to the equator. It orbits the earth every 96.7 minutes at an altitude of 600 km and has a mass of 360 kg. Technologically, the satellite has performed beautifully. The spin stabilization system has exceeded specifications in its effectiveness. Because of the low rate of spin decay, the useful life has been over three years, well in excess of the original goal of six months. Unfortunately, the scientific experiments aboard had to be switched off five days after launch because one of 14 regulators in the power supply system failed. Even so, some interesting observations were made, including a large variation in X-ray intensity from Cyg X-1 and some measurements of neutron and gamma-ray emission from the sun. In addition, a number of tracking experiments have been carried out using tone-ranging, Doppler, and interferometry techniques.

- Satellite for Earth Observations (SEO) is the second Indian satellite and is due to be launched in the near future, again with a boost from Soviet Russia. Weighing about 425 kg, its orbit will be almost the same as that of Aryabhata. The payload will include two TV cameras and three microwave radiometers. The TV cameras will pick up reflected solar radiation in the 0.54 to 0.66 and the 0.75 to 0.85 micron wavelength regions during day-time passes over India. Each frame will cover an area 325 km square with a resolution of one km. The pictures will be helpful in obtaining information on forests and other land areas, rivers and large bodies of water, snow cover, and the like. A two-frequency (19.35 and 22.235 GHz) Dicke-type radiometer will monitor microwave radiation from the sea surface to obtain information on the sea state and water temperature for meteorological purposes.

- Rohini Satellite (RS-1) is designed to monitor the performance of the fourth stage of the SLV-3 launch vehicle which will inject it into orbit. RS-1 will be the first satellite to be launched by home-grown rocket motors. It will also monitor the altitude, angle and velocity of injection, the orbital path thereafter, and operational data of the satellite itself while in orbit. Liftoff is scheduled for sometime in 1979.

- Ariane Passenger Payload Experiment (APPLE), weighing about 630 kg, will be ISRO's first geostationary satellite with three-axis stabilization. It will provide some hands-on experience in developing the technology required to launch, position, and control such satellites for the multipurpose communication functions which are a primary motivation for the whole space program. APPLE is scheduled for launching in 1980 aboard the Ariane rocket launching vehicle in cooperation with the European Space Agency. It will carry two C-band transponders in the 4 to 6 GHz range to be used for some communication experiments.

In addition to these satellite programs, of which the last three are now in full swing, a substantial amount of effort is being devoted to a communications project which will be a follow-on to the SITE program to be described later. Unwilling to wait until it can do everything itself, ISRO has contracted with Ford in America for the design and construction of an operational communication satellite which will be launched in a year or two, probably by NASA.

My guide on the tour of ISAC was Dr. R. M. Vasagam, who is director of the APPLE project and who worked at the Applied Physics Laboratory of Johns Hopkins University for some time. He was at once knowledgeable and enthusiastic about both his own project and the others. He seemed relatively young for such responsibility. In fact there was a youthful air about the whole place. In all those with whom I talked, there was a strong sense of mission and a conviction that ISRO, in general, and ISAC, in particular, would make a substantial contribution to the welfare of the population at large, particularly those living in the rural areas, about which more later. It was interesting to learn that there is great competition among the various engineering groups to put pickaback experiments on the various satellites. If the project director can be persuaded that there is room and that the primary function of the satellite will not be disturbed, such experiments will be authorized. For example, on SEO there will be two such "freeloaders." A panel of arrays of silicon solar cells from India, Germany, and America will be disposed so that their relative durability in the space environment can be evaluated. Also on board will be a heat-pipe experiment aimed at finding out how the absence of gravity will effect its performance.

The laboratories seem to be well equipped with lots of electronic gear, tools, machines, and plumbing. As I took off my shoes for the third time to enter a clean room, it occurred to me that I have had to remove my footwear more often in Indian than in any country I had ever visited. Every time one visits a temple, one must take off one's shoes. (That thought reminded me of the observation, made a long time ago, that in the western world today's accelerators may be tomorrow's cathedrals. Perhaps in India, today's space centers may be tomorrow's temples!) After spending some weeks in Japan, I now realize that India is a distant second in the business of shoe removal.

VIKRAM SARABHAI SPACE CENTRE (VSSC)

Named in honor of the late Professor Vikram A. Sarabhai, founder of the Indian space program and first chairman of ISRO, this largest of the four centers is just outside the city of Trivandrum in the state of Kerala. Along India's southernmost western shore, Kerala was recently brought to the public's attention in the newspaper stories about dangers of radiation which followed in the wake of the Three Mile Island incident. Its soil is rich in radioactive thorium so its population basks in radiation 20 times greater than the world average. Kerala is also famous for its beaches and coconut palms, both of which go on for miles. Because public transport is limited and few Indians can afford cars, most of VSSC's 4500 employees commute to work in a fleet of 38 buses provided by ISRO. There is a late bus to town, about 8:30 in the evening, but the relative inflexibility of the transportation system means that there is very little after-hour effort. This constraint is somewhat bothersome to people who are devoted to their work, of which there seemed to be many in the groups I visited.

VSSC is the main center for research and development in technology relating to sounding rockets, satellites launching vehicles, payloads, ground-based and flight instruments, and production methods for propellants and rocket motors. It has developed a family of solid fuel rockets ranging from the Rohini 100 (for 100 mm diameter) to the SLV-3, a four-stage rocket 23 meters long with a maximum diameter of one meter. It will launch the 40 kg Rohini satellite RS-1 into an elliptical earth orbit with a perigee of 300 km and an apogee of 885 km. The SLV-3 is expected to be the workhorse launcher for a series of Rohini satellites with various missions, both scientific and applied. The technology on which the SLV-3 is based is essentially entirely indigenous, a word which one encounters everywhere in the space community and which is almost synonymous with "successful" in the Indian frame of reference. Some 46 public and private institutions, educational and industrial, have participated in developing the complex array of subsystems which make up a launch vehicle and its ground facilities. ISRO takes great pride in this accomplishment.

Having developed the capability to design and build solid rockets of all sizes and to produce their propellants, VSSC is now engaged in developing a liquid fuel rocket engine with three tons of thrust. With an eye to the more distant future, ISRO is supporting some university research relating to ion rocket motors. I had encountered this facet of its activities before I went to Trivandrum. At the high voltage engineering laboratory in the Indian Institute of Science at Bangalore, there is a research project on the extraction of ions from a mercury arc. I saw this project before my encounter with ISRO and had been a bit startled to find that it was being supported by India's space program. During my visits to ISAC and VSSC, I learned that ISRO supports university research projects to the extent of about 8 million rupees per year. Because indirect expenses as well as staff and student stipends are not charged to research grants at Indian universities, this level of funding buys a lot more than $8 million would buy in American institutions. Moreover, the funds for this support are sequestered in the budget and cannot be diverted to pay for cost overruns in production and development programs. Too many U.S. research investigators have had the painful experience of seeing their projects wiped out when a contractor on a large hardware program had been optimistic in estimating costs or careless in controlling them.

Most of VSSC's efforts are on the applied side, aimed at developing hardware and processes for producing materials and devices which are not commercially available within India. But there is one group which pursues fairly basic research. The Space Physics Division (SPD) has a senior scientific and technical staff which numbers fifteen and is headed by Dr. C. A. Reddy, another of the Indian scientists who has spent substantial time in the United States. His experience was at the Jet Propulsion Laboratory, operated by California Institute of Technology for NASA. Dr. Reddy and his colleagues were official hosts for my stay at VSSC. They personally escorted me on all the visits which they had set up and provided some continuity for what was a somewhat kaleidoscopic series of exposures to various facets of the center's activities. Their interest and kindness were heartwarming.

SPD was created within the VSSC organizational framework to undertake studies of some phenomena in the equatorial ionosphere for which the location of the Thumba Equatorial Rocket Launching Station (TERLS) at VSSC is particularly advantageous because it is only 24 minutes of arc south of the magnetic equator. From the beginning nine years ago, two monitoring experiments have been running continuously. A proton precession magnetometer provides round-the-clock data on the time variation of the local geomagnetic field. Every 15 minutes a C4 ionosonde obtains an "ionogram" which shows the virtual height of the ionospheric level which reflects radiowaves and the dependence of that height upon frequency. The data so obtained are regularly forwarded to world data centers and to many scientific institutions as well as to those scientists who may be conducting rocket experiments at TERLS. With the additional aid of VHF backscattered radar measurements, a number of specific studies of ionospheric phenomena have been carried out. A primary subject of study has been the equatorial electrojet, an intense band of electric current at an altitude of about 100 km which is directly or indirectly responsible for a number of interesting features of the equatorial ionosphere. During the period from August 1975 to July 1976, SPD monitored closely the radiowave transmissions from the ATS-6 satellite as a means of obtaining information on ionospheric scintillations and on total electron content in both ionosphere and plasmasphere regions. These transmissions were in connection with project SITE which will be described below.

Emphasis in SPD is now changing from studies of the ionosphere to studies of the neutral atmosphere. For this purpose three major new experimental techniques are being developed:

(1) meteor trail radar for wind measurements in the mesosphere and lower thermosphere;

(2) laser radar for measurements on dust layers, pollutants and other minor constituents, densities and their fluctuations due to winds, and turbulence in the lower troposphere; and

(3) acoustic radar for measurements of wind, turbulence, inversions, plumes, wave motions, and the like in the altitude range up to 1000 meters.

These observation systems are in various stages of development and are expected to become operational in another year or two.

In addition to these remote sensing experiments, SPD has developed and made some use of three kinds of instrument payloads for *in situ* measurements of atmospheric properties:

(1) a cold-cathode magnetron type of ionization gauge for determining densities at altitudes between 100 and 300 km;

(2) a VLF quadrupole probe to determine collision frequencies of charged particles, the mean mass of ionospheric ions, and the strength of ac electric fields in the equatorial electrojet;

(3) an HF quadrupole probe for measuring electron density and temperature in the ionosphere using plasma resonances in the 1-10 MHz range.

All of these packages have been successfully flown on sounding rockets at least once. The VLF and HF quadrupoles have gone up successfully three times apiece and have yielded valuable data which are still being analyzed.

As is the case with many basic research groups in an enterprise with hardware to develop and missions to fulfill, SPD has not been insulated from the pressures which inevitably build up as practical problems occur in the development programs. Partly in response to these pressures and partly because the problems involve interesting physics, a technical physics and applications group was formed within the division about four years ago. Thus far this group has made extensive studies of the electrostatic charging problem in launch vehicles and satellites, lightning protection for launch complexes (SHAR), thermophysical properties of materials used in aerospace structures, and evaluation of acoustic emission methods for nondestructive testing of material and structural integrity. The last of these studies culminated in a detailed proposal for the acquisition by VSSC of a full-fledged acoustic emission facility based on a strong case for its importance.

The last few lines of this sketch of VSSC and its activities will supply some detail on the Thumba Equatorial Rocket Launching Station (TERLS) which was mentioned earlier. Between its sandy shore and Africa to the west, there is nothing but about 2000 miles of Arabian Sea and Indian Ocean. Managed by ISRO, TERLS was inaugurated in November 1963, was accorded U.N. sponsorship in December 1965, and was dedicated to the U.N. as an international facility in February 1968. Available for use by any U.N. member country, subject to ISRO approval, are a wide variety of rocket magazines and assembly buildings, launch pads, block houses, telemetry stations, radar systems, test facilities, helicopter for surveillance and recovery, sea-going vessel, photographic equipment and processing laboratories, meteorological observatory, fabrication workshops, etc. A major attraction of TERLS is its proximity to the magnetic equator. Many hundreds of rockets have been fired. Scientists from France, Germany, Japan, the U.K., the U.S., and the U.S.S.R. have participated in experiments.

Early in this report I suggested that perhaps India had sound practical reasons to engage in the apparent luxury of a space program even though it is admittedly poor and technologically underdeveloped. Let me now enlarge on the basis for that suggestion. Although India has some of the most populous cities in the world and, surprising to some, the tenth largest industrial plant, by far the largest part of the population lives in relatively small villages scattered throughout a land area subcontinental in size. There are about three quarters of a million of these clusters of people. Most of them are without the amenities that have become commonplace in modern industrial societies: electric power, telephone, running water, gas, good roads, motorized transport and all the derivative functions, and devices which these basic utilities make possible. Perhaps the single most important of these utilities is electric power because it is a vital component of many of the others. For this reason, India has undertaken a massive rural electrification program reminiscent of the REA in America a few decades ago. But even at the impressive rate of 15,000 additions per year, it will be a long time before most of the 750,000 villages are plugged in to the national power grid and able to enjoy the consequent benefits.

One of the more crippling deficiencies which stem from the absence of electric power and a country-wide network of wires and good roads is a lack of easy communication. Such a network has been the basis of western societies' ability to exchange, collect, and disseminate information. In recent years, "wireless" communication by electromagnetic waves and "roadless" transport by airplane have substantially supplemented the more old fashioned channels, but wires and roads still play a vital role in both local and main line distribution of information. If all satellite and microwave communication were blacked out, America would be inconvenienced by not paralyzed. But India has no equivalent network of wires and roads. Postal communication between cities is good (better than in America much of the time!) but a long distance telephone call is often an exercise in patience and futility. In rural areas the situation is much worse. What India has high hopes for is the use of satellites to leap-frog into the modern communications era without having to wait for the long, tedious and expensive construction of a road and wire network. In particular, it is to be noted that television and FM radio receivers do not consume large amounts of power so that relatively small local power supplies would suffice. Thus, with one or two geostationary satellites, it would become possible to deliver information rapidly and at relatively low cost to rural areas all over the country, big as that country is. The power of audio-visual communication would then be available for disaster warning and other emergencies as well as for continuing education of the rural masses in better agricultural practices, health, and hygiene, along with all the entertainment and cultural enrichment which television is so capable of providing. Where telephone, television, and radio by satellite may be something of a luxury in America, they might become a truly vital force in India.

Eager to test and demonstrate this concept, ISRO undertook a Satellite Instructional Television Experimen' (SITE). A joint effort between India and the United States, it made use of NASA's geostationary satellite ATS-6 and ground installations built by ISRO. The satellite was launched on 30 May 1974. After about a year of experiments over the U.S., it was moved to a longitude of 35° East, almost directly over Kenya. Some 240υ villages spread over the states of Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Orissa, and Rajasthan (i.e a large fraction of the Indian land area) received four hours of instructional TV programs every day from 1 Augus 1975 to 31 July 1976. The programs were rebroadcast from the satellite after being received from ISRO ground stations in Ahmedabad and Delhi. Each village had a direct reception system, comprising a community TV set equipped with appropriate antennas and converters so that the signals from the satellite became pictures on the screen. The instructional elements of the programs were in the fields of agriculture, health, family planning, and some general education. The main emphasis was on rural development but national integration and identification were also promoted. Telecasts were in four languages: Hindi, Kannada, Oriya, and Telugu. In addition to th. Department of Space, the Ministries of Information and Broadcasting, Education, Agriculture, and Health an. Family Planning participated in this venture along with the governments of the states in which SITE clusters were located.

ISRO believes that SITE was probably the most complex mass communication experiment with a satelli relay which has ever been attempted. Certainly it was an ambitious undertaking. Not only did intricate ar. extensive hardware have to be designed and fabricated but developing the software for a year of broadcasting in four different languages was no easy task. There were many and difficult managerial problems to be solve Perhaps the hardest task of all, as in many experiments, will be to evaluate the results. The hardware functioned beautifully. There was never any interruption in broadcasting due to "technical difficulties." Reliability of t ground stations was above 99.5 percent for the whole time. After a few initial difficulties were ironed out, the on-line availability of the direct reception systems averaged about 90 percent. The more interesting and importan' evaluation problem is to assess the impact of the broadcasts on the receiving villages and villagers. A large team of social scientists is working on this assessment of data collected in the villages. A comprehensive social evaluatic report has been promised "soon" for two years or so but, even after several inquiries, I was unable to find ou about its status. I did hear several word-of-mouth assertions to the effect that the impact on the target villages wa substantial, that agricultural practices had been improved, that extension workers and teachers had been great stimulated, and that health and hygiene standards had been markedly raised. I, for one, will be eager to hear more about what has been learned in this exciting attempt to advance a primitive culture with space-age technology

Of course, satellites can collect information as well as disseminate it. SEO (Satellite for Earth Observation will be the first ISRO attempt to try this facet of space technology as a means of improving the lot of Indian common man. It has already been well established that satellites can provide an amazing amount of information on all kinds of ground conditions. This ability is of particular importance to India, again because of the absence alternative means of gathering data over wide areas and bringing it together for analysis and interpretation. In anticipation of remote sensing by satellite, some ten remote sensing experiments using aircraft and balloons hav been undertaken. Aerial surveys were carried out over Ananthapur and Patiala districts in 1974-75 in cooperatio with the Indian Council of Agricultural Research under Project ARISE (Agricultural Resources Inventory an Survey Experiment). The results clearly showed that remote sensing can provide much more detailed informatio than can conventional methods on the classification and identification of crops and land use. A major finding fro ARISE was that the acreage devoted to rice in Ananthapur was significantly higher than previous data h. indicated. Another important finding was that many "reserve" forests were more depleted than had been thought

These two applications of satellite technology would in themselves seem sufficiently promising to justi India's commitment to a space program. But some additional benefits have also begun to emerge. Profes Dahwan, Secretary of Space and leader of the program in more ways than one, has said that the greatest return

India's investments in space should be and would be the spin-offs into non-space activities. He believes that the challenge of solving problems will spur industry to efforts which will expand its capabilities in many directions. I had some glimpses of prospective benefits. For example, at SAC I saw a mock-up of a 500-kg satellite which was supported on a spherical air bearing so that its attitude in any direction could be readily varied for several kinds of tests. The bearing comprised a 12-inch sphere mated to a hemispherical cavity with a uniform clearance of 20 microns between the surfaces, i.e., the thickness of the air cushion which provided nearly frictionless support. The machining of this sphere and cap was quite a challenge to the Indian tool industry, but it was successfully met. To one whose experience with air bearings is minimal, it was quite impressive to be able, with finger tip exertion, to move a 500-kg structure freely about.

Another spin-off has its genesis in the propellant development program at VSSR in Trivandrum. Composite formulations based on ground ammonium perchlorate dispersed in a resin binder-fuel are the work-horse propellant in India, as they e elsewhere in the solid rocket world. In order to attain independence and to preserve precious foreign exchange, ISRO put high priority on development of indigenous sources of fuel-binder resins and the perchlorate oxidizer. One result has been a perchloric acid plant with more than enough capacity to meet all the needs for propellant manufacture. It is based on an electrochemical process in which the electrodes are graphite-lead oxide compositions that do not require expensive platinum. It happens that making matches is a large and important enterprise in a populous land where much of the cooking is done over dung fires. About half of present match production takes place in relatively large mechanized plants in cities. The other half takes place in small village industries which are labor-intensive. The village operations are at a competitive disadvantage because an essential ingredient of match compositions, potassium perchlorate, is in short supply. Indeed, it is often available only on the black market, to which the village enterprises do not have ready access. Naturally, the ISRO people are pushing plans to divert the production of perchloric acid not needed for propellants to the manufacturer of potassium perchlorate in the hope of stimulating the village match industry and decreasing the cost of matches.

Another prospective spin-off which has the propellant chemistry group excited stems from its work on developing indigenous sources for polyfunctional alcohols to condense with diisocyanates to make polyurethane resins which have a number of advantages as fuel-binders in solid propellants. Castor oil, long known as an effective lubricant, has a hydroxy group on its hydrocarbon chain. When saponified and reduced, it becomes a bifunctional alcohol. Castor beans, from which the oil is pressed, are readily grown in India. While studying the processing of castor oil to make polyols, the chemists became interested in vegetable oils as a raw material for other purposes. There are many wild trees in India which yield seeds or nuts with a high oil content. For example, a mature "neen" tree will bear 50 kg of seeds per year which are 45% oil. Unfortunately, most of these "wild" oils are not edible because they contain too much tannin, as well as other compounds which are undesirable in food. The ISRO chemists have worked out a fluidized-bed cracking process using a relatively simple alumina-silica-titania catalyst which deoxygenates any and all of these natural oils to form a hydrocarbon product with an average of 14 carbon atoms per molecule. The structure is highly branched so that, with some slight additional cracking, it makes a gasoline which has an intrinsic (without lead) octane rating of 84, almost as high as that of leaded "regular" in American service stations (when you can get it!). The Indians can get quite excited about the prospects for this "space crude" as they have dubbed it. Assuming a labor cost of 20 rupees/day (a fair wage in rural India, especially at times when cultivated crops do not demand much attention) for gathering the nuts or seeds, they estimate a cost of about 1.5 rupees/kg (8¢/lb). If the press cake (residue of bean after the oil is pressed out) can be processed into an acceptable cattle food, the price of space crude is reckoned at 0.9 rupees/kg, in the vicinity of 5¢/lb and somewhat below the present spot price for OPEC crude. It is more difficult to estimate the extent of the prospective supply because information on the nut tree population, like information on most natural resources, is simply not available—a deficiency which ISRO hopes that satellite technology will remedy. Speculation is that as much as a million tons/yr of space crude might become available, roughly equivalent to about a day's production from Iranian wells and about one day's imports of foreign oil to the United States. But in India, which has only 1/60th of the installed generating capacity of the U.S. and many fewer cars, a million tons per year represent a significant contribution to energy needs and a welcome saving in foreign exchange. Moreover, space crude is from a renewable resource of raw material and is much more versatile in use than its BTU equivalent in biomass. As a raw material for "petrochemicals," it may be much more valuable than as a fuel.

INDIA'S HYDERABAD-AN OLD CITY WITH A NEW UNIVERSITY

John B. Fenn

Early in the 12th century A.D., on the Deccan Plateau in south central India, a shepherd pointed out to the local Raja a hill which he thought would be an ideal location for a fortress. Impressed with the idea, the Raja constructed a stronghold which he named "Golconda," from Golla meaning "shepherd" and Konda meaning "hill." In due course that stronghold became the headquarters of the Hindu Qutub Shahi dynasty, whose first three of seven kings enlarged the fortress to its present impressive dimensions between 1518 and 1580. Some five miles of wall surrounded a central redoubt, three stories high, built on the original hill which itself is 300 feet high and commanded an unobstructed view for 15 miles in all directions. An intricate system of reservoirs, pumps, and pipes (hidden in the walls to lessen the danger of deliberate or accidental breakage) supplied water to all parts of the complex which included several palaces, temples, and prisons as well as armories, stables, storehouses, and a huge stage for spectacles which the reigning monarch could watch while floating in a large pool that occupied the orchestra section of the theatre. Among other features of this remarkable structure, many still largely intact, is an acoustic lens which makes a handclap at the summit of the central hill clearly audible at the main gate a mile away Lookouts at the summit, with a panoramic view of the surrounding countryside, could thus give ample warning for closing the gates in case of a prospective attack. When the fortress did finally fall, after a siege of eight months in 1687, it was only because a traitorous commander opened the gate during the night and let the enemy in. The conquerors were the Moghals whose appointed governors ruled the province until 1737. From then until 1947, the fortress and its surrounding territory were the province of a second succession of seven kings, this time of the Asif Jahi dynasty which took over after the demise of the Moghal empire. In that year, 1947, the last vestiges of royalty gave way as India became an independent democratic nation.

In 1587 the fourth king of the original Qutub Shahi dynasty had laid out immediately east of the fortress a city which he named "Bhag-nagar" after the name of his beloved concubine "Bhagmati." Known today as Hyderabad, that city is the bustling capital of the state of Andhra Pradesh. Now, some 400 years later and 10 kilometers west of Golconda, another "city" has been laid out and is being built. This city, to be populated by students and scholars, is the new University of Hyderabad, the sixth in a line of national universities and the first to be located in, and dedicated to, the needs of southern India. Conceived by an act of Parliament in October 1974, it was born on 17 November 1975 when the then Prime Minister, Indira Gandhi, dedicated to the new university a spacious complex of buildings in the center of Hyderabad known as the "Golden Threshold." These buildings comprised the ancestral property of another woman who had achieved some political success as the governor of West Bengal, the late Kumari Padmaja Naidu. She had bequeathed them to the new university. They now house its administrative offices as well as the library and classrooms for the schools of humanities and social sciences. Another tangible vote of confidence for the new school came in the form of 2300 acres of land given by the state government of Andhra Pradesh. This somewhat forbidding but picturesque site will ultimately be the home of a self-contained complex with homes for the faculty (and schools for their children), dormitories for the students and buildings to house the classrooms, laboratories, offices, and libraries which comprise a university. About 15 kilometers from downtown Hyderabad, the new campus is a piece of rock-strewn wilderness boasting some scraggly brush and weeds as its natural flora and an occasional goat as its only visible fauna. What catches the visitor's eye are granite boulders ranging in size from "smaller than a bread-box" to larger than a several-story building. Sometimes piled three or four high, one on top of another, these rocks are scattered over the landscape like the building block remnants of a once-great structure which was playfully demolished by some giant vandals. Loath to penetrate myths, however picturesque or suggestive, geologists insist that glaciers did the scattering. How the shaping occurred is not quite so clear.

A third major tangible asset of the new university is in the form of coin of the realm. The national government originally authorized 60 million rupees for capital expenditures and has since added an additional 10 million. A rupee in India has roughly the same purchasing power for domestic goods and services as a dollar in the United States. Consequently, the capital budget can provide a lot of buildings and equipment, especially since their servicing and staffing are entirely chargeable to the operating budget which is separately appropriated.

* This article is reprinted from the ONR Tokyo Scientific Bulletin (Volume 4, Number 2, 1979)

The guidelines governing the use of these substantial resources are set forth in the act of Parliament which created the new institution. In its words the objectives are: "To disseminate and advance knowledge by providing instructional and research facilities in such branches of learning as it may deem fit . . . in particular, to make special provisions for integrated courses in humanities and science . . . and to make appropriate measures for promoting interdisciplinary studies and research." Such language is broad enough to accommodate the aims and activities of almost any university. To identify the particular features and flavor which may distinguish this one from others, it is revealing to examine the actions which have thus far been taken to implement the charter objectives. The pattern which emerges quite clearly emphasizes the natural sciences and suggests that research will receive at least as much attention as classroom instruction, probably more.

Of the seven component schools now on the organization chart, no less than five are identified with the natural sciences, of which four are now functioning:

— Mathematics and Computer/Information Sciences. Professor and Dean is Dr. M. Venkataraman. Along with three readers and one lecturer, his interest is pure mathematics. Two other readers count statistics as their field of interest. One lecturer is concerned with computer methods. Another considers himself an applied mathematician. Students can choose one of the following areas for specialization: analysis (classical, functional and harmonic), geometry and topology (general, algebraic, cumulative and homological; Lie groups and Lie algebra), probability (with applications to game theory), graph theory, numerical analysis and computer methods, mathematical modelling.

— Physics. Dr. G. S. Agarwal is Professor and Dean. He lists laser physics and statistical mechanics as his specialities. There are two additional professors, four readers, and eight lecturers whose fields of interest include: low temperatures, thin films, solid state, particle physics, chemical physics, field theory, magnetism, Mössbauer spectroscopy, critical phenomena, atomic collisions, and scattering theory. Ph.D. candidates can pursue research in solid state, laser or chemical physics.

— Chemistry. An organic chemist, Dr. Goverdhan Mehta is Professor and Dean. One more professor, two readers, and six lecturers make up the rest of the present faculty. Indicated fields of interest are physical chemistry, biophysical chemistry, organic chemistry, inorganic chemistry, and electrochemistry. The research programs offered to graduate students include projects in inorganic, physical, and biophysical chemistry, and in some areas of chemical physics and statistical mechanics.

— Life Sciences. Dr. A. N. Radhakrishnan is Professor and Dean. Four readers and three lecturers are also on the staff. Indicated fields of interest include metabolic chemistry, membrane transport, cell biology, reproductive physiology, algal physiology and nitrogen fixation mechanisms, molecular biophysics, and plant genetics.

— Environmental Geosciences. Not yet in operation.

— Humanities. Professor and Dean is Dr. Shiv. K. Kumar. The school is now divided into a Department of English whose faculty includes Professor Kumar, one other professor, three readers, and four lecturers, and a Department of Philosophy with Dr. Ramachandra Ghandi as professor and two readers making up its faculty. A Department of Hindi is planned.

— Social Sciences. This school will comprise departments of economics and history. A department of political science and a department of sociology and anthropology are also planned, as are a center for regional studies and a center for human sciences. In prospect is an off-campus program leading to an advanced diploma or a Master-of-Philosophy degree at the National Institute for Rural Development which has been functioning for sometime in Hyderabad. This school is in its very early stages and no listing of faculty was available.

Blocks on an organization chart may not accurately reflect the actual allocation of resources. More revealing is the distribution of faculty appointments. Of the 54 faculty members now on the rolls and counted in the above outline, 42 are in the sciences. All of the schools have openings for additional faculty so the actual final distribution cannot now be reckoned with any certainty. It seems unlikely that the relative concentration of scientists will be diluted. A noteworthy observation upon scanning the faculty rolls is that more than a third have advanced degrees from universities in Europe and North America.

Another bit of evidence for the bias toward science was apparent in the appointment of Dr. Gurbakshsh Singh as vice-chancellor. He is a scientist, having received his Ph.D. in organic chemistry from Harvard. He had been the respected chairman of the chemistry department at Benares University. The vice-chancellor is the real chief executive of a national university. His nominal superior, the chancellor, is the President of India who assumes the title *ex officio*. Dr. Singh erased any possible doubts about his commitment to science early in the game. One of his first acts was to allocate 20% of the total original capital budget for the acquisition of modern research instruments! Moreover, the first permanent building to be constructed is an instruments facility to house them effectively. Centrally located, and to be shared by all schools, that building was nearing completion when I made my visit in February. The inventory of instruments already commissioned is impressive and includes: an AEI-KRATOS mass spectrometer (with gas chromatograph and interface); a JEOL Fourier transform NMR spectrometer; a JEOL X-Band EPR spectrometer; a Bruker magnetic susceptibility apparatus; a PAR photoacoustic spectrometer (the only one in India and one of a very few which have yet been produced); a Perkin-Elmer IR spectrophotometer; an ENRAUF X-ray Weissenberg diffractometer; a Cary UV vis-nir spectrophotometer; a JEOL scanning electron microscope; a Jobin-Y von Ramanor Raman spectrometer with an argon ion laser source; an ELSCINT Mössbauer spectrometer; and a Phillips liquid nitrogen plant. Most of these instruments are equipped with microprocessors for programming and data-processing. In addition, a DCM Spectrum-7 minicomputer is installed at the center for student use.

Responsibility for this instruments facility is in the devoted hands of D. Balasubramanian, professor of chemistry, who obtained his Ph.D. from Columbia University. His enthusiasm for the concept of a central cooperative facility is sincere and infectious but he recognizes the dangers and problems. I, too, understand the attractions but am somewhat less optimistic. Having experienced the attenuation of interaction by distance, I am a bit apprehensive about the inhibitory powers of a hot 200 meters or so of sun-baked landscape. I might walk a mile in the desert for a camel. I would be less eager to walk 200 yards to obtain the spectrum of a sample. Most of all I would be irate if a bureaucratic money-minder denied me funds for a mass-spectrometric detector on my beam machine on the grounds that one was available at the center.

The master plan for this still-almost-wilderness stemmed from a nation-wide ideas competition. The planners were charged with creating an environment which would provide a simple but noble lifestyle, would permit free and easy movement, would promote efficient working, and would encourage effective dreaming! Clearly, to finish construction of the planned buildings will take several years. In order to get things going, the organizers provided some "temporary" buildings for classrooms and laboratories. Thus it became possible to start instruction at the new site in September 1977. Of course, temporary buildings have a way of becoming permanent. These, in particular, are ground-hugging one-story masonry structures, already well landscaped and sufficiently attractive that they are unlikely to become eyesores. I suspect that they will be in use for many years, long after the newness has worn off the permanent buildings whose construction for the most part is just beginning.

In the foreseeable future, all instructions will be at the graduate level with curricula leading to one of four possible degrees, M.A., M.S., M.Phil., and Ph.D. The M.A. and M.S. programs will require two years (four semesters). An M. Phil. degree can be earned in one year (two semesters). A pre-research degree, it can be terminal for those interested primarily in teaching. Any one of these master's degrees may satisfy the prerequisite requirement for admission to the Ph.D. program. I detected some misgivings about the desirability of the M. Phil. program. (Yale University recently offered a degree of the same name to be awardable to any candidate who had finished all requirements for the Ph.D. except the dissertation. It, too, was designed for prospective teachers, but as a program it never really flew. If one can get an M.A. or M.S. in one or two years, why put in more time and effort to get an M. Phil.? At least that was the apparent conclusion of students at Yale.) At Hyderabad the M. Phil. is easier to obtain than the M.A. or the M.S. One wonders whether a kind of Gresham's law will apply so that it will drive its less easily attainable namesakes out of circulation. However, Indians tend to take the details of degree labels much more seriously than Americans, so perhaps the three different master's degrees will retain a meaningful identity.

Whether they relate to faculty on hand, students enrolled, acres of campus or rupees to be spent, numbers are limited in what they can communicate about the performance and prospects of an academic institution. Not much more enlightening are descriptions of courses and curricula, the kind of information found in college catalogs. Most important are the largely intangible attitudes and aspirations of the faculty and students because they determine whether the atmosphere is exhilarating, depressing, or somewhere in between. I came away from Hyderabad with a feeling that this new venture would make a substantial mark. There was an esprit de corps and a pervasive excitment in the air which was evidenced in many ways. *Item:* Because it will be some time before housing for either faculty or students will be available at the campus, everyone must commute from Hyderabad—by bus or bike, because almost nobody can afford the luxury of a personal car. In spite of these transport difficulties, absenteeism is not prevalent. At the two seminars I gave, the students in the audience were more numerous, interested and responsive than any I have encountered in a long time. *Item:* Last year when the contractor suspended construction because he could not obtain building blocks, the students and faculty pitched in and organized a block-fabrication operation which put the builder back on the job. *Item:* The day I visited the instrument center the air conditioning was off because some rearrangements and adjustments were taking place which had limited available electric power. Moreover, what power there was suffered from fairly wide voltage fluctuations. Consequently, all instruments had been shut down to avoid damage. But the factory representatives from JEOL were there to install and adjust the new electron microscope and, for this purpose, they needed a reasonably stable power supply. The solution to this problem was both startling and heartwarming: a crude but effective voltage regulator consisting of a man, a manually variable transformer, and a voltmeter! With such spirit and determination, this bold new venture seems destined to be viable, vigorous, and, finally victorious in its pursuit of knowledge and understanding.