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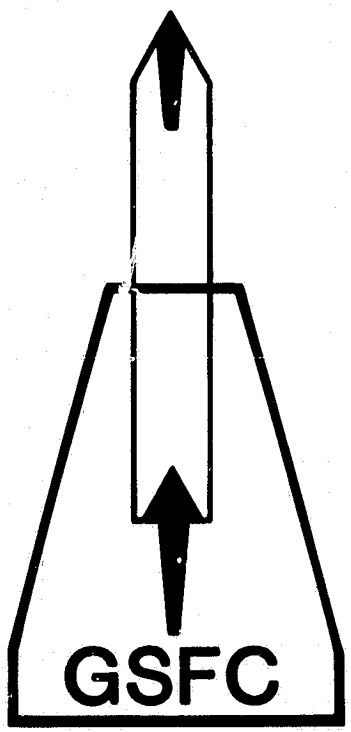
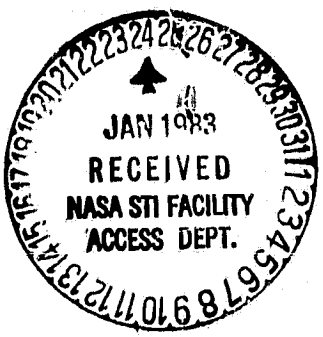
Fiscal Year 1982 Annual Report



Research and Technology



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Goddard Space Flight Center
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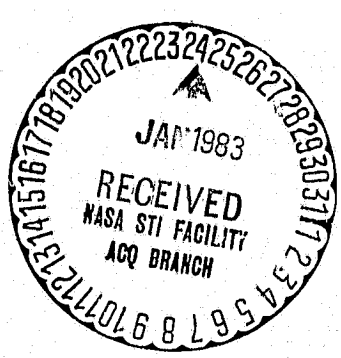

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Introduction and Summary

During Fiscal Year 1982, the Goddard Space Flight Center continued to contribute to the goals and objectives of the Nation's space program by undertaking a wide variety of basic and applied research, technology developments, data analyses, applications investigations and flight projects. The highlights of these research and technology efforts are described in this book.

Introduction and Summary

During Fiscal Year 1982, the Goddard Space Flight Center continued to contribute to the goals and objectives of the Nation's space program by undertaking a wide variety of basic and applied research, technology developments, data analyses, applications investigations and flight projects. The highlights of these research and technology efforts are described in the following paragraphs.

In the Space Sciences Program, a number of important scientific discoveries were made through continued flight missions and data analysis. Some of the significant achievements during the year include:

- The International Ultraviolet Explorer (IUE) completed its fifth year of full operation.
- The Solar Maximum Mission (SMM) continued to make significant observations with functioning at a reduced level.
- Development began on a major large-area photon counting ultraviolet detector system.
- A New Ultraviolet Imaging Telescope was begun for future flight on manned OSS-3 through 7 missions.
- Work continued on the Solar Optical Telescope which will provide ultrahigh resolution observation of solar magnetic and dynamical phenomena.
- Measurements continued from the Interplanetary Monitoring Probe 8, the International Sun-Earth Explorer 1 and 3, and the Dynamics Explorer 1 and 2.
- The Voyager 2 spacecraft encounter with Saturn provided a wealth of new data about the planet.

In the Space and Terrestrial Applications Program area, a number of significant accomplishments are reported in the areas of Atmospheric Science and Applications, Upper Atmospheric Research, Earth Science and Applications, Information Extraction and Sensor Development. Some of the accomplishments included:

- The first high resolution Seasonal Cycle Simulation Experiment was initiated using the GSFC Climate model. To predict atmospheric response to the annual cycle of solar isolation and the changing surface boundary conditions.
- The first observational study of the interannual variability of the global, monthly mean sea level pressure was completed by constructing January and July maps for each 16 years.
- Three instruments designed for remote sensing cloud top physical properties were flown on a high altitude aircraft in the Cooperative Convective Precipitation Experiment.
- Nimbus-7, operating in its fourth year, continued to provide several climate related data sets.
- The FGGE/MONEX research discovered strong midlatitude and tropical coupling over preferred regions downstream on the jet stream over Japan which impacts on synoptic events over North America.
- Studies of the carbon monoxide budget concluded that the largest sources of tropospheric CO emissions are located in the tropics.
- The Solar Backscatter UV Instrument on Nimbus-7 has provided the first direct evidence of stratospheric ozone changes related to changes in the ultraviolet solar flux.
- The Pioneer Venus Orbiter Mass Spectrometer data enabled scientists to identify deuterium as the dominant mass 2 ion in the ionosphere.

- Visible images obtained during the second Shuttle flight (STS-2) were used to track ocean current patterns and to derive water surface velocities.

The Flight Project and Mission Definition Study Program continues to work in developing spacecraft for near-term missions and defining advanced mission concepts, payloads and requirements for future missions. The major flight missions on which Goddard engineers continued to work included:

- Continuation of the development of the Space Telescope and the Solar Optical Telescope Observatory.
- Flight of the first GSFC Shuttle Mission, the OSS-1, in March 1982.
- Integration of a Search and Rescue flight hardware into the TIROS spacecraft (NOAA-E) scheduled for launch in 1983.
- Plans continued for the Solar Maximum Repair Mission to be demonstrated on a future STS flight.
- Development work continued on the Cosmic Background Explorer (COBE) and the Upper Atmospheric Research Satellite (UARS) mission.
- The first Multimission Modular Spacecarft was launched with the Landsat D in July 1982.

The Space Tracking and Data Systems Program concentrated on communication link, data transport, support services and precision tracking activities. Some of the significant project efforts in this program area included:

- Development of a new long lifetime cryogenic refrigerator to operate in space for up to 5 years.
- Development of advanced heat transport devices for future space stations.
- New Microwave and Optical components and technology have been developed for space systems which will transfer data at rates of thousands of megabits per second.
- Design of an optical disk system for image processing.
- Development of a Radio Frequency Simulation Operations Center.
- Development of a Global Positioning System Timing Receiver.
- Development of an Automated Pilot Advisory Systems for air traffic information.

The Space Technology Program continued its effort in developing advanced technology for application in cost-effective and reliable space systems that are of public benefit and that support national needs. Significant accomplishments were made in areas of information systems, infrared observation sensors, and power systems. The major accomplishments in this area included:

- Development of technology for advanced data systems to improve NASA data handling capabilities.
- Development of an Autocuer Speech Analyzing Aid for the Deaf.
- Continuation of development work on a Massively Parallel Processor and a Data Base Management System.

Space Sciences

The GSFC space sciences activities are directed toward the investigation of the Earth's space environment, the Sun, the solar system, the interplanetary medium, galactic and extragalactic phenomena, and the interrelationships of each of these. GSFC scientists continued to pursue a wide variety of research studies, data analysis efforts, instrument developements and measurement projects to increase man's understanding of the universe. Major efforts were devoted to the detailed study, analysis, and interpretation of data obtained from observations of a number of space missions.

ASTRONOMY AND SOLAR PHYSICS

The Laboratory for Astronomy and Solar Physics supported operations of orbiting observatories, continued planning and development work on future space missions and experiments, initiated development of a major new detector system, and operated data analysis and retrieval facilities for visitor and staff use.

The IUE Observatory continued in full operation, while the Solar Maximum Mission (SMM) functioned at a reduced level. SMM continued to make many significant observations, including additional high precision measurements of the solar constant. Plans have been made for an SMM Repair Mission that would restore the full or nearly full scientific and operational capabilities of the SMM.

Development began on a major new large-area, photon-counting ultraviolet detector system that is readily adapted to experiments requiring different format sizes and shapes as well as to different spatial resolutions. Also under development by the Laboratory is the Ultraviolet Imaging Telescope, which will fly on the manned OSS 3 through 7 missions. One or more of these flights may be directed toward observations of the Comet Halley.

The Laboratory continued to participate in the development of advanced facilities for research in solar physics with the Solar Optical Telescope, designed to provide ultrahigh resolution observations of solar magnetic and dynamical phenomena, and the Solar Extreme Ultraviolet Telescope, which is expected to fly on a Spacelab mission.

The High Resolution Spectrograph for the Space Telescope reached an advanced state of development with the preliminary testing leading to the full laboratory calibration.

A successful flight of a Laboratory-developed ultraviolet imaging camera aboard a sounding rocket launched from White Sands Missile Range provided new data on extragalactic and globular cluster targets and demonstrated an improved spatial resolution compared to previous ultraviolet imagery of celestial targets. Other suborbital facilities work included further development and flight testing of a solar gamma ray balloon payload.

Symbiotic Stars

R Aquarii is a member of an interacting binary system known as "symbiotic stars." This term was originally used to describe stars of two essentially dissimilar kinds which seem to occur together and which appear to "need" each other. In practice, these objects comprise a peculiar group of stars that display a combination of low-temperature absorption spectra and high-temperature emission lines. They undergo semiperiodic nova-like outbursts and exhibit the spectral changes of a slow nova superimposed on the features of a cool star. Their spectra are midway between those of planetary nebulae and true stellar objects.

An unusual jet in R Aquarii has been investigated with IUE, the VLA (Very Large Array of radio telescopes), and on optical photographs. A comparative study of VLA maps and photographs made with the 3-m telescope at Lick Observatory revealed the existence of a compact radio source located at about 3 arc min from the star along the same direction as the 10 arc sec optical jet. IUE spectra show that the jet emits a strong continuum in the 1200A-3000Å range that increases in strength toward shorter wavelengths, in contrast to the rather flat continuum observed from the nebulosity associated with the stellar source.

The two Goddard astronomers involved in these observations have proposed that the jet in R Aquarii resulted from supercritical accretion of mass from the irregular long-period star to a hot companion in a highly elliptical orbit. They further noted a Japanese chronicle of a nova-like event seen in 930 A.D., which might have been associated with the ejection of gas that comprises the outer nebulosity seen in photographs of this star. According to their model of R Aquarii, episodic accretion events may occur at 44-yr intervals.

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The Inconstant Solar "Constant"

For over a century astronomers have wondered if the Sun's output of electromagnetic radiation--the so-called "solar constant"--was really constant. An instrument known as the Active Cavity Radiometer Irradiance Monitor (ACRIM) aboard the Solar Maximum Mission spacecraft has shown that the fluctuations in solar luminosity varies from day to day and from week to week, although by very small amounts.

The biggest drops in observed luminosity coincide with the passage of major sunspot groups across the central part of the solar disk. This causes an apparent "blocking" effect. The deepest dip in the fluctuations occurred in late July 1981 with the passage of the largest sunspot group seen in the two years of SMM operation. It appears that the short-period increases in radiation correlate with passage of faculae, which are bright extra-hot solar regions.

It is premature to know if the observed changes can be correlated with climatic effects. The measurements by SMM provide a valuable step in accumulating the long-term record that the solar "constant" does indeed vary.

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Crab Nebula's Jet

Using the 0.9-m telescope at Kitt Peak National Observatory, two Goddard astronomers have obtained new long-exposure images of the Crab Nebula's jet in light of doubly ionized oxygen (5007Å). The jet, which was originally noticed by S. van den Bergh in 1970, has very parallel edges and appears to be a hollow cylinder. It does not point back to the Crab pulsar. The structure is thought to be material breaking out of the magnetic field defined by filaments originally ejected by the 1054 A.D. supernova. Whether it is associable with energetic particles from the pulsar is yet to be established.

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First Observation of Neutrons Reaching Earth from a Solar Flare

An intense burst of gamma rays usually accompanies a solar flare, and protons and alpha particles are highly accelerated within a few seconds. These particles interact with the solar atmosphere to produce neutrons. The first clear observation of neutrons reaching the Earth from a solar flare has been made using the Gamma Ray and Neutron Spectrometer aboard the Solar Maximum Mission satellite. The measurement was accomplished during a major solar flare on 21 June 1981. This detection is useful in providing a better understanding of the number of different atoms in solar flares and the mechanism by which flare protons are accelerated to high speeds.

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Sharpest UV Photos of Galaxy Obtained by Rocket Camera

A Black Brant rocket was flown on 16 April 1982 and achieved its objective. The barred spiral galaxy M83 was observed, and the camera aboard obtained the sharpest photographs of a galaxy ever made in ultraviolet light. They reveal a striking contrast with photographs from ground-based telescopes: the galaxy's bar is missing. This difference is attributed to stellar population effects--the bar is composed of older and cooler stars and hence does not appear in the UV. Instead, the new photographs emphasize regions of hot young stars where star formation is in progress today.

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Will Eta Carinae be the Next Supernova?

The massive object Eta Carinae is now believed to be a star which has already passed through several stages of evolution, rather than the young hot object as previously thought. This conclusion is based on IUE and ground-based spectral observations of the brightest outer condensation among the known ejecta of the star. The condensation is nitrogen-rich, with five observable ionization states of that atom, although carbon and oxygen are not found. The results suggest that Eta Carinae is one of the most promising candidates for near-term (by astronomical standards) supernova eruption.

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ASTROPHYSICS

Research in Astrophysics including infrared, X-ray and gamma-ray astronomy and cosmic ray studies have flourished in the last decades, producing many important and often surprising results. Those topics presented here continue that history, and with missions like the Cosmic Background Explorer (COBE) and the Gamma Ray Observatory (GRO) already underway, several shuttle payloads in the development stages and several explorers in the wings, a better understanding of our solar system and the universe seems assured.

The Exploration of the Distant Heliosphere

After a journey that has already lasted more than 10 years, Pioneer 10 is at a heliocentric distance greater than 28 AU (4.2 billion km) from the Sun while Voyagers 1 and 2 and Pioneer 11 are clustered between 10 and 13 AU. These latter 3 missions are moving toward "nose" of the expected heliopause while P-10 is heading in the opposite direction toward the tail region. This asymmetric shape is produced by the relative velocity of some 20 km/sec of the solar system with respect to the local interstellar gas.

The data from the cosmic ray experiments on the Pioneers and Voyagers combined with those on ISEE-3 and Helios near 1 AU, have provided new insight into both the physical processes invoked in producing the long term (11 year modulation) and the magnetic field configuration in this region. At both 1 AU and 25 AU the integral cosmic ray intensity with energies>100 MeV decreased by a factor of 2 while galactic cosmic ray protons with energies between 120 and 220 MeV were reduced by some 600%. The percentage change was approximately the same at both 1 AU and 25 AU. Most of the reduction occurred in 3 major episodes, each of which extended over 3-5 consecutive rotations. There is a quasi -26 day periodicity within two of these episodes suggesting the formation of a co-rotating structure in the outer heliosphere. Flare-generated shock waves appear to play a role in the formation of this structure.

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Gamma-Ray Astronomy

The high energy gamma-ray telescope, which is a joint effort of the Max-Planck-Institut fur Extraterrestrische Physik, Stanford University, Grumman Aerospace Corporation, and Goddard Space Flight Center, was the first of the Gamma Ray Observatory scientific instruments to complete its Preliminary Design Review. The sensitive area of this instrument exceeds earlier high energy gamma ray satellite telescopes by more than one order of magnitude.

Results from a medium energy gamma-ray balloon flight have shown that the gamma radiation from the central region of our galaxy is consistent with a cosmic ray electron interaction origin. The study of medium energy gamma-ray sources, including active galaxies, will be pursued in the future with a new instrument which is currently being developed. This detector system is an advanced double Compton telescope which incorporates features to improve angular resolution and suppress background.

A new derivation of the extragalactic diffuse gamma radiation with energies above 35 MeV has been carried out using galaxy counts as a tracer of galactic matter. The correlation with the data is quite encouraging. Not only can the galactic radiation be separated clearly, but also it seems possible to establish constraints on the relative contribution of bremsstrahlung and Compton radiation to the galactic gamma radiation.

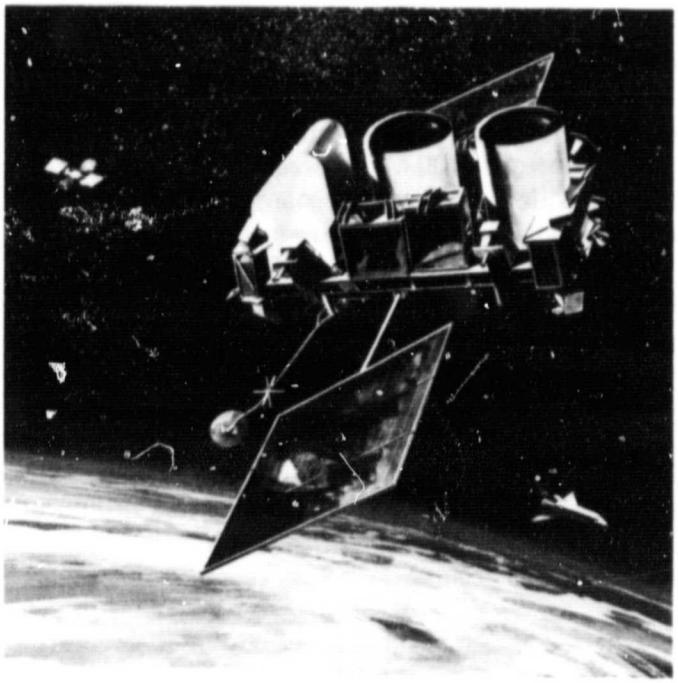

Photo of the Gamma Ray Observatory

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Gamma Ray Spectroscopy and Transient Studies

During the last year a variety of advances were made in the fields of celestial gamma ray spectroscopy and of gamma ray transient astrophysics. The GSFC high-energy astrophysics program in high-resolution gamma ray spectroscopy provided, from a southern hemisphere balloon-borne exposure, definite confirmation for the time variability of the 0.511 MeV annihilation line from the galactic center. The sensor used was an intrinsic germanium spectrometer. The drastic variation in time of the line intensity since an earlier HEAO-C observation is proof for the compact nature of the source object.

An additional new result is the accomplishment of the first known high resolution (Ge) spectrum of any non-transient extragalactic source, in this case the active-nucleus galaxy Cen A.

The program in gamma ray burst astrophysics has investigated the unique "Schaefer" optical transient source region with a repeat Guest Investigation using the VLA radio exposure. This searches for time variability or proper motion over a several year interval that could provide the missing link for source identification through the radio regime. Other very small (several arc min^2) error boxes were defined for additional gamma ray bursts and these regions are being surveyed both for archival "Schaefer" type optical transients and in first-epoch studies using the VLA.

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X-Ray Astronomy

The brightest X-ray sources in the galaxy have been known for a decade, to be neutron stars accreting matter from their companion stars in binary systems but the variety of periodic phenomena they exhibit has been poorly understood. The two fundamental periodicities were identified as the binary orbit timescale and, in the case of "pulsing" X-ray sources, the rotation period of a highly magnetized neutron star. In both instances, however, the reproducible structure (i.e., dips and peaks) in their "light curves" has eluded a general model applicable to all the variations observed.

Detailed study of data from the GSFC X-ray astronomy experiments onboard the HEAO-1 and HEAO-2 satellites has now allowed us to unify these results. We have found that the pulsar light curves can be explained in terms of two separate beaming mechanisms, one perpendicular to the stellar rotation axis and one parallel to it, where the latter becomes increasingly dominant with luminosity. Similarly, increasing luminosity creates a "corona" of hot gas around the disc of infalling material spiralling into the neutron star, which can explain the variations in the light curves associated with the binary periods. Virtually all the pulsar and binary light curves in the catalog of galactic X-ray sources are now explainable with the same straightforward model. We thereby have a basic framework for further studies of X-ray binaries, particularly in the investigation of weaker aperiodic effects characteristic of the underlying neutron star structure itself.

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The Cosmic Background Explorer (COBE)

The COBE satellite, under study by NASA since 1976, will map the spectrum and the angular distribution of diffuse radiation from the universe over the entire wavelength range from 1 micron to 1.3 cm. It carries three instruments: a set of Differential Microwave Radiometers (DMR) at 23.5, 31.4, 53, and 90 GHz; a Far Infrared Absolute Spectrophotometer (FIRAS) covering 1 to 100 cm^{-1}; and a Diffuse Infrared Background Experiment (DIRBE) covering 1 to 300 microns. They will use the ideal space environment, a one year lifetime, and standard instrument techniques to achieve orders of magnitude improvements in sensitivity and accuracy, providing a fundamental data base for cosmology. The instruments are united by common purpose as well as similar environmental and orbital requirements. The data from all three experiments will be analyzed together, to distinguish nearby sources of radiation from the cosmologically interesting diffuse background radiations. Construction began in 1982 for a launch in 1989.

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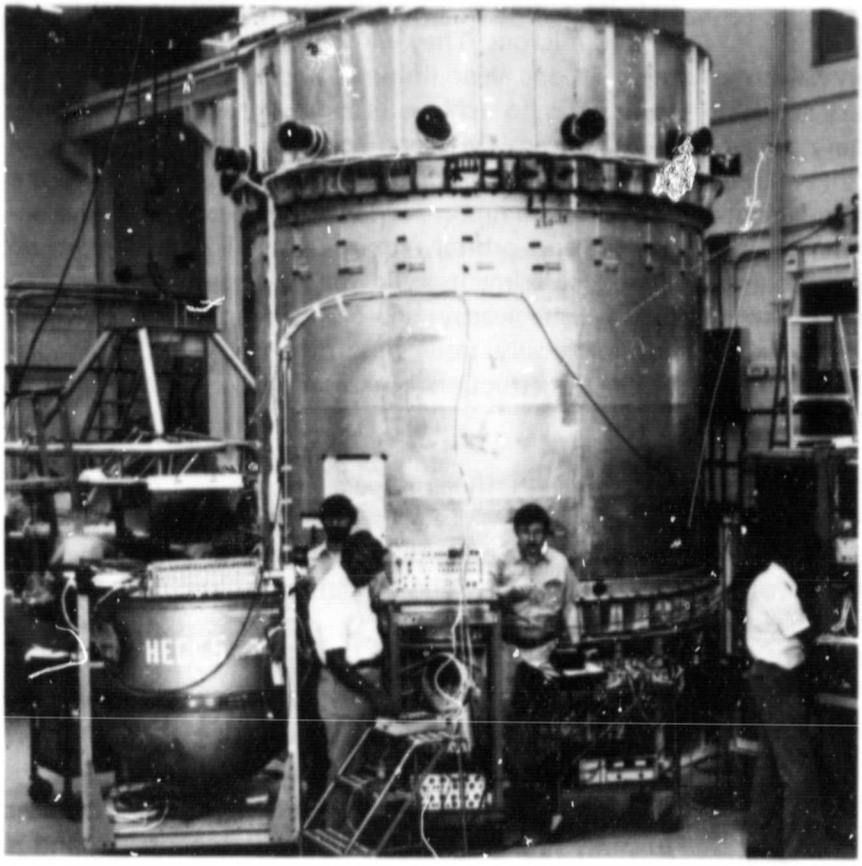
High Energy Cosmic Rays

A large gas Cherenkov spectrometer has been built to study primary iron nuclei and its secondaries and is being tested and calibrated for a balloon flight this fall (1982). The results from a successful balloon flight would extend our knowledge of the secondary/primary ratio from the energy region 50 GeV/amu to 250 GeV/amu and also give the composition of cosmic rays ($15 \leq Z \leq 20$) in the several hundred GeV/amu range, the highest energy at which direct composition measurements have been made.

This balloon-borne experiment will make use of several novel techniques to identify individual nuclei. A hodoscope array of triangular scintillators is used to compose a large area detector which is sensitive to both the charge and trajectory of incident cosmic rays. The energy resolution of the Cherenkov device has been optimized by the use of surface-applied organic waveshifters to convert ultraviolet Cherenkov light to wavelengths to which photomultipliers are most sensitive. Results from the upcoming flight should improve our understanding of the processes of particle acceleration on the galactic scale and the storage mechanism of cosmic rays in the galactic magnetic field.

The storage mechanism and the distribution of sources in the galaxy are also reflected in the details of the composition of the particles. New data obtained by the Danish-French Cosmic Ray experiment on



A large Cherenkov spectrometer has been built, and is being tested, for a balloon flight to study primary iron nuclei and its secondaries.

HEAO-3, in the 1 to 15 GeV range, have enabled new constraints to be placed on the models using this data. The data lend support to the idea that the acceleration of cosmic rays is done by shocks in the hot interstellar medium generated by supernova explosions. However, not all the data are consistent with the model, and further observations at much higher energies will be required to see if the shock mechanism really can solve the problem of the acceleration of cosmic rays.

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Fermi Acceleration at Parallel Shocks

A Monte Carlo simulation of first-order Fermi acceleration at a parallel shock with a free escape boundary upstream is compared to ISEE-1 observations of diffuse ions at the Earth's bow shock. At energies above 30 keV/Q, the observed spectra (Ipavich et al. 1981) are approximately exponential in energy per charge with an average e-folding value of 20 keV/Q. Low energy observations (Gosling et al. 1978) show a sharp turnover just above solar wind energies. The figure compares spectra calculated at several distances upstream from the shock with the free escape boundary adjusted to give the observed e-folding value. In addition to spectra, the simulation matches quite well observations of efficiency, composition, anisotropy, and the observed slowing of the incoming solar wind (Ellison 1981, Ellison and Jones 1981).

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The figure at right is a graphic representation of the differential energy spectrum (shock frame).

High Energy Cosmology

In an ongoing program applying new advances in theoretical particle physics to cosmology, we have continued to develop a baryon symmetric big-bang cosmology based on grand unified gauge theory in which clusters of antimatter galaxies form in the universe as well as matter galaxies. We have shown how this theory can account for the recent observation of cosmic ray antiprotons at an intensity 1000 times larger than expected from secondary production, as well as accounting for the detailed spectral shape of the gamma-ray background radiation. We have proposed additional tests for cosmic antimatter using cosmic ray neutrino telescopes. We have also proposed that a search for a cosmic UV isotropic background line from cosmological neutrino decay could provide a test for substructure in neutrinos, other leptons and quarks, and have identified a candidate line which could be from the decay of a neutrino of mass 15 eV/c^2.

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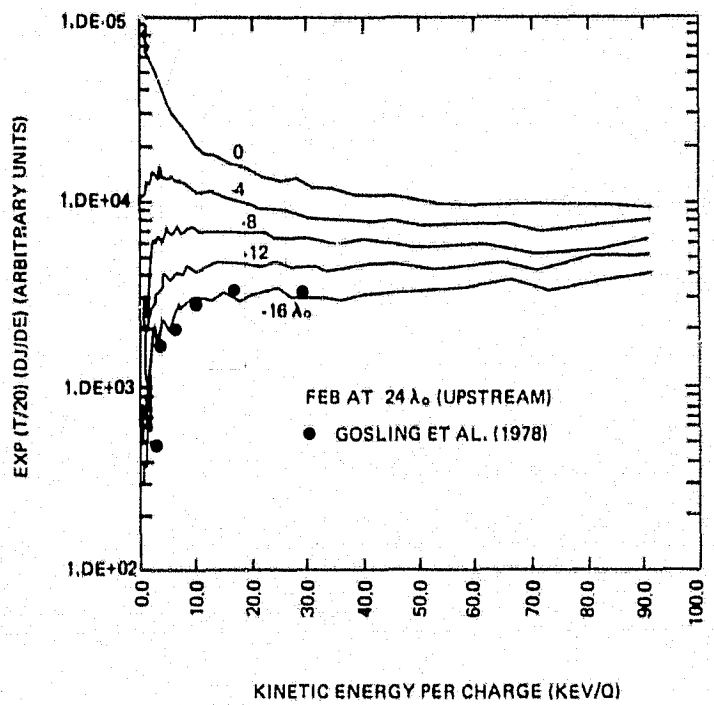

Infrared Astronomical Data Base and Catalog of Infrared Observations

A computer data base of infrared astronomical observations has been established at NASA/Goddard Space Flight Center. It contains a summary of all infrared (1 μm-1000 μm) observations of celestial sources outside the solar system, published in the major scientific journals since 1960, as well as the contents of infrared surveys and catalogs. A Catalog of Infrared Observations (CIO) has been developed from the data base in printed and magnetic tape versions. A bibliographic Guide to the Infrared Astronomical Literature, and an Atlas of Infrared Source Names and Positions are published in conjunction with the catalog. Future plans include development of an interactive data system at Goddard which will give a user direct access to the computerized data.

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MAGNETOSPHERES AND SPACE PLASMA PHYSICS

The past year has been busy and fruitful for Goddard scientists pursuing research concerned with the study of the interplanetary medium, planetary magnetospheres and solar-planetary relationships. Measurements continue from the Interplanetary Monitoring Probe 8, International Sun-Earth Explorer 1 and 3, the Scather spacecraft and Dynamics Explorer 1 and 2 in the near-earth regions as well as Helios, Pioneer and Voyager spacecraft throughout the solar system. As the following topics suggest, continuing analysis of the Voyager data from the Jovian and Saturnian encounters is very productive. Complementing the research activities associated with these flight programs are a number of theoretical studies, sounding rocket experiment and instrument development programs that provide a means of enhancing the returns from prior programs and advancing our capability for future advances.

Electric and Magnetic Fields in the Earth's Magnetosphere - Ionosphere System

Intense, variable electric fields have been observed by DE-2 using the double probe technique at ionospheric altitudes in high latitude regions. Measurements are made of both components of the electric field in the orbit plane (90° geographic inclination) at a rate of 16 samples/s (0.5 km spatial resolution). Small scale, spike-like variations with amplitudes of over 100 mV/m are frequently seen in the polar cusp region and, to a lesser degree, also in the nightside auroral oval. Magnitudes up to 240 mV/m have been observed. These variations often occur over scale lengths of a few km or less. The fine structure in the cusp is consistent with the concept of limited regions of direct access within a larger overall region. It would appear that the intense electric fields which are observed at higher altitudes in the magnetosphere may penetrate to lower altitudes more extensively than indicated by previous measurements.

Results of the electric and magnetic field observations from the DE-2 satellite show a remarkably good correlation between the north-south component of the electric field and the east-west component of the magnetic field in many passes of the field-aligned current regions. For a dayside cusp pass on August 15, 1981, the coefficient of correlation between these components was 0.996. A preliminary inspection of the available data from the first 6 months indicates that the close correlation of electric field structures and magnetic field signatures of the field-aligned currents is a commonly observed feature at all local times. We interpret this high correlation to be an indication that the closure of the field-aligned current is essentially meridional. When the correlation between these components is not good, the closure current is likely to be flowing along the auroral belt. When the correlation between the electric and magnetic fields is high, it is possible to estimate the height-integrated Pedersen conductivity from the observed field components.

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The Electrodynamics of the Middle Atmosphere

Our understanding of the electrodynamics of the middle atmosphere is undergoing important changes. Recent measurements of electric fields dispute the time-honored picture of a passive region in which external sources of electric fields smoothly couple. These new measurements indicate the existence of sources of electric fields in the upper stratosphere and mesosphere which have magnitudes of up to volts/meters. The source mechanism of these fields is at present unknown. Recent measurements have also indicated the possible coupling of neutral winds with electric field structures.

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Plasma Motions Near Jupiter and Saturn

The magnetic fields measured from the Pioneer and Voyager spacecraft close to Jupiter and Saturn are due in each case to a dynamo interior to the planet. Beyond distances of a few planetary radii, however, currents carried by magnetospheric plasma make a substantial contribution. These currents flow longitudinally around the planets and tend to stretch field lines radially from the configuration they would have otherwise in a vacuum. Of course, the motions of plasma particles are affected by the very magnetic fields which they generate, so understanding the charged particle motions in these regimes involves solving the plasma and electromagnetic equations simultaneously. A step in this direction has been taken by using magnetic models derived empirically from Voyager data and calculating the responses of individual particles. The motions are drastically different from what they are in the field of the internal dynamo alone, especially for Jupiter which has a very strong (about 300 million amperes) magnetospheric current.

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Jovimagnetic Secular Variation

The possibility of temporal variations in Jupiter's magnetic field has been studied by comparison of a Jovian internal field model obtained from the Voyager 1 magnetic field observations with the GSFC Pioneer 11 model. No significant secular variation of either the magnitude or position of the Jovidipole was found for the years 1974.9 through 1979.2 although a small earth-like variation is also consistent with the observations. The models imply a decrease of the main dipole term of only 0.06% per year with an uncertainty of 0.11% per year. The rate of decrease of the Earth's main dipole term, by comparison, is approximately 0.075% per year. These uncertainties are 10 to 100 times smaller than previous estimates and are of importance in theories of Jupiter's interior and in dynamo theory.

The success of the methods used to obtain an estimate of the Jovian internal field from the Voyager 1 observations raises the possibility that flybys planned for the future with similarly large periapses can be used to further constrain Jovimagnetic secular variations. A comparable determination of Jupiter's internal field from either the International Solar Polar Mission or Galileo could, in principle, distinguish between an Earth-like and no secular variation of Jupiter's main field.

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Jupiter's Distant Magnetic Tail

Observations from the Voyager 2 magnetic field, plasma, plasma wave and radio astronomy experiments covering the period October 1980 to August 1981 provide compelling evidence for a long, comet-like Jovian magnetotail that extends at least 9,000 Jovian radii from the planet. At the times of the tail encounters, which occur nearly every 25 days, magnetic fields stretched out parallel to the Jupiter-sun line and plasma densities as low as 10-3cm-3 are measured, as well as non-thermal VLF continuum radiation common to Jupiter's magnetosphere. The dynamical motion of the tail is apparently influenced by solar wind stream effects much like a wind sock flapping in a gusty breeze. There is also a strong suggestion from measurements of the magnetic field, whose magnitude decreases during these encounters, that the tail expands to envelop the spacecraft at those times.

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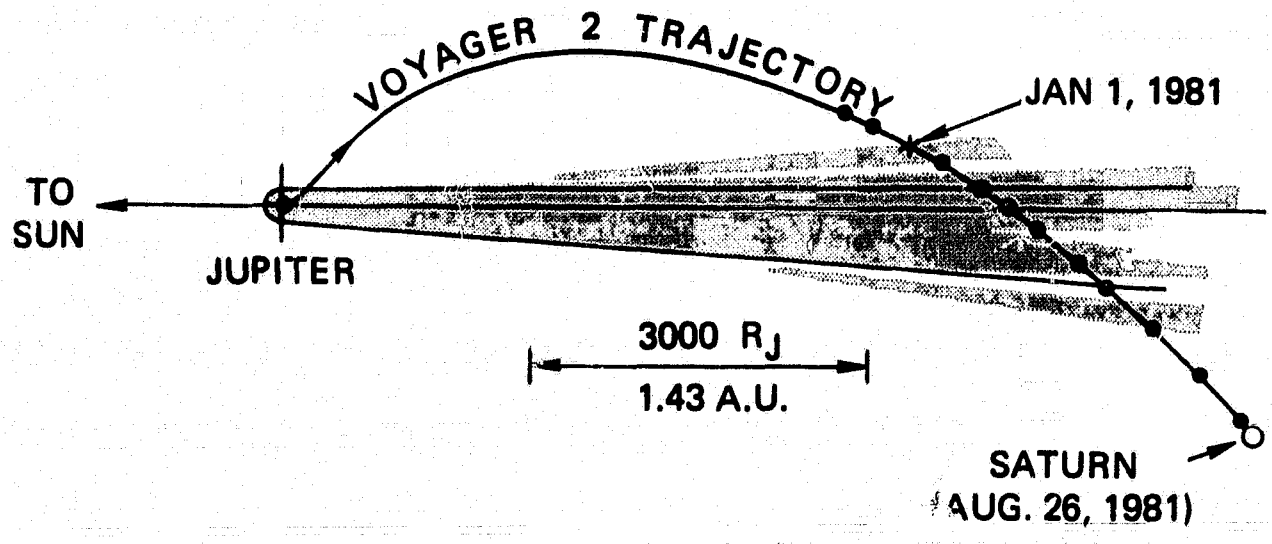

The filled circles (●) show the times during the Voyager 2 flight from Jupiter to Saturn when the long magnetic tail of Jupiter appeared to envelop the Voyager Spacecraft.

Jovian Magnetic Field Model From Voyager

A new estimate of Jupiter's planetary magnetic field has been obtained from Voyager observations of the Jovian magnetosphere. Preliminary attempts to obtain an internal field model from Voyager 1 magnetometer observations were frustrated by the large periapsis of Voyager compared to Pioneer 10 and 11 (4.9 versus 2.8 and 1.6 Jovian radii) and by the ubiquitous presence of a large-scale equatorial current system associated with the Jovian magnetodisc. Analysis techniques recently developed at GSFC have enabled us to separate the externally created field (magnetodisc plasma currents) from the planetary field. The refined Jovian internal field model obtained from the Voyager 1 data is very similar to the Pioneer 11 model derived from GSFC magnetometer data. The best-fitting magnetodisc lies in the centrifugal equator, 2/3 of the way between the rotational and magnetic equators, as appropriate for centrifugal loading of the magnetosphere by a cold plasma.

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Jupiter's Magnetosphere

The release of magnetospheric electrons from Jupiter into interplanetary space is modulated by the Jovian rotation period. This modulation permits us to study III asymmetries in the Jovian magnetosphere and interplanetary propagation of electrons. The average modulation period is equal to the Synodic period of Jupiter, but over intervals of weeks, it can differ by several minutes. A shorter period appears to be associated with decreasing plasma loading in the magnetosphere and hence a continuous decrease in the sweep-back of magnetic field lines. Longer periods were seen infrequently and we suggest that they may occur when volcanism on Io suddenly increases the plasma in the magnetosphere. The magnetic anomaly of Jupiter's magnetic field is responsible for non-uniform ionization of the Torus. As the plasma moves into the outer magnetosphere, a separation should occur at the boundary from light to heavy plasma loading because the Alfvene velocity is lower in the denser plasma. This low plasma density region inhibits the release of electrons and causes the Jovian modulation. The decrease of the modulation with distance from Jupiter permits us to place limits on the interplanetary electron diffusion coefficient. Of particular interest was the observation of modulation during the Voyager 2 tail encounters in 1981 which occurred about 4 AU behind Jupiter. This corresponds to an electron mean free path in the magnetotail in excess of 0.75 AU.

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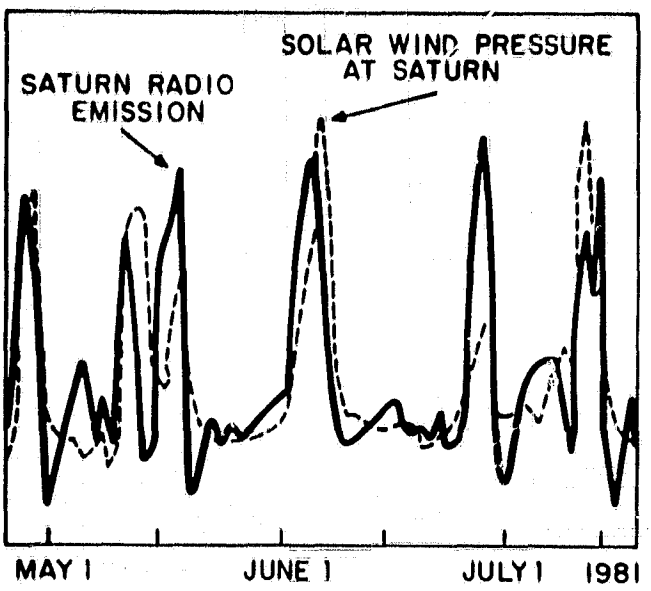
Voyager Radio Astronomy Studies of Saturn

The discovery of the emission of intense, nonthermal, radio waves by Saturn increased to three the number of known planetary radio emitters (Jupiter and Earth are the other two). The radio waves are in the gigawatt power range, but due to Saturn's great distance from Earth they can only be detected by spacecraft relatively near Saturn. Not long after the discovery of the radio emission, Goddard scientists noted a striking tendency for the radio emission intensity to wax and wane intermittently and sometimes to disappear completely for several Saturn days. This long-term modulation was in addition to the 10 hr 39.4 min long intensity modulation that led Goddard scientists to the first determination of Saturn's intrinsic spin period. Statistical analysis of the long-term intensity variations revealed that Saturn's radio waves were being powered largely by the flux of hot electrons and protons incident on Saturn's magnetosphere from the Sun. They found that when this flow of solar wind plasma is unusually dense and fast, the radio wave intensity might increase a hundred-fold over radio-quiet times when the solar wind is relatively sparse and slow.

This result indicates that, in spite of the strong shielding effect of Saturn's magnetic field, the influence of the solar wind can be felt near the ionosphere of the planet where the radio sources are located. In this respect, Saturn is much like the Earth which also has a radio source driven by the solar wind (and dramatic auroral displays that are often concurrent



Variations in the dynamic pressure of the solar wind (dashed line) measured at Voyager and extrapolated forward to Saturn and in the relative level of Saturn radio noise emissions (solid line) are plotted for a 90 day interval as Voyager approached the ringed giant. Fluctuations in the two measurements follow one another almost exactly.

events). Goddard investigators are now attempting to define the nature of the solar wind-radio source interaction more completely to understand in what ways it is both like and unlike the terrestrial case.

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Saturn's Magnetic Field - A Voyager Vista of Saturn's Interior

A new and surprising solution to a very puzzling aspect of Saturn's magnetic field may prove invaluable to both dynamo theory and studies of Saturn's interior. Early Pioneer 11 studies suggested that Saturn's magnetic field was that of a simple dipole nearly perfectly aligned with Saturn's rotation axis but displaced very slightly northward from the center of the planet along the rotation axis. Preliminary analyses of the Voyager 1 magnetic field observations confirmed the near-perfect alignment of the magnetic dipole and rotational axes but did not confirm the northward displacement of the dipole. We now have a new and unique model of Saturn's planetary magnetic field, deduced from the Voyager 1 and 2 magnetic field observations, that reconciles the Pioneer and Voyager observations.

The model is a zonal harmonic model of order 3, with the property that all non-axisymmetric components of the field are zero. This unique magnetic field configuration is not that of a simple displaced dipole but rather appears to be the axisymmetric part of a complex dynamo field. This result was predicted by a recent model of the interior of Saturn, in which differential rotation of a metallic fluid shell above the active dynamo region attenuates all non-axisymmetric components of the dynamo field. In the model, this conducting shell above the dynamo is a result of the insolubility of helium in hydrogen (a particular pressure-temperature regime) leading to 'helium rain' and a stable conducting shell above the dynamo. Jupiter does not have such a zone in its interior and, like the Earth, has a very complex (non-axisymmetric) magnetic field structure.

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Saturn's Magnetosphere

The Voyager 2 encounter with Saturn provided a wealth of new data. Of particular interest were the observation of energetic protons (>48 MeV) in the inner magnetosphere and of the micro-absorption signatures of Tethys, Enceladus, and an object in the orbit of Mimas. During the outbound part of the encounter, we observed impulsive electron acceleration to energies above 1 MeV. The electrons were probably accelerated in the magnetotail because the spacecraft was magnetically connected to that region.

To observe the energetic protons in the inner magnetosphere, the HET detectors had to be used in an unconventional coincidence configuration and a substantial amount of analysis was required to extract the desired information. Two energy channels are available 48-63 and 63-160 MeV. The ratio of these channels agrees with CRAND spectra (Cosmic Ray Albedo Neutron Decay) found at earth at $L = 2.1$. The angular distribution can be estimated by comparing

inbound and outbound observations. This gives us measurements at two pitch angles in addition to having a roll of Voyager 2 near the G ring. The results are that the energetic proton flux is isotropic outside the orbit of Enceladus, inside the angular distribution becomes increasingly flatter until it is $\sin^6$ at 3.3 Rg. It is proportional to $\sin^4$ inside the orbit of Minas, becomes 1+2.4 sin-at the G ring and then flatter again ($\sin^7$) at 2.75 R_S. These changes agree in general with what would be expected from absorption by satellites and rings. A flat pancake distribution would also be expected from a CRAND source at the A, B and C ring provided the secondary neutrons are not absorbed in the ring plane.

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Infrared Observations of the Saturnian System from Voyager 2

During the passage of Voyager 2 through the Saturn system, infrared spectral and radiometric data were obtained for Saturn, Titan, Enceladus, Tethys, Iapetus, and the rings. Combined Voyager 1 and Voyager 2 observations of temperatures in the upper troposphere of Saturn indicate a seasonal asymmetry between the northern and southern hemispheres, with superposed small-scale meridional gradients. Comparison of high spatial resolution data from the two hemispheres poleward of 60° latitude suggests an approximate symmetry in the small-scale structure, consistent with the extension of a symmetric system of zonal jets into the polar regions. Longitudinal variations of 1 to 2K are observed. Disk averaged infrared spectra of Titan show little change over the 9-month interval between Voyager encounters. By combining Voyager 2 temperature measurements with ground-based geometric albedo determinations, phase integrals of 0.91 ± 0.13 and 0.89 ± 0.09 were derived for Tethys and Enceladus, respectively. The subsolar point temperature of dark material on Iapetus must exceed 110K. Temperatures (and infrared optical depths) for the A and C rings and for the Cassini division are 69 ± 1K (0.40 ± .05), 85 ± 1K (0.10 ± 0.03), and 85 ± 2K (0.07 ± 0.04), respectively.

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Titan's Ion Exosphere Observed From Voyager 1

Electron and ion measurements made by the Voyager 1 plasma science instrument revealed a plasma wake surrounding Titan in Saturn's rotating magnetosphere. This wake is characterized by a plasma that is more dense and cooler than the surrounding subsonic magnetospheric plasma. The density enhancement is produced by the deflection of magnetospheric plasma around Titan and the addition of exospheric ions picked up by the rotating magnetosphere. By using simple models for ion pickup in the ion exosphere outside Titan's magnetic tail and ion flow within the boundaries of the tail, the interaction between Saturn's rotating magnetosphere and Titan is shown to resemble the interaction between the solar wind and Venus. Outside the magnetic tail of Titan, pickup of H+ formed by ionization of the H exosphere is indicated when synthetic and observed ion spectra are matched. Close to the boundary of the tail, a reduction in plasma flow speed is found, providing evidence for mass loading by the addition of N_2+/H_2CN+ and N+ to the flowing plasma. The boundary of the tail is indicated by a sharp reduction in the flux of high-energy electrons, which are removed by inelastic scattering with the atmosphere and centrifugal drift produced when the electrons traverse the magnetic field draped around Titan. Within the tail the plasma is structured as the result of spatial and/or temporal variations. The ion mass cannot be determined uniquely in the tail; however, one measurement suggests the presence of a heavy ion with a mass of order 28 amu: One candidate is H_2CN+, suggested as the dominant topside ion of the ionosphere, which may flow from the ionosphere into the tail.

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Features in Saturn's Rings

Saturn's rings show much structure. The most obvious is the separation into the A, B, C, D, etc. rings. Some of the ring boundaries (and sudden changes in optical depth within a ring) have been explained by the gravitational effects of satellites such as Mimas. Other features cannot be so explained. Among these is a prominent and sudden change by a factor of two in optical depth within the B ring at 1.625 R_s. We have shown that this boundary is (within about $\pm$ .002 R_s) at the marginal stability radius in the ring plane of highly charged sub-micron dust particles or plasma particles. Because of their charge, these particles are constrained to move along magnetic field lines if they leave the ring plane. Two forces control the motion along the field line (for particles in circular orbit about Saturn): gravitational and centrifugal (thinking now in the frame rotating with Saturn). Gravity tries to slide the orbit along a field line into the planet, while centrifugal force tries to bring it back to the ring plane. Because gravity goes as $1/r^2$ and centrifugal force as r, gravity wins close to Saturn if a particle is perturbed slightly out of the ring plane by a collision, for example. Far away from Saturn, centrifugal force wins and the particle remains in the ring plane. At 1.625 R_s, where the step in optical depth occurs, the two forces are equally influential and marginal stability results. How very small ($\leq$.01μm) particles are (or were at some earlier time) involved in forming this step, requires further study.

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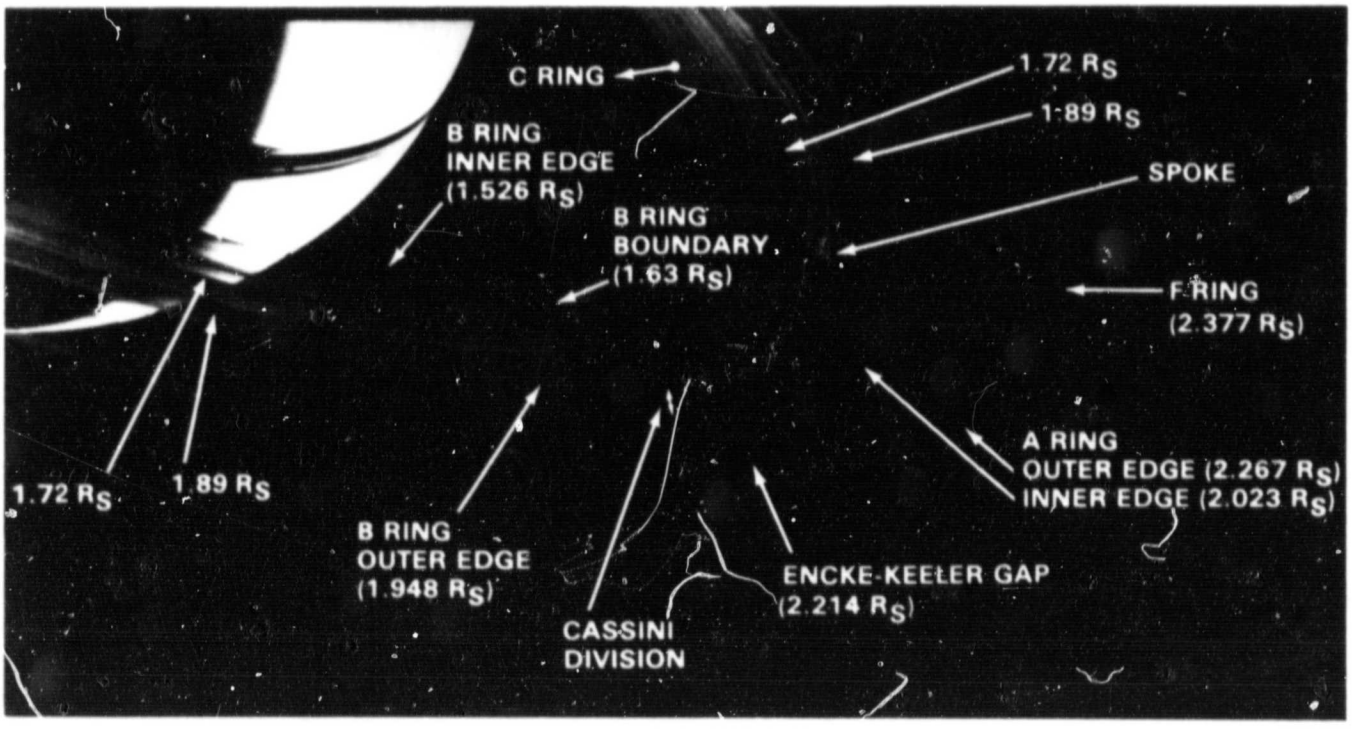
Stereoscopic Observations of Interplanetary Type III Solar Radio Bursts

ISEE-3 and Helios-2 are equipped with radiometers covering the frequency range from 1 MHz to 30 kHz and with spinning dipoles for source direction finding. The location of a solar radio burst can be uniquely determined at up to 10 frequencies by triangulation from the 2 spacecraft. This procedure provides the trajectory of the radio burst centroid between 10 and 215 R from the Sun. Spacecraft noise on Helios-2 has limited the number of events studied at this time to 25. For these events, the type III burst trajectories have been determined, thereby indicating the large scale magnetic field configuration along which the exciter electrons propagate. Many of the events show



Photograph depicting the rings of Saturn.

a spiral field configuration, but this is not always the case. The majority of electron density distributions derived from the triangulated positions have an R^{-2} radial distance dependence. This differs from the $R^{-2.6}$ dependence previously determined for Type III storms which appear to occur only in dense regions. We conclude that intense individual Type III bursts are usually emitted from regions which do not have enhanced densities.

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Magnetic Clouds and Coronal Transients

Two interplanetary magnetic clouds observed by the Helios-1 spacecraft were found to be associated with coronal transients observed by the NRL Solwind coronagraph on the spacecraft P78-1. The first of these magnetic clouds arrived at Helios-1 on May 28, 1979, when the spacecraft was at 0.43 AU and 90° west of the earth-sun line. This was related to a coronal transient observed at the west limb on May 27. The transit time from the Sun to the spacecraft gives an average transit speed of ~535 km/s which is close to the speed of the front of the magnetic cloud observed at Helios, viz. (500 ± 20) km/s. A second magnetic cloud was observed by Helios-1 on June 20, 1980 when the spacecraft was at 0.53 AU and again nearly 90° west of the earth-sun line. This was associated with a large coronal transient observed over the west limb on June 18, 1980. The speed of the front of the transient at Helios-1 was (470 ± 10) km/s, which is somewhat slower than the mean transit speed (~570 km/s), suggesting that there was some deceleration between the Sun and 0.5 AU. These magnetic clouds are similar to others described in the literature: The magnetic field strength is higher than average; the density is relatively low; the magnetic pressure greatly exceeds the ion thermal pressure; and the magnetic field direction changes through the cloud by rotating parallel to a plane which is highly inclined with respect to the ecliptic.

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Science and Applications Computing Facility

The Science and Applications Computing Center provides general purpose computational services to support scientific research at Goddard. A significant milestone was accomplished in FY82 when an IBM 3081 and supporting peripherals were installed to replace an aging IBM 360 system.

The 3081 is IBM's most advanced mainframe processor and utilizes a highly integrated circuit technology packaged in Thermal Conduction Modules (TCM's). The TCM is a helium filled, encapsulated module, measuring 125 x 134 x 35 millimeters, and contains tens of thousands of logic circuits. Benefits of the new technology include significant increase in computing capability, along with significant reductions in space, power, and cooling requirements.

The overall strategy in upgrading the facility is to support a highly adaptable environment for evolutionary growth and continue to exploit advances in technology as they are available and appropriate.

There are three immediate planning thrusts as a part of this strategy. The first is to improve the on-line availability of data by installing a mass storage device. This unit will ultimately provide storage for 400 billion bytes of data. A second thrust is to enhance interactive data analysis tools and techniques, with specific emphasis on interactive graphics. Applying rapidly advancing networking technology is a third near-term thrust. The intent is to provide very high speed access for shared use of the central processor and high volume data storage through local and remote links.

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Space and Terrestrial Applications

The major goals and primary thrust of Goddard's Space and Terrestrial Applications activities are to conduct research and technology studies and experiments necessary for the full utilization of space science and technology for applications on Earth.

During Fiscal Year 1982, GSFC made important contributions to the overall Space and Terrestrial Application's Program goals through proper use of space science and technology in the following areas: 1. Atmospheric Sciences; 2. Upper Atmospheric Research; 3. Planetary Atmospheres; 4. Earth Science and Applications; 5. Crustal Dynamics; 6. Sensor Development; 7. Information Extraction, and 8. Space Applications.

Atmospheric Sciences

The Goddard Laboratory for Atmospheric Sciences (GLAS) is responsible for applying and demonstrating the utility of measurements made by space-related techniques with respect to weather predictions, assessments of climatic hazards, management of air resources, and monitoring of the atmospheric and hydrospheric environment. It identifies problems and requirements for remote observations of atmospheric, oceanic, and hydrologic processes; investigates theory and techniques needed to obtain measurements relevant to these problems; develops the methods (such as mathematical algorithms) needed to extract measurements required from space observation; and develops advanced instrumentation and sensor systems which provide needed environmental data sets. This laboratory plans, develops, executes, and interprets experiments designed to observe the structure, composition, energetics, kinematics, dynamics, and radiative properties of those portions of the atmosphere in which meteorological processes occur. The specific parameters of interest are those useful for studying climate, global weather, and severe storms including atmospheric temperature, humidity, winds, land surface and sea surface temperature, surface albedo, emissivity, vegetation cover precipitation, soil moisture, snow cover, sea ice concentration, cloud parameters, tropospheric and stratospheric aerosols, ozone and other trace gases.

Global Weather and Climate Modeling - Climate

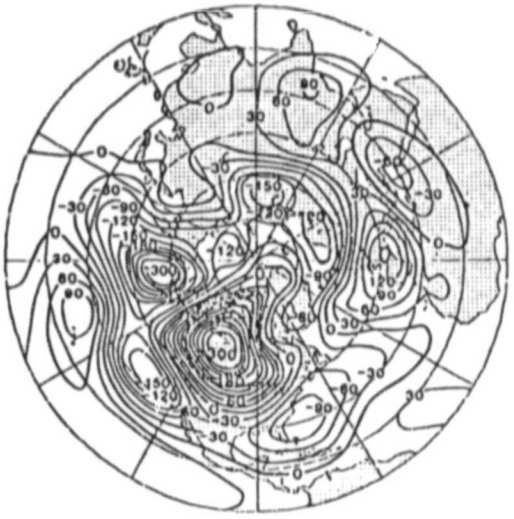
During the past year, the first high-resolution Seasonal Cycle Simulation Experiment (450 days) was initiated on the Langley Cyber 203 computer using the GLAS climate model. The model predicts the atmospheric response to the annual cycle of solar insolation and the changing surface boundary conditions. This monumental 400-day numerical experiment of the atmospheric general circulation will test the ability of the GLAS Climate Model to simulate the seasonal transitions of the global climate. It is by far the longest simulation ever performed with the model. Thus far, 250 days have been completed and have produced the most realistic winter-summer climate transition yet obtained by an GCM. In addition, an extensive set of diagnostics codes has been developed to process, analyze, and graphically display model outputs, globally as well as complete time-height cross-sections of the instantaneous atmospheric evolution at over 50 point over the Earth. These diagnostics show the dynamical and non-linear physical interactions taking place and are as complex a program as the model itself.

The short-term predictability of the climate due to both internal atmospheric dynamics and to anomalous boundary conditions was explored extensively. Predictability due to internal dynamics alone was explored using an ensemble of nine model simulations differing only in the initial conditions, three very different sets of initial conditions were used, with several perturbations about each. Examination of the growth of errors in the largest scale components indicates that they remain predictable up to at least a month, far longer than the predictability of the synoptic scales. This result carries the extremely important implication that time and space averages (or miniclimates) are potentially more predictable than weather, even in the absence of anomalies in boundary conditions.

A large number of studies to determine the effects of anomalous boundary conditions were conducted. The relationship between tropical Atlantic sea surface temperature (SST) anomalies and drought over northeast Brazil was studied by comparing the model's response to SST anomalies associated with such droughts (warm anomalies to the north, cold

anomalies to the south) with the model's response to normal SST's. The model responded to the anomalous SST's by producing anomalous circulation patterns resembling those actually observed during drought years. The ITCZ moved northward of its mean position, yielding enhanced rainfall to the north, but drought conditions over northeast Brazil. The results suggest that SST in the equatorial Atlantic can be used to predict the Brazilian drought.

Recent observational evidence strongly suggests that SST anomalies in the equatorial Pacific can lead to anomalous mid-latitude circulations via the meridional propagation of stationary Rossby waves. Composite SST anomalies were introduced into the equatorial Pacific in the model, and the resulting circulation anomaly showed clearly the meridional propagation of Rossby waves leading to intensification of the ridge near the preferred blocking location off the west coast of North America.



Shown in the diagram are the anomalies of the 300 mb geopotential height field.

The first observational study of the interannual variability of the global, monthly mean sea level pressure was completed by constructing January and July maps for each of 16 years. These maps are of importance in understanding the nature and extent of year to year variability and accurately assessing the realism of model simulations.

Pioneering methods for determining the evolution and decay of large-scale Rossby waves were developed and applied to observed global data. The results indicate that these waves possess a life cycle, and do not propagate continuously as had been suggested previously. Rossby waves are related to the atmosphere's zonal index cycle, and also may become resonant, possibly leading to persistent blocking configurations.

The interaction between cumulus clouds and radiation in the general circulation model was studied by comparing a July integration in which cumulus cloudiness was ignored for radiative purposes to one in which the cumulus cloudiness was not ignored, but each cloud was assumed to fill the grid box. The former integration was more realistic, corresponding to the fact that in nature, the frictional cloudiness produced by cumulus clouds is very small. Besides emphasizing the delicacy of handling cloud-radiative interactions realistically in models, the study identified a positive feedback between cumulus convection and radiation. The radiative effects of cumulus clouds tend to favor further convective activity.

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Global Weather

The Global Weather and Simulation Branch utilized the Goddard Laboratory for Atmospheric Sciences (GLAS) analysis/forecast system to further investigate the usefulness of satellite data for numerical weather predictions. Maximum forecast skill was obtained during periods when the atmospheric planetary waves were quasi-stationary. For two such episodes during the First GARP (Global Atmospheric Research Program) Global Experiment (FGGE) in 1979, 10-day integration were performed with the high-resolution GLAS forecast model from initial conditions which included satellite data. Both forecasts retained significant skill for the first eight days.

The influence of tropical wind data on the numerical prediction of ultralong waves was examined. Two experiments were performed, one with and one without tropical wind data. After two days, a reduction in the extratropical wind error was found in the experiment which utilized tropical wind data (including cloud-track wind data). For the six pairs of forecasts examined, the effect of tropical wind data on the 72h ultralong wave prediction was positive in four cases, negative in two over the western half of

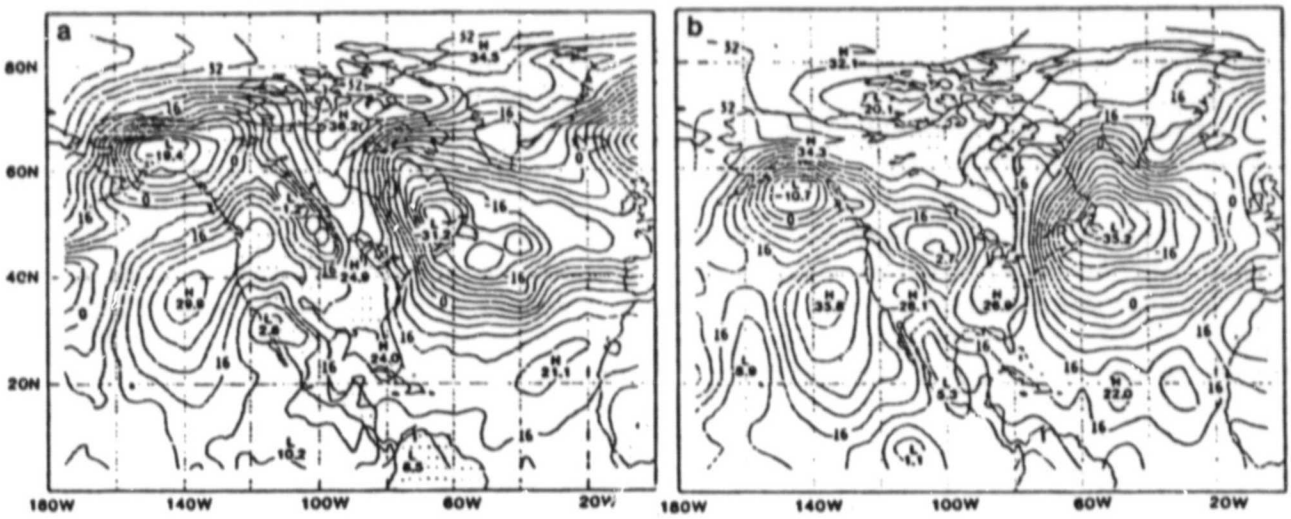


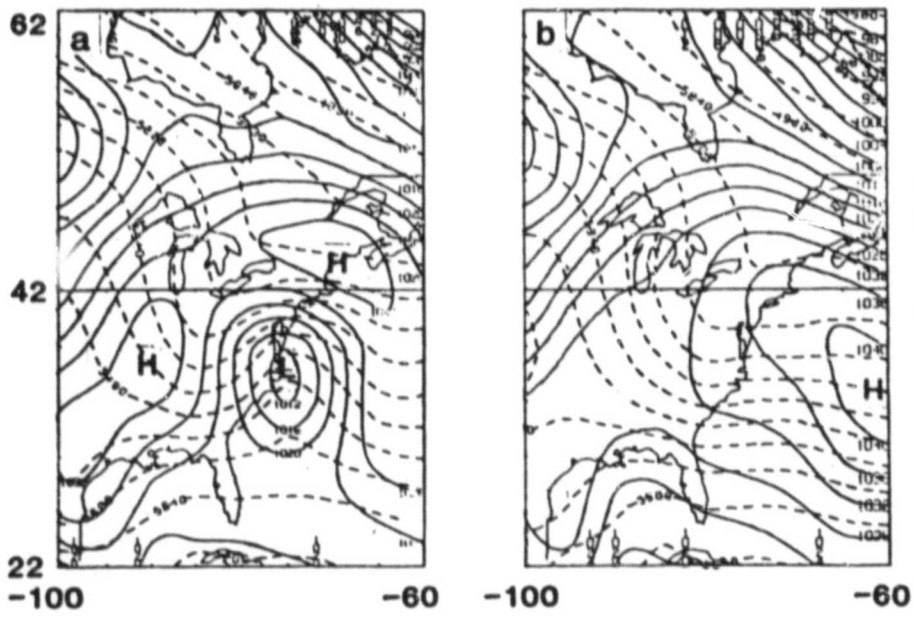
Figure a) - GLAS eight-day forecast from 0000 GMT 29 January 1979, Figure b) sea level pressure verification from 0000 GMT 6 February 1979.

the Northern Hemisphere.

The GLAS analysis/forecast system was also utilized to evaluate the usefulness of surface wind data from the Seasat-A scatterometer for numerical weather prediction. An objective dealiasing procedure was developed in which the meteorological reasonableness of the scatterometer data can be interactively checked using the Man-computer Interactive Data Access System (McIDAS). Preliminary results indicate that the use of the Seasat data contributes to increased forecast skill in the Southern Hemisphere if satellite temperature soundings from the Vertical Temperature Profile Radiometer (VTPR) are not used. However, if the satellite temperature soundings are utilized, the scatterometer data are largely redundant.

Experiments conducted with the GLAS analysis/forecast system have shown an excellent 36 to 48 hour forecast of the severe "President's Day" snow storm of February 19, 1979, which the operational model failed to predict. The experiments also showed that the most important elements in the rapid intensification of the storm were the strong sensible and latent heat fluxes from the ocean near the coast.

A GLAS temperature retrieval system to extract global atmospheric data from the HIRS/MSU sounder on TIROS-N was completed. It is based on a multichannel inversion of the radiative transfer equation. It can determine not only atmospheric temperature soundings with good accuracy, but also ground temperatures, sea surface temperatures, cloud heights,



36 hour GLAS forecasts of sea level pressure and 500 mb geopotential for 1200 GMT 19 February 1979 with, (a) and without (b), surface fluxes of sensible and latent heat.

cloud fractions, and microwave surface emissivity fields which can be related to ice and snow cover and ocean surface winds. The sea surface temperature anomaly field for January 1979 was in general good agreement with that of the Fleet Numerical Weather Center sea surface temperature analysis.

This temperature sounding system has now been integrated into the GLAS analysis/forecast system. Preliminary experiments carried out with the case of 21 January 1979 have shown remarkable improvements in forecast skill both in the Northern and Southern Hemispheres.

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Analysis, Prediction, and Detection of Climate Change

Using seven years (1974-1981) of earth radiation budget data from the radiometer measurements on polar orbiting satellites, the low frequency variability (time scales ranging from monthly to interannual) in the global distribution of diabatic heat sources and sinks has been studied. The study has focused on variation in the large-scale circulation features derived from these measurements in relation to the Southern Oscillation/El Nino phenomenon.

Examination of the global distribution of the net IR flux at the top of the atmosphere and the inferred frequency of occurrence of highly convective clouds reveals many interesting features reflecting significant changes in the large-scale tropical circulation and teleconnections between the tropics and midlatitudes. Results show that there are strong teleconnections between IR-inferred convection over the equatorial central Pacific to that over (i) the maritime continent of Indonesia and Borneo, (ii) the Amazon basin and (iii) south and southeast of the United States, and (iv) the southeast Pacific. These teleconnections are stronger during winter than during summer, suggesting that the teleconnectivity of the atmosphere is a function of the seasons. Lag-cross-correlation calculations show that the southeast U.S. and East Asia are most strongly correlated with the central Pacific with a 5-month lag. It is suggested that these teleconnections are related to the below-normal intensities of both the summer and winter monsoon over East Asia as well as the abnormally severe winters over the continental U.S. during the latter part of the 70's as a result of the influence of sea surface temperature changes on the distribution of diabatic heat sources and sinks in the tropics.

The main application of this work is in determining the potential predictability of the extra-tropics using satellite observations in the tropics. The problem of monthly to seasonal predictability is being studied with respect to the separation between noise due to the natural variability of the system and the signal forced by external changes such as sea surface temperature. While the observed interannual variability of monthly averaged IR flux is smaller in winter, this is more than compensated for by a smaller noise level, so that signal-to-noise ratios tend to be larger in winter. The feasibility of using satellite data alone and as a complement to conventional meteorological data to produce long-range weather or short-term climate predictions will be quantitatively assessed in further research.

Cross correlations and teleconnections are often analyzed in terms of empirical orthogonal functions (EOF's). This method can be easily applied to any data set, but various errors in both the set of functions and the variance spectrum can seriously hinder the identification of geophysical signals. Monte Carlo simulations have been employed in previous attempts to isolate the noise part of the spectrum, but that can be as expensive as the data analysis itself. The noise spectrum has now been derived analytically. It is a simple function of the ratio of the number of grid points to the number of samples, and provides considerable aid in the identification of signals as well as in planning optimal sampling strategies for future data sets. The ability to remove the error in EOF's is especially important, considering the potential use of EOF's in climate prediction.

Improvement in our ability to predict climate change must be accompanied by improvements in our detection capabilities. Predictions already exist for changes in climate due to present and future changes in atmospheric CO_2. However, early detection of such changes is difficult because they can be obscured by the natural, day-to-day variability of weather. To deal with this problem, a method of treating both land-based and satellite data designed to maximize the chance of detecting climatic change as early as possible has been developed. The method can be applied to the problem of detecting the surface warming already expected from increasing carbon dioxide concentrations in the atmosphere. Preliminary estimates of the efficacy of the method suggest

that it can decrease by several years the time when the global warming can be detected in the data.

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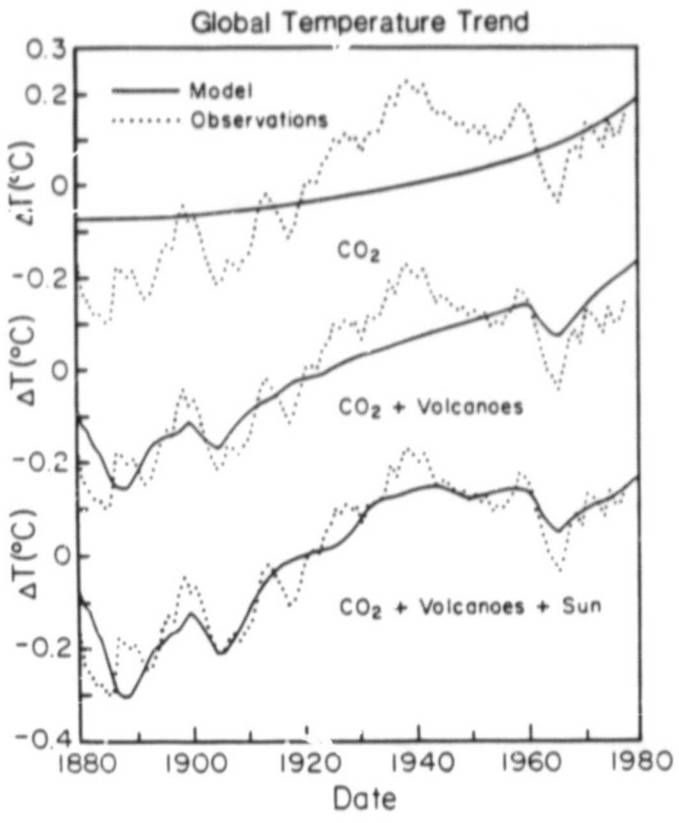
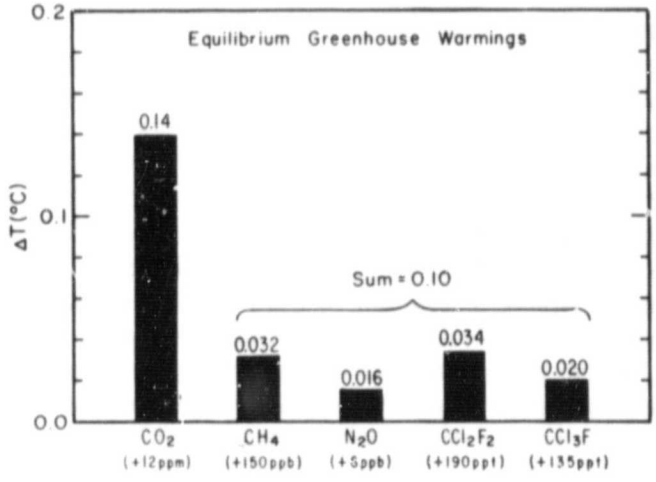
Long Range Climate Studies

Mechanisms of long-range climate change are being studied at the Application Directorate's Goddard Institute for Space Studies (GISS). An analysis of global temperature change in the past century was completed during 1981 showing that global temperature trends are consistent with the calculated greenhouse effect due to measured increases of atmospheric carbon dioxide. Variations of volcanic aerosols and possibly solar luminosity appear to be primary causes of observed fluctuations about the mean trend of increasing global temperature. It was shown that the anthropogenic carbon dioxide warming should emerge from the noise level of natural climate variability by the end of the century, and there is a high probability of warming in the 1980's.

Other gases, in addition to CO_2, may be changing by amounts sufficient to influence global climate. Indeed the abundance of several trace gases, including methane (CH_4), nitrous oxide (N_2O) and the chlorofluorocarbons (CFC's), were observed to increase in the decade 1970-1980. We have used simple one-dimensional climate models to show that the equilibrium warmings for these trace gases added to the atmosphere in the 1970's was between 50% and 100% of the equilibrium warming for the measured increase of CO_2 during the same 10 years. This implies that is is important to establish accurate monitoring of a number of trace atmospheric gases in addition to CO_2.



Observed global temperature trends (dotted line) and calculations based on one dimensional climate method with sensitivity ~ 3°C for doubled CO_2. Diffusions of heat into the deep ocean is based on observing mixing rates of passive tracers. The CO_2 and volcanic aerosol forcings are observed quantities, while the solar forcing is based on a relationship between solar irradiance and visible features on the sun hypothesized by Hoyt.



Equilibrium greenhouse warmings for estimated 1970-1980 abundance increases of several trace gases, based on one-dimensional climate model with sensitivity ~ 3°C for doubled CO_2.

Many physical mechanisms are likely to be significant in affecting long-range climate change, and thus complete analysis of observed climate and reliable prediction of future climate will depend upon development of comprehensive modeling capability and definition and execution of global measurements. Our current research is focused on the development of a global three-dimensional climate model which can be used to simulate long-range climate with improved realism. In particular, the objective will be to realistically simulate regional climate, including the transient response of the climate system to gradually changing atmospheric composition.

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Cloud Radiation Experiment

Three instruments designed for remote sensing cloud top physical properties were flown on a high-altitude aircraft for a two-week period in the Cooperative Convective Precipitation Experiment. The instruments were: A multichannel cloud radiometer (MCR), a cloud lidar system (CLS), and an advanced microwave moisture sensor (AMMS). The MCR is a seven-channel scanning radiometer designed to use the reflectance properties of clouds in the near infrared and emission in the thermal infrared to remotely sense several cloud parameters. These parameters include optical thickness, cloud top pressure altitude, phase, effective particle size and temperature. The CLS is a nadir pointing dual wavelength (1.06 and 0.53μm) and dual polarization lidar which is used to remotely sense cloud top geometrical altitude, phase (through the depolarization ratio) and either volume extinction coefficient or optical thickness depending upon whether the cloud is optically thick or thin. Finally, the AMMS is a four-channel (92GHz and 183GHz) scanning radiometer which is sensitive to the columnar amount of cloud and the vertical distribution of water vapor.

Since the observations were made, most of the analysis effort has been used in assembling and calibrating the data. Development of algorithms for remote sensing of cloud physical parameters are also being carried out. Up to now, algorithms to infer cloud scale optical thickness, cloud top altitude, volume scattering coefficient, cloud top thermodynamic phase, and effective particle size have been developed for plan parallel clouds. Application of the algorithm to data analysis is underway. Intercomparisons of the remotely sensed parameters from different instruments have been made for a limited part of the data. Two of the results of these comparisons are: (i) using radiosonde observations, the temperatures of the cloud top surfaces agree with the ambient temperature field to within $\pm 2^{o}C$ for the small cumuli observed; and (ii) ice phase was identified for temperatures less than $260^{o}K$ and water phase for warmer temperatures. Plans have been formulated to compare the remotely sensed data with in situ data. Selected portions of these data will be presented in one-dimensional and two-dimensional map format. Some of the intercomparisons will also be presented.

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Nimbus-7 Climate Data Set Development

Operation of the Nimbus-7 spacecraft into its fourth year is producing several climate-related data sets. Data from Nimbus-7 instruments, once validated, are made available from Federal archives. These data sets are in various stages of development, and their status is presented below.

Data from the Coastal Zone Color Scanner (CZCS) consisting of radiance, chlorophyll, sediment, and sea surface temperature, and covering most of the first year and part of the second year of operation has been archived. Data production and validation continue.

Solar and Earth radiation from the Earth Radiation Budget (ERB) Experiment have been produced, and will be archived in 1982. Production of the third year of data has begun.

The entire Limb Infrared Monitor of the Stratosphere (LIMS) Experiment data set covering seven months (LIMS cryogen lifetime), and containing stratospheric temperature, ozone, water vapor, nitric acid, and nitrogen dioxide profiles, has been produced, and will be archived in 1982.

A two-year data set of stratospheric aerosols in the polar regions from the Stratospheric Aerosol Measurement (SAM II) Experiment has been archived. Third year data production is nearly completed, and archival is scheduled in 1982.

The first year of global ozone data, consisting of vertical concentration profiles and total burden concentrations from the Solar Backscatter Ultraviolet (SBUV) and Total Ozone Mapping Spectrometer (TOMS) Experiment, was archived in 1982. The production of the second year of data is nearing completion, and archival is scheduled for 1982. The production of the third and fourth years' data sets is underway, with archival of third year data scheduled for early 1983.

The production of the Scanning Multichannel Microwave Radiometer (SMMR) Experiment data now extends into the third year of orbital data. The data consists of brightness temperatures, and the following derived products: sea ice (multiyear ice fraction and sea ice concentration), total atmospheric water vapor over oceans, sea surface temperature, and sea surface wind speed. The first year data set is scheduled for archival in early 1983.

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Ocean-Atmosphere Coupling Studies

The role of large-scale air-sea interaction during El Nino is studied by simple coupled ocean-atmosphere models. Two such models are developed, and controlled experiments are being undertaken to investigate feedback mechanisms involving atmospheric Hadley and Walker-type circulations and dynamical processes in the upper layer of the ocean. One model employs, in the tropical atmosphere, analytical solution to diabatic forcings as a function of the sea surface temperature anomaly (SSTA). The induced circulation then provides surface wind stress which drives the ocean and further causes SSTA to change. The second model uses a spectral representation of the global atmosphere to investigate the effect of remote response to SSTA by meridional wave propagation in the sphere. The atmosphere models are coupled to the same one-layer ocean.

A very interesting result found from studies using both models is that the model ocean-atmosphere can exhibit a bimodal climate state corresponding to two preferred longitudinal locations of the tropical diabatic heat source over the Pacific. As a result of the flip-flop between two modes, the El Nino condition may or may not develop depending on the strength of the large-scale air-sea coupling. The western and the eastern sectors of the Pacific are found to play a markedly different role in the feedback between ocean and atmosphere. The simplicity of the coupled models allow many more similar experiments to be run to explore further plausible causes and physical interpretations concerning specific aspects of the diverse phenomena associated with El Nino/Southern Oscillation.

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Oceans and Ice Branch

Satellites are restricted to measuring the ocean at its surface, while oceanographers need to know the deep flow that makes up the Gulf Stream and similar currents in order to understand the ocean's circulation and its role in the global climate. To make the extension from surface observation to reliable statements about the deep flow the Ocean and Ice Branch is exploring the use of numerical dynamic models which incorporate the surface data in a well-defined, optimal way. The estimation theory upon which this work is based establishes not only what the most likely pattern of the flow is, but also how accurate it can be expected to be. It provides a direct means for estimating the error in the circulation calculation for different measurement techniques and strategies, and thus provides an invaluable tool for satellite program design.

Large scale changes in the sea surface temperature (SST) can have important effects on weather and climate for many months. These temperature anomalies can be driven by ocean currents and transport of warmer or colder water into the region of interest. Mixing of colder, deep water up into the surface layer can also provide extremely effective lowering of SST. Numerical models of the upper ocean are being used

to study the changes in ocean currents and mixing in response to variations in the tropical winds, and to evaluate the predictability of SST changes several months in advance of their appearance. Results of these model experiments will be used to develop a coherent monitoring plan for measuring surface winds, currents, the height of the ocean surface and temperatures, in order to provide predictions of these fields.

The ocean color program has focused its emphasis on the upwelling dynamics and associated bioproductivity of the Gulf Stream front along the Florida-Georgia continental shelf. The studies have incorporated data from the U-2 Ocean Color Scanner, the Thematic Mapper Simulator, and Nimbus-7 Coastal Zone Color Scanner (CZCS). Since the upwellings are produced by several different mechanisms and occur on a variety of space and time scales, it is difficult to locate and adequately sample upwelling events using traditional ship and mooring techniques. The thermal and visible imagery have provided an instantaneous view of sea surface temperature and surface chlorophyll concentration, both of which provide information necessary in determining which mechanisms are at work for the particular situations observed. Analysis of data taken during 1979 and 1980 has shown that, contrary to earlier assessments, episodes of high productivity do occur regularly on the outer continental shelf. This work is being expanded to incorporate a year's time series of CZCS imagery of the entire South Atlantic Bight (Cape Canaveral to Cape Hatteras) in order to study nearshore as well as shelf break processes and the coupling between them. Also, new initiatives have been started using CZCS and AVHRR-II data for investigating oceanic processes in the Gulf of Mexico, the NE coast of Spain and the Kuroshio in collaboration with field projects being conducted in these areas. These field data are being used for validation tests of SST from the AVHRR-II.

The key to the study of the ocean by remote sensing techniques from satellites is the understanding of the microscale ocean surface dynamics. More specifically, we need the statistical properties of the ocean surface. During this year, we have established that:

(1) The electromagnetic (EM) biases in altimetric measurements exist both in the mean sea level and the significant wave height determinations. A laboratory simulation offered a unifying explanation of the previously scattered empirical data. In general, the biases increase with increased EM wavelength of the radar used. The biases are best expressed as the percentages of the significant (or rms) wave height.

(2) A non-Gaussian statistical model of surface elevation of nonlinear random wave fields was developed. The probability density function for surface elevation of a nonlinear random wave field is established using a simple mapping method. The wave model used is based on the complete Stokes expansion. The probability function for the deep water case depends only on the rms surface elevation and the significant slope. This mapping method can be applied to the shallow water case as well. For the shallow water case, an additional parameter, the nondimensional depth, is also required. An important difference between the present result and the Gram-Charlier expansion is that the present probability function is always non-negative. It is also found that the usually neglected constant term in the Stokes expansion plays a critical role in determining the details of the density function.

The Goddard Short Pulse Radar Ocean Wave Spectrometer (ROWS) program is concerned with developing a viable satellite remote sensing technique for global measurements of ocean wave directional spectra. (The distribution of wave energy in wavelength and direction). Considerable progress toward this end has been made in the past several years. It has been shown that these measurements can be made rather simply and economically using existing short-pulse satellite altimeters such as Seasat altimeter, modified to include a near-nadir ($0 \sim 10^{o}$) conical scan mode in addition to the nadir altimeter mode. In the near-vertical, specular backscatter regime it has been shown theoretically that rather accurate measurements of the directional wave height spectrum can be made using a simple, first order linear scattering model (tilt model). The final analysis of the Fall '78 Mission aircraft data set completed this year confirms the theoretical predictions. The aircraft data show remarkable spectral fidelity and demonstrate the capability to infer absolute energy levels (significant wave height accuracy ~ 20cm). The program emphasis is now on 1) defining a Shuttle experiment to demonstrate the technique in space 2) applying the Fall '78 Mission data set to tests of numerical wave models and 3) conducting joint flight experiments with the Wallop's Surface Contour Radar (SCR). The SCR is a "direct" measurement technique that can provide deep-water spectral measurements with a directional resolution comparable to the ROWS (nominally 20^{o}). Buoys simply do not have the

directional resolution to serve as adequate surface truth for the ROWS, especially in complex seaways.

Further improvements have been made in the algorithms used to calculate sea surface temperatures (SST) and sea ice properties, from Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR). These serve to produce more consistent results throughout the year. They are now being applied to the study of sea surface temperatures and sea ice properties, such as compactness and age, using a full one-year data set.

Sea ice is a highly variable feature of the Earth's surface both reflecting and influencing climatic conditions. The extent of sea ice and the area of open water within the ice pack of the southern ocean have been described in detail for the four-year period 1973-1976 using microwave imagery from the Nimbus-5 satellite. Although the total sea ice cover decreased significantly by 9.7 percent in the annual mean from 1973 to 1976, considerable interannual variability and interregional contrast occurs in the ice cover. Although additional data on ice extent through 1981 shows that the sea ice extent has partially rebounded in recent years with a nearly complete recovery in the Weddell region where most of the mid-1970s decrease occurred. Deduction of possible secular trends will require systematic analysis of long-term passive microwave observations.

New insight into the Weddell polynya, an occasional large open water region in the midst of the southern ocean pack ice during winter, has been obtained from modeling results. Separate runs of the GSFC sea ice model, with only the wind fields altered, succeeded in simulating both winter seasons with a polynya and winter seasons without a polynya. The results suggest the importance of the winds in the formation and positioning of the Weddell polynya.

Sea ice concentrations derived from the 0.81 cm wavelength radiances of the Nimbus-7 SMMR were used in a comparative study of the Bering Sea ice cover during 1979. Comparison of the SMMR-derived ice concentration maps with surface, aircraft, and TIROS-derived ice charts shows that the microwave data correctly locate the ice edge to within approximately 30 km, the spatial resolution of the 0.81 cm SMMR channels.

Preliminary results of a study of Arctic sea ice using the dual-polarized, multispectral microwave radiances obtained from SMMR during its first year of operation show significant spatial and temporal variations in the observed radiances. These variations result largely from the seasonal variation of the ice cover itself, the seasonal march of surface temperature, and from the variations of the distribution of first-year and multiyear sea ice types. Analysis of these multispectral microwave sea ice signatures will improve our current capability of determining sea ice parameters from satellite, such as ice concentration, age, and ice temperature. The improved retrievals will aid in our understanding of the polar region and its role in global climate.

Satellite altimetry offers a potentially unique capability for determining the growth or shrinkage of polar ice sheets and adjacent floating ice shelves. Analysis of Seasat radar altimetry has demonstrated the advantages and limitations of a radar altimeter for determination of ice elevations and changes in ice volume. On the smoothest and flattest region of the ice sheets a height precision of 30 cm is achieved, but the precision degrades over rougher terrain. Preliminary analysis of the radar altimeter range data along an intersection of an ice shelf front has also shown that the position of the ice front can be determined to an accuracy better than 1 km. Because most of the Antarctic ice discharges into the ocean through ice shelves, accurate repetitive measurement of the ice front position would provide an indication of critical changes in ice flow.

A collaborative field study with scientists of the Federal Institute of Technology (Zurich, Switzerland) was completed examining the effect of pressurized sub-glacial water on the basal movement of Findelengletscher, in Switzerland. This is a fundamental process in the present-day movement of the Antarctic Ice Sheet and has a major effect on how the Antarctic Ice Sheet responds to climatic changes. The problem of predicting the current and probable future behavior of the Antarctic Ice Sheet is being investigated with sophisticated numerical models.

Studies are in progress looking at scientific missions which could be conducted by flying scatterometer and ocean color instruments. Science working groups were organized, and they provided requirements and guidance for the design of experiments using these instruments. Engineering work showed that a scatterometer or color scanner could fit on the TIROS series, although the scatterometer would require major modifications of the vehicle. A project will make a detailed design for the color scanner, while a scatterometer group will investigate a more appropriate vehicle.

Sponsor: Office of Space and Terrestrial Applications

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Severe Storms

Meteorological uses of satellite observations have been important to meteorological predictions since the first TIROS satellite was launched over 20 years ago on April 1, 1960. Earlier usage of satellite observations concentrated on larger (synoptic) scale features such as hurricanes and frontal systems identified by their characteristic cloud patterns and the intervening fair weather regions. With the advantage of satellite observations, global observations (previously impractical due to cost of observing over vast ocean and uninhabited regions) became a reality. With the increasing space and time resolution provided by improved instrumentation, use of a wide variety of wavelengths for observing, and development of geosynchronus satellites, even extensive sub-synoptic or mesoscale meteorological observations became practical. Previously, such smaller scale observations were accomplished only at great expense over very limited areas for very limited time periods and were very useful primarily for research purposes. At present, there is an ever increasing interest in studying meteorological observations from satellites, aircraft, balloons, and ground facilities in order to develop a most cost-effective combined observation system to support predictions which are most useful to our society. Severe storms are of primary interest to our society since they present such a great potential for death and property damage. These storms are most frequently a mesoscale occurrence embedded in, and influenced by, a synoptic-scale atmospheric environment. Conversely, the small-scale storm is also often an important influence on this large-scale environment.

One effective means of research in severe storm prediction is carried out by an interactive process of parameter selection (based upon current physical knowledge), observation, analysis, research, and modeling. These processes are carried out concurrently and must be interrelated frequently. If an optimal observing system of useful parameters is applied to a model which optimally incorporates our current physical knowledge, the result should be the best forecast possible, given our present state of knowledge. Goddard research in severe storms is directed toward developing a better physical understanding of severe storm mechanisms in order to improve our storm model observation techniques, and parameter selection. Two powerful tools are routinely used in our research: (1) an interactive computer display facility is available to map, overlay, compare, and otherwise analyze data from a variety of sources; and (2) models uniquely developed to accommodate satellite data and to include mesoscale atmospheric processes, are being developed in order to verify research results, study parameters for observation, and to facilitate inclusion of satellite data into the prediction process.

In our research, satellite data (visible imagery data, IR imagery data, microwave sounding, and stereo observations) are combined in a variety of ways with each other and with non-satellite data to verify and improve our parameter selections, parameter definitions, and related algorithms; and to learn more about mesoscale and cloud-scale atmospheric physics for use in model improvement. Recent significant accomplishments include the first stereo observations of a tropical storm, hurricane Frederic near Mobile, Alabama, on September 12, 1979. These were made at 7.5 minute intervals from 2 geosynchronous satellites using sophisticated triangulation techniques. These observations are used in the preparation of cloud top topography and cloud top growth rate data. The combination of Doppler radar, cloud stereo-height and satellite infrared data have been used to accurately measure cloud top growth rates. Knowledge of these growth rates have been used successfully to monitor intensity changes of convective storms, and to identify storms which have the greatest potential for producing severe weather. Since there are certain difficulties in presently obtaining large quantities of true stereographic, small time-scale data, a technique has been developed to effectively utilize the visible and IR data to produce useful, hightime resolution cloud-top data of a similar nature. Analysis of these cloud top data are providing new knowledge and insights into the structure, morphology, and physics of severe thunderstorms. Such knowledge is being applied to research and/or prediction models of severe thunderstorms. Such analyses are being made over tornado-bearing thunderstorm areas in the midwest, as well as over hurricanes. An example of research findings from these analyses

is that rainfall rate has been found to be related to the cloud top height or cloud top temperature. This provides a possible physical basis for the estimation of convective rainfall amounts by the use of satellite data. Another example is the use of these analyses in the subtropical ocean regions to estimate the tropopause temperature and heights for the inner core of hurricanes. From this information, determination of the storm intensity (maximum wind) and direction of motion can be made. Such hurricane information from satellites can greatly reduce the need for hurricane data observed from aircraft flights into the storms.

The VISSR (Visible and IR Spin Scan Radiometer) Atmospheric Sounder (VAS) which operates from the geosynchronous GOES satellite, has the capability to provide temperature and moisture soundings through the atmosphere with a relatively fine time resolution and a reasonable space resolution. Extensive research efforts are underway to use the VAS for monitoring the pre-thunderstorm environment. The ultimate goal is to determine the optimal space and time resolution of such VAS data, and to use it effectively in predictive models which deal with development of severe storms. Recent results have clearly demonstrated the ability of VAS to measure low-level water vapor, upper-level water vapor and sea surface temperature. The utility of these water vapor measurements for monitoring areas of convective instability, has been demonstrated. These and other results indicate a considerable potential for VAS as an important data source for improvement of conventional forecasts as well as for short term forecasts of severe local storms.

During the past year, there has been improvement in our severe storm models. A sixth order numerical model has been developed and tested within a real-time forecasting environment. This model shows tremendous promise not only in prediction of severe storm outbreaks, but also in use for determining the impact of various kinds of satellite data on accuracy of the severe storm predictions.

In cooperation with the Information Extraction Division at GSFC, a General Meteorological Software Package has been developed for use with the man-computer interactive system mentioned previously (Atmospheric and Oceanographic Information Processing System-AOIPS). This software makes it possible to combine data from a wide variety of sources to use in analyses and diagnostic studies, using the computer facilities in an interactive mode.

A final example of results during the past year are completion of detailed case studies which illustrate the importance of rapid, small-scale changes in upper and lower tropospheric jets in the development of severe winter and summer storms. These study results are now being applied as benchmark data requirements for model initialization and subsequent simulation of these severe storm morphological processes. Results of research using these models and the models themselves will be important in improving our severe storm predictive capabilities.

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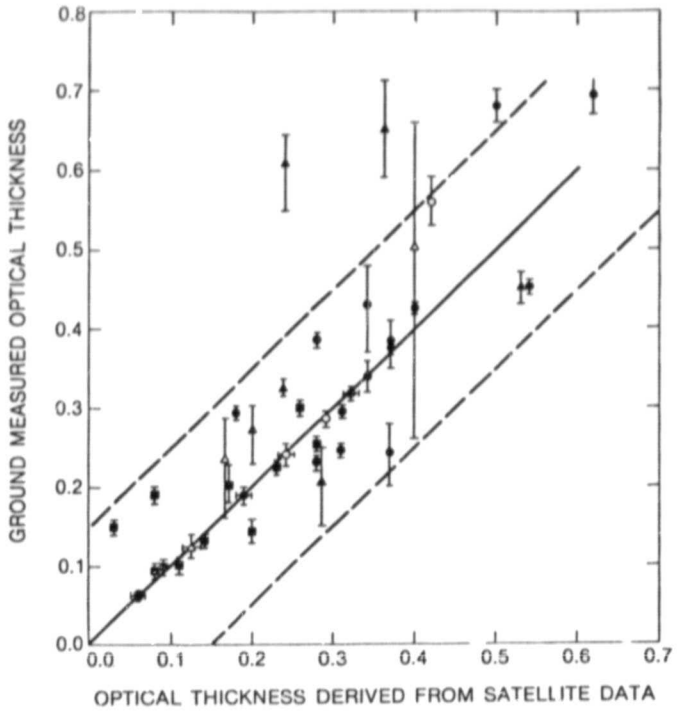
Aerosol Research

Methods are being developed to monitor anthropogenic aerosols with satellite observations. The first observations used for this purpose are made by the Visible Infrared Spin Scan Radiometer (VISSR) mounted on geostationary satellites. The radiance of sunlight scattered from the Earth is measured in a spectral band centered at 0.61 μm.

An algorithm was developed to derive the aerosol optical thickness over land from the VISSR measurements. These values were compared with those derived from solar transmission measurements from the ground at Goddard Space Flight Center, Columbus, Ohio, and Miami.

The aerosol optical thickness measured from the ground showed a strong consistency in its statistical properties. The measurements were made in eight spectral bands within the range 0.44 to 0.87 μm during two summers. The aerosol optical thickness at 0.61 μm was 0.7 during the summer of 1980 and 0.6 for the summer of 1981. The optical thicknesses were separated into these classes: low, medium, and high values. In each class the mean optical thickness equaled a constant times the wavelength raised to a power ($c\lambda^{-1.6}$), which is the same for the three classes. As a result, the size distribution of the aerosol particles for each of the three classes also was given to their diameter raised to a power. This fact is used to simplify the algorithm for deriving optical thickness from satellite measurements of radiance. The optical thickness values for the eight bands were strongly correlated, implying the aerosol optical thickness for



The data given is for a wavelength of 0.61 μm. The vertical bars give the range of surface values within one-half hour before and after OISSR values. The good quality of the Satellite values is indicated by the standard error of estimate of only 0.08.

only a few bands could characterize the values for the entire spectrum of 0.44 to 0.87μm.

The effect of aerosols on satellite observations of the Earth's surface is also being investigated. The character of the surface reflectance from the region outside the area covered by the instantaneous field of view has a significant effect on the spatial resolution of the observations. This effect is called the adjacency effect.

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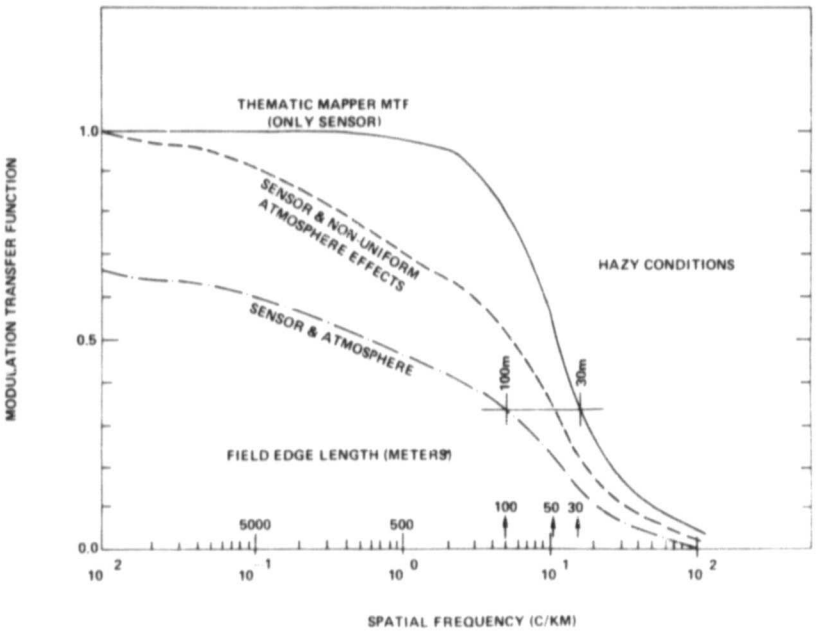
Boundary Layer Studies

Sea surface temperature, water vapor and liquid water content in the atmosphere, and surface wind speed derived from Nimbus-7 Scanning Multichannel Microwave Radiometer data for two 30-day periods (October-November 1978, and February-March 1979) reveal the gross characteristics of the atmospheric boundary layer over the global oceans. In the subtropical subsidence regions of the eastern sectors of the oceans low water vapor (~1 g/cm2), liquid water (~10 mg/cm2), and weak surface winds (<5 m/s) are observed. While in the convectively active western



The figure shows the adjacency effect for one of the visible bands of the Thematic Mapper. The ordinate is the Modulation Transfer Function (MTF), which gives the reduction in amplitude of the radiance of a sinusoidal surface reflection pattern whose spatial frequency is given by the abscissa. The top curve gives the normalized MTF of just the sensor alone. The lowest curve gives the MTF of the sensor and atmosphere combined. The middle curve represents the improvement, if a perfect correction is made for the atmosphere, except that the adjacency effect is ignored. Methods to correct for the adjacency effect have not been developed yet.

sectors of the oceans, where warm ocean currents (e.g., Gulf Stream and Kurashio) are present, excessive amounts of liquid water (~50 mg/cm2), water vapor (3 g/cm2), and strong winds (~10 m/s) are observed. Weak surface winds are also sensed in the equatorial oceanic areas. This satellite-sensed information of the boundary layer over the ocean is extremely valuable to the air-sea interaction studies and studies involving regional and seasonal climatic changes.

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Optical Sensor Research

Significant improvements in the measurement of basic atmospheric parameters are required for improved weather forecasting, the prediction of climate change, and increased understanding of atmospheric processes. GSFC is conducting advanced research on a number of new remote sensing techniques. These include the development of new lidar techniques for the measurement of atmospheric pressure, temperature, density, carbon dioxide, boundary layer, and cloud properties as well as conducting high resolution spectroscopic measurements.

There is a requirement for remote measurements of the atmospheric pressure field and for improved measurements of the atmospheric temperature profile. Although pressure is one of the fundamental atmospheric state variables, there are no current remote sensing techniques for measurement of the pressure field. Thus, important forecasting tools such as maps of surface pressure and 500 mb height contours must be produced either by In Situ measurement or by indirect methods. The development and application of temperature sounding to improve the understanding and forecasting of weather is a major thrust of NOAA and NASA Meteorological Programs. The capabilities of current passive sounders have not been able to meet the required accuracy level of $1^{o}C$, and the development of new techniques, such as lidar sounders using pulsed lasers, is needed.

New lidar techniques for the measurement of atmospheric pressure and density profiles, surface pressure, and temperature profiles have been developed at the Goddard Space Flight Center. Field measurements using continuous wave lasers have demonstrated measurements of surface pressure to accuracies of 1 mb and temperature to accuracies of $0.6^{o}C$. A pulsed laser experiment for measuring vertical profiles of pressure and temperature from ground-based and aircraft platforms has been constructed and initial measurements of atmospheric backscatter have been made using a dual laser system. These measurements are the first time a continuously tunable high energy solid-state laser (Alexandrite) has been used for measuring atmospheric properties. The development of this new technology will allow the extension of these measurements from field experiments to satellite application using compact, efficient, high reliability laser systems.

Theoretical studies supporting this work which have been conducted in FY82 include: A detailed analysis of the lidar temperature method; the development of a new technique for measuring atmospheric density; a comprehensive analysis and solution of the problem of laser finite bandwidth for the lidar measurement; and, initial studies of the effects of inelastic scattering processes on lidar absorption experiments.

The feasibility of lidar measurements of the distribution of atmospheric carbon dioxide has also been investigated and initial laboratory experiments have been successfully conducted. In order to understand how much of the excess CO_2 is recycled by vegetation and by solution in the cold sea surface of polar areas and in regions of upwelling, CO_2 measurements are required diurnally.

The development of airborne lidar for cloud radiation and storm dynamics studies has produced successful results. Over the past several years a lidar system has been deployed on high-altitude aircraft cloud observation missions. The acquired measurements include a wide variety of cloud top structure observations. These data graphically present the height resolved structure of storms in a manner not previously realized and have proven a useful adjunct to In-Situ and other remote sensing observations. Analysis development is in progress to obtain the maximum interpretation of data in terms of cloud particle parameters and to corroborate simultaneous passive remote sensing observations for study of cloud radiation parameterization.

Goddard researchers have also developed a laboratory which has the capability to measure molecular line parameters with a unique, cold optics, 3-meter

focal length grating spectrometer which operates from 1 to 30 μm and also with a tunable diode laser spectrometer. Extensive measurements and analysis of the spectrum of H_2S have been conducted with the tunable diode to gain a better understanding of water vapor. We have also successfully obtained the first spectra from the cold optics instrument. Selected measurements of CO, CH_4, and OCS have been made in both the 2 and 10 μm (1000 cm^{-1}) spectral regions. A resolution better than 0.017 cm^{-1}) has been demonstrated in both regions. This is the highest resolution obtained beyond 5 μm with a grating spectrometer and shows, in part, the signal-to-noise enhancement obtainable with the use of cold optics.

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Microwave Sensor Research

Theoretical investigations performed during the last fiscal year included the mechanisms of radiation from lightning, simulation of precipitation radar systems performance, algorithm development for water vapor profile retrievals, and interferometric synthesis of a large aperture from multiple smaller apertures. In a program to develop rain and water vapor mapping systems, data from the advanced microwave moisture sounder (AMMS), a multifrequency microwave radiometer which has flown on the NASA WB-57 high-altitude aircraft in conjunction with Cooperative Convective Precipitation Experiment (CCOPE) was used to demonstrate water vapor profile retrievals. Similarly, truck-mounted radiometers were used to investigate the microwave properties of snow and of agricultural fields with varying soil moisture and vegetation cover.

Nearly 4 years of data from the Scanning Multichannel Microwave Radiometer (SMMR) are now in hand. Goddard researchers are deeply involved in the effort to extract ocean surface and marine atmospheric parameters from these data. This effort has resulted in sea surface temperature retrievals with better than $1^{o}C$ accuracy.

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FGGE/MONEX Studies

FGGE/MONEX data are used to study short-term planetary scale interaction over the tropics and midlatitudes during FGGE SOP-1 period. The study focuses on the mechanisms leading to the onset of severe monsoon cold air outbreaks over East Asia, and their effects on (i) tropical convection and (ii) downstream synoptic events over the Central North Pacific and (iii) teleconnections between equatorial Central Pacific and North America.

The most significant results of the first phase of the research, which is now near completion, is the discovery of strong midlatitude and tropical coupling over preferred regions downstream of the jet stream over Japan, which significantly impacts on synoptic events over North America. A scenario of the onset and subsequent influence of cold surges involving triggering due to midlatitude wave disturbance and positive feedback from tropical convection is established.

Phase two of this study will be to use Earth radiation budget data from NOAA polar orbiting satellites and FGGE level III B data to investigate both the diagnostics and the energetics of the cold surges and related teleconnection patterns. The satellite data will provide valuable information regarding the distribution of convective heat sources and sinks in the tropics where geopotential and wind analyses are less reliable. The FGGE Level III B data will provide a unique data set with high resolution and extensive global coverage to study the problem of midlatitude-tropical interaction.

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UPPER ATMOSPHERE RESEARCH

GSFC's activities in upper atmosphere research include experimental and theoretical programs devoted to expanding our understanding of the physical, dynamic, and chemical processes which determine the state of the stratosphere and mesosphere. Experimental efforts include the balloon-borne lidar system for measurement of the hydroxyl radical (OH), balloon and rocket in situ measurements of ozone in the troposphere and stratosphere, the Solar Backscatter Ultraviolet Experiment on Nimbus-7 for global monitoring of stratospheric ozone, rocket flights of an ultraviolet spectrometer to measure atmospheric attenuation of the solar irradiance, and the Upper Atmosphere Research Satellites (UARS) project. Theoretical efforts include interpretation of measurements utilizing sophisticated models of photochemistry and radiative transfer and the prediction of future changes in upper atmospheric composition due to anthropogenic effects and solar activity. Theoretical effort is progressing in the study of the coupling among the chemical, radiative, and dynamic processes in the upper atmosphere. One of the goals of this effort will be to gain the ability to evaluate chemical perturbations of the atmosphere with an accurate representation of atmospheric dynamics.

Tropospheric Photochemistry

Research on tropospheric photochemistry at GSFC is directed towards improving our understanding of the relationships between observed trace species concentrations and the physical, chemical, and biological sources and sinks which influence these concentrations. The program consists primarily of the development and use of mathematical modes. Present emphasis is on the use of 1-D and 2-D models to investigate the general features of the global distribution of selected trace species.

Several studies have been completed on various aspects of the oxygen, nitrogen, and carbon budgets of the troposphere. An investigation of the ozone budget using a 1-D zonally, vetically, and annually averaged latitude-dependent model showed that photo-chemical processes were an essential element in explaining the observed latitudinal ozone distribution. A net photo-chemical source of ozone was calculated over the northern latitudes from 25 to 65 degrees where anthropogenic activities are concentrated and a net photochemical sink was found in the tropics. Industrial activity is responsible, in this model study, for the greater concentration of ozone in the Northern Hemisphere.

A study of the carbon monoxide budget concluded that the largest sources of tropospheric CO emissions are located in the tropics. These are, presumably, natural sources and their magnitude was calculated to exceed that of industrial emissions by a factor of three to five.

The implications of natural source distributions for the latitudinal gradients of odd nitrogen in the unpolluted troposphere were studied with a 1-D model. Substantially different distributions of odd nitrogen were calculated depending on whether the source was assumed due to stratospheric injection alone or lightning discharge alone. This model study suggests that characteristic latitudinal gradients should be recognizable in odd nitrogen measurements if either of these sources is dominant, though more measurements would be needed to test this hypothesis.

The effects of intermittent loss of nitric acid due to precipitation events was investigated with a model which considers the effects to photochemistry, raindrop size distribution, and gas to liquid phase transport. The results showed that calculated odd nitrogen concentrations as well as the partitioning of odd nitrogen among components: NO, NO_2, and HNO_3, can differ substantially from the results of equilibrium calculations. Under the conditions simulated: mid-summer, mid-afternoon rain events, HNO_3 concentrations may decrease by about 70 percent in the several minutes after the onset of precipitation. The rapidity and the extent of HNO_3 recovery to pre-rain values depends significantly on the nighttime chemistry of odd nitrogen which is poorly understood at present.

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Stratospheric General Circulation with Chemistry Modeling (SGCCM)

The stratosphere is a complex region in which the solar heating of ozone forces motions that transport minor constituents that are important in the chemical production and loss of ozone (including ozone itself), and these minor constituents interact with each other through a complex set of reactions. This complexity requires large numerical models that are capable of treating these various aspects of the problem in an interactive manner together with extensive analysis of satellite data to check against model results. In addressing these problems, the SGCCM has three principal thrusts:

(1) Development of a gridpoint general circulation model of the troposphere-statosphere-mesosphere system. Testing and debugging of this model including an altered solar and infrared radiation scheme. Initiation of a climatology simulation run (46 levels, 9^{o} latitude by 10^{o} longitude) and a stratospheric forecasting test (27 levels, 4^{o} latitude by 5^{o} longitude) using two versions of this model.

(2) Development of a spectral transform general circulation model of the troposphere-stratosphere-mesosphere system. The computer code has been developed, written, and debugged for the zonally symmetric circulation and for linear eddy motions. Efforts are underway to simulate stratospheric warmings with the full dynamics model.

(3) Analysis of a multiyear stratospheric general circulation data set. Four winter seasons of monthly Northern Hemisphere general circulation data (0-55 km) have been analyzed. Mean zonal winds and eddy transports of heat and momentum plus Eliassen-Palm fluxes have been computed. These results illustrate the differences between monthly circulations averaged over several years and those of a particular year.

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Balloon LIDAR Measurement of Hydroxyl Radical

The hydroxyl radical is one of the most important species in the stratosphere insofar as ozone is concerned. It controls ozone concentration in the upper stratosphere by a direct catalytic destruction process and affects the ozone concentration indirectly in the middle and lower stratosphere by its reactions with chlorine and nitrogen compounds. Despite its key role in the stratospheric ozone problem, hydroxyl has never been measured in the lower and middle stratosphere (15-30 km). The balloon lidar being developed by GSFC scientists seeks to measure hydroxyl by exciting the molecule to fluorescence using laser light. By measuring the intensity of the fluorescence and relating this to the intensity of the laser beam transmitted, the amount of hydroxyl present can be deduced.

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Total Ozone Mapping Spectrometer (TOMS)

The very high quality daily global total ozone maps from the Nimbus 7 TOMS permitted GSFC scientists to identify many features which resemble the patterns found in meteorological charts for the upper troposphere although the ozone sensed by TOMS resides primarily in the stratosphere. The reasons for this enigmatic finding are now becoming clear from several investigations in progress at GSFC. In a real-time experiment with Northwest Airlines meteorologists in 1981, GSFC scientists found that the ozone patterns coincide with pressure troughs and ridges near the tropopause. Furthermore, the tropopause height was found to be highly correlated with total ozone. The high correlation was confirmed by independent GSFC studies of TOMS data over Europe. These studies also showed that the location of steep gradients in total ozone correspond to the jet stream with its characteristics discontinuity in tropopause height. These results are finding applications in several areas. Since TOMS maps appear to be equivalent to upper air charts but with higher resolution, they can be used by operational meteorologists to locate such features as jet streams, cut-off lows and

fronts. Another important application is in temperature retrievals from IR and microwave sounders where the errors are greatly reduced by specifying the tropopause height from the total ozone relationship.

An unrelated, but important, finding from the 1982 real-time TOMS experiment was the observation of a major volcanic eruption, that of El Chichonal in southern Mexico. The stratospheric gas cloud inferred from TOMS measurements was mapped in its entirety and found to consist primarily of SO_2. The cloud was tracked as it drifted with the stratospheric winds. These results permitted GSFC scientists to determine the time of passage over ground stations, and to calculate the total SO_2 volume and its rate of conversion to sulfuric acid.

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Penetration of Ultraviolet Radiation into the Stratosphere

Measurements of the attenuated solar irradiance from balloon platforms in the stratosphere have provided significant information on the absorbing properties of the oxygen molecule. Comparison of the atmospheric data with calculations based on cross sections derived in the laboratory have shown acceptable agreement in the spectral region of the Schumann-Runge bands, 175-200 nm, which is responsible for the dissociation of oxygen molecules in the mesosphere. In the Herzberg continuum of molecular oxygen, 200-240 nm, a substantial discrepancy exists between the observed attenuated solar irradiance and that computed from cross sections that are widely used in photchemical models. Laboratory data in the Herzberg continuum derived by different groups have historically shown a large scatter. The GSFC balloon results support values near or somewhat below the smallest of the laboratory measurements. The reduced cross section implies an increase in the computed solar energy that penetrates into the stratosphere in a spectral region where numerous trace gases, important in the ozone balance, absorb radiation and dissociate.

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Long Term Changes in Stratospheric Ozone

Analysis of global ozone distribution derived from the GSFC's Backscattered Ultraviolet (BUV) instrument on Nimbus 4 and the Solar Backscattered Ultraviolet (SBUV) instrument on Nimbus 7 during the decade of the seventies continues a worldwide decrease of ozone of about 0.5 percent per year in the vicinity of 40 km. This decrease while in reasonable agreement with theoretical predictions for the catalytic destruction of ozone by the release of chloroflurocarbons into the atmosphere by human activities needs confirmation by independent measurement and analyses. During this time period no significant change was found in the total ozone column amount over the globe.

The SBUV instrument on Nimbus 7 has also provided the first direct evidence of stratospheric ozone changes related to changes in ultraviolet solar flux. These short term changes in ozone are in phase with ultraviolet variations in the solar flux. These observations, when combined with recently developed models of ultraviolet solar flux variability, indicate that any continuing ozone decrease in the vicinity of 40 km cannot be the consequence of solar cycle variations in ultraviolet solar flux.

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Ozone Profiles (Balloon)

A balloon-borne instrument, based on the Dasibi ozone monitor, is being developed by GSFC scientists to provide accurate profiles in the troposphere and lower stratosphere. This instrument draws air into a cell and the ozone content is determined from its absorption of the 254 nm emission from a self-contained mercury lamp. The new version under construction at GSFC is better adapted to balloon use in

terms of power and data systems, temperature control, and pressure environment. Particular attention is given to minimizing the loss of ozone to the walls, to the effects of turbulent flow, and to the effects of internal and external temperature variations. Careful simultaneous measurement of air pressure and air temperature enable the observed ozone values to be expressed accurately in either number density versus geomagnetic altitude or in mixing ratio versus pressure altitude. An ozone profile from the Nimbus 7 SBUV instrument, September 6, 1979, near Palestine, Texas, has been compared to the profile from the GSFC Dasibi instrument flown the same day. The SBUV profile between 3 and 40 mbar pressure altitude was 3.6±2.7% lower than the Dasbi profile, well within the combined estimated errors of the two systems.

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Ozone Profiles (Rocket)

To provide the accurate ozone profiles in the stratosphere that are needed in the characterization of data from remote sensors (e.g., SBUV and Dobson) a photometer is ejected from a small rocket at an altitude of about 65 km. As it descends, suspended from a parachute, the photometer measures the absorption by ozone of selected solar ultraviolet emissions as a function of altitude. Since 1963, more than 300 flights have been made from rocket ranges in the United States (including Alaska and Hawaii), Canada, Brazil, Argentina, and Antarctica. The current effort is directed toward upgrading the system in terms of accuracy, precision, and reliability. These improvements involve the photometer (filter stability, reduction of noise), the data processing (up-to-date values of ozone absorption across sections and solar spectra), the systems which provide radar and pressure/temperature profiles, and operational support (improved calibration, preparation, and field procedures). With careful, ongoing attention to all aspects, this system will provide ozone profiles between 25 and 55 km with an absolute accuracy approaching 5% and a reliability of at least 80%.

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Solar Ultraviolet Flux Measurements

Continued concern about the stability of the Earth's ozone layer has increased scientific interest in determining the variability of the Sun as an ultraviolet light source. The wavelength region of interest is 120 to 400 nm where the energy of the solar protons is sufficient to dissociate molecules involved in either the photochemical production or destruction of ozone. To this end, periodic measurements are made of the Sun's intensity using sounding rockets, high altitude balloons, and instruments such as the Scanning Backscattered Ultraviolet Experiment on the Nimbus 7 satellite. Measurements by GSFC scientists are believed to be accurate to ±10%. Improvements to the procedure for calibrating the flight spectrometers at GSFC should lead to an absolute accuracy approaching ±5% and a precision on the order of ±2%.

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Upper Atmosphere Research Satellites (UARS)

There has been increasing concern in recent years about the sensitivity of the atmosphere to external influences associated with natural phenomena and changes arising from the by-products of various human activities. Specific threats to the atmosphere have been postulated in the release of chlorofluoromethanes (freons) in the troposphere and of nitric oxide emitted from high-altitude aircraft. Several current satellite measurements in the stratosphere and mesosphere address some of the chemical processes associated with these concerns, but these measurements generally represent different times and geophysical conditions so that the relationships between them are tenuous at best. The Upper Atmosphere Research Satellite (UARS) project will bring together

as many of the appropriate measurements as possible in the same time frame in a coordinated research program designed to greatly further our understanding of the basic physical and chemical processes that control this vital region of the Earth's environment.

The UARS, to be launched by the Space Shuttle in the fall of 1988, will allow measurements over most of the Earth and in addition will permit studies of local time effects (dawn-dusk, night-day, etc.) in the upper atmosphere. The fall launch, combined with the nominal minimum lifetime of 18 months, will permit measurements over two winters in the Northern Hemisphere, a period of particularly interesting meteorological activity.

Seven of the eleven instruments on the spacecraft perform their measurements by remotely sensing atmospheric radiation parameters, from the ultraviolet to the infrared. These, in turn, will yield altitude profiles of atmospheric temperature, winds, and chemical species of interest. The other four sensors provide a quantitative assessment of the solar spectral energy and magnetospheric energy incident on the atmosphere. To ensure prompt processing and analysis of the scientific data from the UARS program a Science Team has been formed, consisting of the individual scientists responsible for each instrument and 10 theoretical scientists who will participate in the geophysical interpretation of the data. The Science Team members will be aided by a data handling system tailored specifically to their needs, consisting of a central facility to collect and process the data and remote terminals at the scientists' laboratories, complete with mini-computers on which they can perform their own extensive analyses, using all the data obtained.

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PLANETARY ATMOSPHERES

The thrust of the GSFC effort in this area is to investigate the atmospheric and ionospheric properties of Earth and the planets, and to understand the influence of variable solar processes that affect both short-term perturbations and the long-term evolution of these environments. The research includes studies of solar processes in active regions, and the modeling of the radiation emanating from these regions, as well as the analysis of the effects of the energy components contained within the solar wind. Owing to the unique characteristics of each planet, including extreme differences in magnetic field and rotation rates, the study of comparative planetary responses to similar solar variations constitutes the best opportunity for advancing our understanding of solar-terrestrial relationships. Such relationships involving various forms of energy coupling are believed fundamental to achieving a full understanding of the energy balance of the near-Earth environment.

Deuterium on Venus

The identification of the mass 2 constituent in the atmosphere of Venus, being either deuterium or molecular hydrogen, has been an elusive goal for more than a decade. Using the ion measurements they made with their Bennett Ion Mass Spectrometer on the Pioneer Venus orbiter, GSFC scientists recently performed a detailed analysis of the behavior of the mass 2 ion to identify its genus. The study was performed by considering the measured ion height distribution in the region of the ionosphere where chemical equilibrium prevails, because such ion profiles for deuterium and molecular hydrogen are easily distinguishable in this region. This analysis led to the identification of deuterium as the dominant mass 2 ion in the ionosphere. From a chemical analysis involving the observed density of deuterium ions, they determined that the density ratio of neutral deuterium to atomic hydrogen is about 2×10^{-2}, which is about a hundredfold greater than the corresponding ratio in the Earth's atmosphere. The deuterium enrichment at Venus is believed to be due to a substantial loss of hydrogen by atmospheric escape during the lifetime of the atmosphere. In terms of water, the amount of hydrogen lost is equivalent to about 0.3 percent of a terrestrial ocean, suggesting that Venus may have had large oceans.

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Solar Variability and Response of Planetary Atmosphere

The atmospheres of the Earth and other planets depend directly and strongly upon the solar electromagnetic radiation flowing outward from the Sun. GSFC scientists have shown that variations in both the total and spectral radiation reaching the Earth can be accurately modelled. The variations are measured by instruments on the Atmosphere Explorer, Nimbus 7 and the Solar Maximum Mission satellites. They show day-to-day variations in the solar "constant" up to 0.4%, variations in some ultraviolet lines of as much as a factor of two. Models of this variability are leading to a better understanding of solar changes. Secular or long term changes in the solar constant have also been inferred by GSFC scientists through measurements of solar radius changes as deduced from solar eclipse timings. From this, it is known that from 1715 to present, changes in the solar diameter of order 0".5 have occurred. Observations from terrestrial telescopes are subject to atmospheric errors, which are not random and cannot be "averaged out". To overcome this limitation, development of a space platform solar disk telescope has been initiated and is processing. This will provide a new tool to study solar constant changes from space in a more sensitive and noise-free fashion. The solar diameter observations from space will augment the solar constant observations constant and will be less sensitive to active region modulation which gives rise to the day-to-day solar constant variability.

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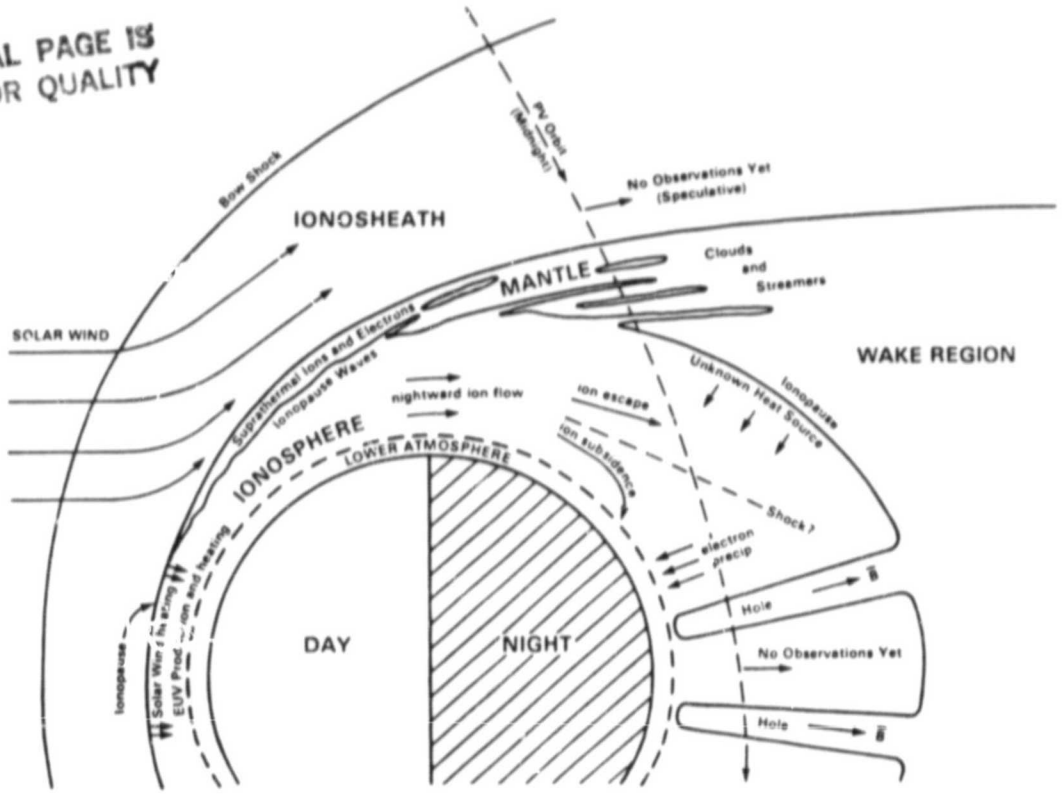
Pioneer Venus Orbiter

Since its injection into Venus orbit in December 1978, the Pioneer Venus Orbiter has been providing in situ measurements of the environment of Venus above 150 km altitude, including the upper atmosphere, ionosphere, ionosheath, bowstock and solar wind. These data, which continue to be acquired, are being employed to explore the nature of the interaction of the solar wind with the atmosphere and ionosphere of Venus. Three of the key instruments, the neutral mass spectrometer, the ion mass spectrometer, and the Langmuir probe, were provided by Principal Investigators from GSFC.

Significant discoveries have been made thus far about the upper atmosphere of Venus and changes induced by solar wind interaction. Solar EUV radiation, falling on the dayside thermosphere, creates an ionosphere which is in photochemical equilibrium near its peak at about 142 km where the major ions are O_2+ and NO+. The upper ionosphere is nearly in diffusive equilibrium much of the time, although ion transport to the nightside and the loss of plasma at the ionopause frequently causes departures from diffusive equilibrium. The major ion above 200 km is O+, except in the predawn sector where H+ has comparable concentrations owing to changes in the neutral gas composition. The ionosphere is heated internally by Solar EUV induced photoelectrons and heated from above by the downward conduction of solar wind energy deposited at the ionopause.

The day to night plasma pressure gradient across the terminator drives a nightward flow to ions, usually at supersonic velocities. Some of these ions subside to contribute to the formation of the nightside ionosphere, and other ions may be convected into the wake by electrodynamic forces. The great variability of the nightside ionosphere is believed to arise from changes in the proportion of the flow which is lost to the wake. Even without the nightward ion flow, a nightside ionosphere would be formed by the precipitation of electrons with energies up to a few hundred eV, although the measured electron fluxes do not appear adequate to constitute the only source of nightside ionization.

Large scale radial holes or plasma depletions extend downward to nearly the peak of ionization in the antisolar region. These holes which occur in north-south pairs, enclose regions of strong radial magnetic field that are believed to originate in the magnetotail of Venus. The holes, or more precisely



This figure illustrates a number of the more significant discoveries that have been made thus far about the upper atmosphere of Venus and changes induced by solar wind interaction.

the radial magnetic fields, act as barriers to the flow of ionization into the antisolar region and may be related to the greatly elevated ion temperatures observed there.

The ionopause itself is a highly dynamic and complex surface which extends from an average altitude of 290 km at the subsolar point to about 1000 km at the terminator. Its altitude varies from 200 to over 3000 km on the nightside, though its height in the antisolar region cannot be measured from the current PV orbit. The increase in ionopause altitude toward the terminator reflects the decline of solar wind pressure with solar zenith angle. The ionopause altitude is highly variable, probably with a time constant of less than an hour. On the dayside these variations are caused by solar wind interactions which continuously remove just enough plasma from the top of the ionosphere to maintain a static balance between the solar wind and ionospheric plasma pressures. Thus the ionopause altitude varies inversely with solar wind pressures. The solar wind pressure is conveyed to the dayside ionosphere primarily by means of an enhanced magnetic field which is approximately parallel to the ionopause surface, although it is possible that some of the solar wind plasma interacts directly with the ionospheric plasma.

Just above the ionopause is the mantle, a transition region between the ionospheric plasma and the flowing shocked solar wind plasma. A variety of solar wind interaction products are observed in the mantle. These include suprathermal ions and electrons, ionospheric photoelectrons, enhanced plasma wave activity, and clouds or streamers of ionospheric plasma that appear to be swept downstream by ionosheath flow. These features are probably signatures of the plasma acceleration processes that form the ionopause and divert the solar wind about Venus, however the specific processes have not been identified.

This mission has provided the first opportunity to conduct an extensive examination of the solar wind interactions with any planet other than the Earth. An important difference between the two planets is the strong intrinsic magnetic field of Earth and the absence of such a field at Venus. The Earth's field diverts the solar wind far above the atmosphere and ionosphere, so there is little direct exchange of energy, except perhaps at times of solar magnetic

disturbance. At Venus, however, the solar wind penetrates the atmosphere and ionosphere and continuously removes plasma and neutral atmospheric gases through acceleration and charge exchange processes. This escape of material from Venus operating over geological time may have played a significant role in the evolution of the atmosphere to the state in which we see it today and in the loss of its oceans.

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Venus Climate Studies

Analysis of data returned by the Goddard Institute for Space Studies (GISS) cloud photopolarimeter onboard the Pioneer Venus Orbiter is establishing an improved characterization of important aspects of the climate in the cloudtop region of the Venus atmosphere. Measurements of the detailed geometric dependence of the intensity and polarization of sunlight scattered by the clouds at four different wavelengths permit the determination of aerosol physical properties and information on vertical structure. In addition to an extensive, 20 km thick main cloud of ~1 μm-radius concentrated sulfuric acid droplets which had been deduced from previous ground-based data, we have found a submicron-sized haze mixed with and extending above the main cloud. The haze, which may also be composed of sulfuric acid droplets, has been observed to increase or decrease in thickness by as much as an order of magnitude over a few weeks, in addition to exhibiting a long-term decrease over the Pioneer Venus Mission to date. Since nearly half of the solar radiation not reflected by Venus is absorbed in the upper cloud and haze region, characterization of the haze production and its interaction with the main cloud is important for obtaining improved understanding of cloud/radiation feedbacks.

By tracking the motion of cloud features in near-ultraviolet images obtained with the cloud photopolarimeter, we are also able to characterize the general circulation patterns for the cloudtop region. The mean circulation is dominated by strong zonal winds of order 100 m/s in the equatorial region and a latitudinal profile approximately corresponding to constant angular velocity. Meridional winds are an order of magnitude smaller and exhibit an equator-to-pole circulation probably corresponding to the top branch of a Hadley cell. There are, however, significant temporal variations in the mean circulation; perhaps most notable is the occasional appearance of a "jet," or region of relatively higher zonal velocities, in the midlatitudes. Information on the nature of the build-up and dissipation of such jets may provide insight regarding the mechanism which maintains the extremely strong zonal circulation.

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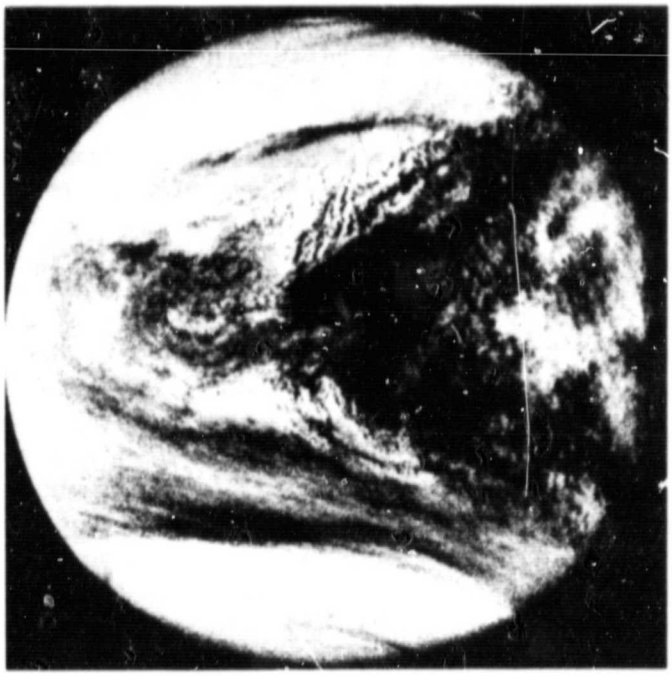

Image of Venus ultraviolet wavelengths taken by the photopolarimeter/imager on the Pioneer Venus orbiter spacecraft. Image has bright polar clouds caused by a thick layer of haze particle and small scale convective features at low latitudes.

EARTH SCIENCE AND APPLICATIONS

This program involves basic and applied research which focuses on improving our understanding of the features and dynamical processes occurring within the Earth and on or near the Earth's surface, and on improving our ability to better manage the resources of the Earth. The research is conducted with emphasis on the use and evaluation of remote sensing and space-technology in particular. The research includes the development of models that make use of the inherent synoptic, high spatial density and repetitive coverage attributes of satellite remotely sensed data to represent the dynamics and interactions of physical systems near, on, or within the Earth. Independent analyses of various forms of remotely sensed data provide quantitative evidence to corroborate the models or to identify where the models need to be extended and improved in order to more accurately describe how the observed processes occur and evolve.

Supporting these efforts are fundamental research efforts to improve our ability to quantitatively interpret remotely sensed observations and improve remote sensing techniques applicable to Earth science studies. Research efforts in the past year covered a wide spectrum of disciplines including geodynamics, geophysics, and hydrology and geology of the Earth, and associated sensor developments. Also studied were agriculture, forestry, water resources, land cover management and monitoring.

Geodynamics

A new gravity model GEM-L2 has been derived as part of the analysis of orbital data provided by NASA's Crustal Dynamic Project. GEM-L2 relies heavily on precise laser ranging data from the Lageos satellite. Two and a half years of laser tracking data from Lageos, acquired from over 20 globally distributed laser ranging tracking stations were combined with the existing tracking data from 30 other satellites which had been utilized in the previous best satellite-derived model for geopotential, GEM-9, to develop the new Lageos model. This solution, complete in spherical harmonics through degree and order 20 was derived from well over 600,000 laser range measurements, more than half of which were taken from Lageos. Lageos' unique contribution toward the resolution of the long wavelength geopotential has resulted in a two-fold improvement in our knowledge of terms through degree and order 4 over the GEM-9. The geoid for these terms has an accuracy estimated at ±8.1 cm in GEM-L2, as compared to ±15.9 cm in GEM-9. This significant improvement of the long wavelength geoid contributes to an increased understanding of long wavelength features such as sea slope across broad ocean basins. A comparison of global station-to-station distance baselines from independent sets of alternating 15-day orbit segments of Lageos data show total interstation positioning to an accuracy of ±1.6 cm in baselines, a greater than three-fold improvement over the GEM-9 solution of ±6 cm. These accuracy results for the station positioning in particular confirm the utility and inter-plate deformations. Such accuracies in inter-station positioning have never been achieved by any previously existing models developed by the national or international research community.

Laser tracking data covering a 6 year period (1975-1980) have been analyzed for the development of a specialized Earth gravity model for the French laser target satellite "Starlette." RMS fits for GSFC laser data used in 5-day orbital arcs have been improved from the level of several meters to a few decimeters. A detailed analysis of the Starlette data recorded during 1980 has been performed for the estimation of tracking station coordinates and ocean tidal constituents. This solution is a simultaneous least squares solution based upon normal equations for multiple 5-day arcs of laser tracking data. Comparisons between the station coordinate values derived from Starlette with those from independent Lageos solutions indicate an rms agreement of about 20 cm. The recovered values for the K_1, O_1, K_2, M_2, and S_2 ocean tidal constituents are in good agreement with the Schwidersky values and with values from previous work based upon analysis of the long period evolution of the orbit for the recovery of the tidal parameters. With these geodetic model improvements, the Starlette laser data provides a strong complement to the Lageos data for Crustal Dynamics investigations.

The geographic variability of short wavelength geoid power spectra (geoid roughness), has been mapped for the world's oceans between latitudes 72^{o}N and 72^{o}S. A spectral analysis of Seasat altimeter data, reduced to sea surface heights, has been performed at 2 minute intervals for 15 consecutive days of the 3-day repeat orbit. The geoid roughness represented by these spectra for wavelengths shorter than about 220 km is separated from the total sea

height variance and is displayed in the form of a global contour map. The global average geoid roughness is 32 cm rms, varying from a low in the southeast Pacific near the East Pacific Rise. This average value agrees well with previous estimates based on gravimetry and GEOS-3 altimetry. In general, the smoothest areas in the marine geoid overlie relatively young seafloor adjacent mid-ocean spreading centers, where even short-wavelength topographic variations tend to be isostatically compensated.

A multilayer half-space model of the Earth has been used in finite element calculations of time dependent deformation and stress following an earthquake on an infinitely long strike slip fault. The model involves shear properties of an elastic upper lithosphere, a standard viscoelastic linear solid lower lithosphere, a Maxwell viscoelastic asthenosphere, and an elastic mesosphere. Time dependent displacements, strains, and stresses are computed both at the surface of the Earth and at depth. The analysis includes both systematic variations of fault and layer depths and comparisons with simpler elastic lithosphere over viscoelastic asthenosphere calculations. For conditions which may be appropriate for the Earth, the creep of both the lower lithosphere and the asthenosphere can contribute to the postseismic deformation. The magnitude of the deformation is enhanced by a short distance between the bottom of the fault (slip zone) and the top of the creep layer but is less sensitive to the thickness of the creeping layer. Furthermore postseismic restressing is increased as the lower lithosphere becomes more viscoelastic, but the tendency for the width of the restressed zone to grow with time is retarded.

The free oscillation of the Earth is usually considered as a linear combination of an infinite number of normal modes. Traditionally, the investigation of the Earth's free oscillations has mainly been concerned with seismic modes but with little regard to the rigid-body motions. Studies of the rigid-body motions for both non-rotating and rotating Earth models show that there are only six rigid-body modes (corresponding to six degrees of freedom), three of which are characterized by a translational motion and three by a rotational motion. Analyses which are in progress show how the six rigid-body models can be excited and how the excitation formulae for each rigid-body mode can be obtained. In particular, it is shown that the free precession of the Earth, known as the Chandler wobble which is of great astronomical and geophysical interest, is indeed a rigid-body rotational mode belonging to a rotating Earth model; and therefore can be studied using the established theory of normal mode.

Interest in improved knowledge of the Earth's gravity field for studies of processes taking place within the Earth has prompted the development of a gravity field mapping mission. The mission, consisting of two spacecraft in similar orbits at 160 km altitude and separated by a few hundred kilometers, senses the anomalies in the Earth's gravity field by the induced variations in the distance between spacecraft. Precise measurement of the range rate between the two spacecraft enables the gravity field to be derived. It is planned that the two spacecraft will remain in orbit for about 6 months and be "drag-free" --a system that compensates for the action of air drag on the satellite, thereby maintaining the spacecraft at its designed altitude of about 160 km. This mission, Geopotential Research Mission, will map the Earth's gravity field to an accuracy of about 1 milligal (about 1 part in 10^6) with a resolution of approximately 100 km, globally; representing an improvement of about two orders of magnitude over our present knowledge. The primary reasons for requiring this improvement in our knowledge of the Earth's gravity field are to answer many important geophysical questions relating to the formation of continents and basins, form and scale of convection in the mantle, and the processes that are taking place along the boundaries of the tectonic plates that cover the surface of the Earth. In addition, the gravity field provides the level surface, or geoid that represents the mean level of the ocean in the absence of winds and currents and is an important reference surface in studies of ocean circulation.

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Geophysics, Geobotany and Geology

The first major publication of results from the Magsat mission occurred in the April 1982 issue of Geophysical Research Letters. In all, 36 papers were published, including one which contained a description of the mission and an overall summary of results. Other papers presented data analysis techniques,

magnetic anomaly maps and charts, core and external fields results and interpretation of crustal anomalies. GSFC personnel authored or co-authored ten of the papers, including one which presented both scalar and vector crustal anomaly maps. The vector maps are particularly interesting, as they were generated from the first global data of this type ever collected.

Separation of the core and crustal contributions to the Earth's magnetic field is an important problem. Recent study has shown that, for the Magsat satellite data, the core field dominates a spherical harmonic representation of the magnetic field for degree and order less that 14, while above degree and order 14 crustal sources dominate. It is this separation that allows production of the crustal anomaly maps.

Studies of the global distribution of magnetic anomalies have revealed some consistent trends: many Precambrian shield and platforms, most submarine plateaus and some subduction zones are characterized by positive magnetic anomalies. Deep ocean basins and many failed rifts where volcanism was scarce have negative anomalies overlying them. In Asia there is very good correlation between the distribution of magnetic anomalies and major tectonic blocks: large rifts, sutures and foldbelts and age province boundaries often separate both blocks and anomalies. In this same area regions of thinned crusts are generally characterized by negative anomalies, while positive anomalies overlie thick crustal blocks like the Anabar and Aldan shields.

Continuing studies of the relationship between satellite magnetic anomaly data and continental rifts reveals the following generalizations: young active rifts generally show relative magnetic lows, regardless of whether the rift is "wet" or "dry" in terms of volcanic activity. This is due to the extensive crustal thinning and high heat flow associated with young rifts. Older failed rifts may be characterized by either magnetic highs or lows. Positive anomalies, like that over the Oslo Graben, occur where magmatic activity has concentrated high magnetic susceptibility material in the rift close to or at the surface. Negative anomalies are often found near "dry" failed rifts where the depressed crust is overlain by extensive sedimentary cover.

A map of Asia showing the distribution of magnetic anomalies and major tectonic blocks.

Modeling of individual magnetic anomalies has shown that the Alpha Ridge, over which lies the strongest positive anomaly in the Artic region, is probably continental in nature. Using constraints on the thickness, the satellite anomaly is best matched by using magnetic susceptibility characteristics of intermediate continental crust rather than oceanic crust. By contrast, the nearby Mendeleyev Ridge appears to be relatively nonmagnetic, implying a very different nature for this feature. The so-called Kentucky anomaly has been modeled as a large mafic peralkaline intrusive which must occupy much of the crustal layer. Combined gravity and magnetic data have been used to infer a magnetization of 4 A/m and a density of 3 gm/cm3 for a body roughly 200 km long, 70 km wide and 35 km thick. The setting for the intrusive seems to be a failed rift of Precambrian age, which may be similar to the Central North American Rift System.

Laboratory studies of Curie points and magnetization values of lower crustal rocks were conducted for samples from three distinct tectonic settings: convergment plate margins, rift valleys and continental plate interiors. Magnetization values for ultrabasic rocks from the deep crust are similar to values inferred from satellite anomaly modeling studies. In the United States, where the thickness of the lower crustal layer is reasonably well known, it is possible to account for some of the variation in the satellite anomaly pattern by variation in the lower crustal layer thickness. The magnetization values obtained by requiring the anomaly source to be confined to only the lower crustal layer are quite consistent with the above mentioned laboratory experiments. However, some of the strong anomalies (like that over the Colorado Plateau) are probably due to lateral variations in both magnetization and thickness of the layer.

A number of factors control the magnetization of rocks and hence control the determination of the magnetization from anomalv studies. These factors include the abundance and oxidation state of iron, the abundance of sulfur and titanium, the ratio of induced to-remanent magnetization, and the temperature, pressure, and oxygen fugacity during and subsequent to formation of the rocks. Using reasonable values for these factors in a model of the New Madrid Fault Zone, it was found that the observed anomaly is significantly smaller than might be expected. More detailed knowledge of the local heat flow and geothermal gradient is required to investigate this discrepancy, as high heat flow may cause the Curie isotherm to be above the magnetic crustal layer in this region.

Geobotanical field studies continue using two pairs of mineralized and non-mineralized test sites in the sulfide district near Mineral, VA. New data confirms previous conclusions that the reflectance in spectral bands 0.63-0.69 and 1.55-1.75 μm (which correspond to bands 3 and 5 on the Landsat-4 Thematic Mapper) is higher for vegetation growing in mineralized soil. The optimum observation time for recording this higher reflectance is just prior to senescence. A companion experiment showed that recovery of dormant vegetation after winter first occurred over the non-mineralized areas, as recorded by color infrared photography. There now appears to be a 2-3 week spring time window as well as a fall window for detection of mineralization through vegetation spectral reflectance. A "blind" experiment will be performed in 1982 at a site for which the mineralization of the soil is not known a priori. This experiment will simulate the exploration procedure and allow determination of error sources in the adopted techniques.

A comparison of morphometric parameters of 2000 volcanic cones on Mars with diameters less than 1 km with small terrestrial volcanoes has been completed. Measurements of base diameter and central pit diameter were made, as well as spatial density. The small cones appear to be of one genetic type, and appear to be somewhat larger and more widely distributed when found on fractured as compared with smooth plains. Comparison of the Martian cones with terrestrial volcanic features suggests that Icelandic pseudocraters--formed where lava comes into contact with water or water-saturated ground--may be the best terrestrial analog of the subkilometer martian volcanoes. On Mars the likely mechanism is lava-ice contact, and the location of the cones may be a clue to the past distribution of surface or near-surface ice on Mars.

A major new photogeologic study was begun under support of the Director's Discretionary Fund. Landsat imagery of large parts of the Canadian Shield is being studied for lineament mapping to determine whether or not preferred directions exist in the concentration of major linear structures. When compared with other major shield regions it should be possible to determine whether or not a "global regmatic shear pattern" does indeed exist, as has been suggested.

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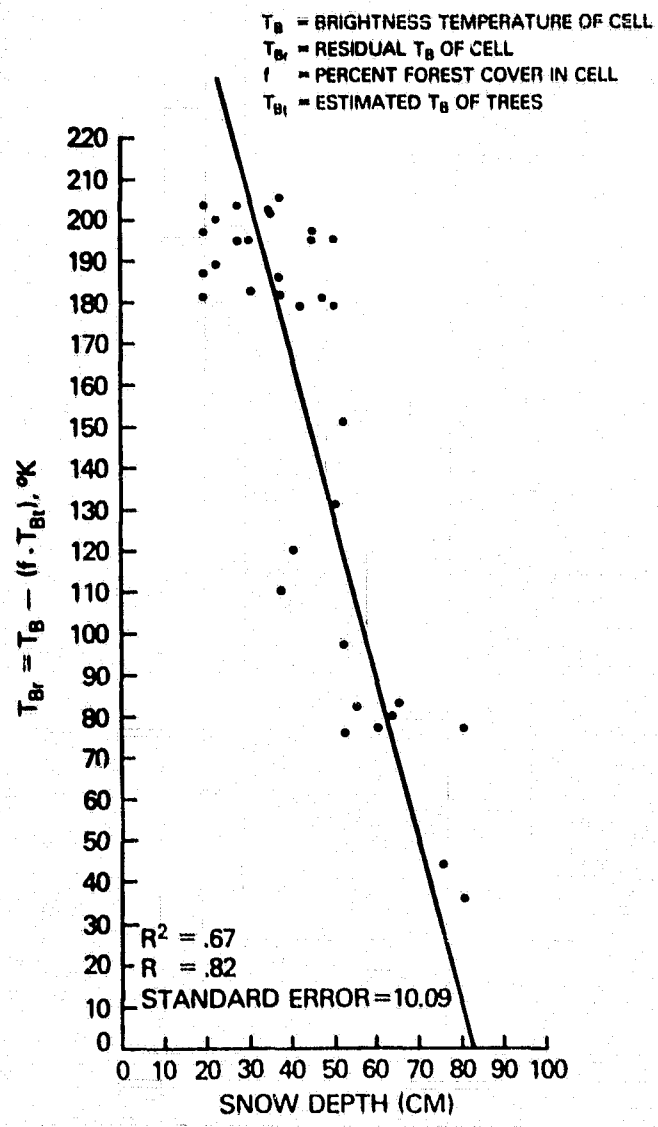
Hydrology

The thrust of research in hydrology is to develop techniques for using remote sensing to monitor hydrologically important variables and processes. Thus, ongoing projects focus on measuring snowpack properties, such as the amount, location, and wetness of snow, monitoring soil moisture, characterizing watersheds and flood plains, and studying permafrost-related features and processes. These projects blend field work with theoretical and numerical modelling to identify and understand the electromagnetic signature of the hydrological variables and processes at all wavelengths practical for satellite remote sensing -- microwave, thermal infrared, near infrared, and visible. Much work emphasizes microwave sensors, because they are useful in all weather conditions, which is a distinct advantage for hydrological applications.

As part of an ongoing program to develop techniques for measuring hydrologically important snowpack properties remotely, field experiments were conducted in Northern Vermont and the Great Plains. These studies used truck-mounted or airborne microwave radiometers operating at frequencies from 6 to 37 GHz (wavelengths from 5 to 0.8 cm). Results indicate that microwave emission measurements are useful for distinguishing between melting and dry snowpacks (due to the different dielectric properties of ice and liquid water) and for estimating the amount of snow present. The new data confirm and expand on results obtained from radiative transfer modeling and from similar experiments performed in the Colorado Rocky Mountains during previous winters. The Vermont field data reveal that the presence, spacing and thickness of ice layers strongly modulate the microwave signature of snowpacks.

In other snow research, GSFC investigators developed a simple model to remove the effects of forest cover from Nimbus 7 SMMR data. This advance makes it feasible to use microwave remote sensing techniques to measure snow cover in heterogeneous and forested areas (previous studies have been limited to large uniform regions like the Northern Great Plains). The best correlations between microwave response and snow depth were obtained at the SMMR frequency of 37 GHz; lower frequencies showed increased effects of the underlying soil moisture. SMMR data are also being used in a time series to follow seasonal changes in the snowpack in a key agricultural belt of the Northern Great Plains. One advantage of this approach is that ambiguities in interpreting the microwave data in terms of snowpack properties on a given day may be resolved by looking at the data as a time series.

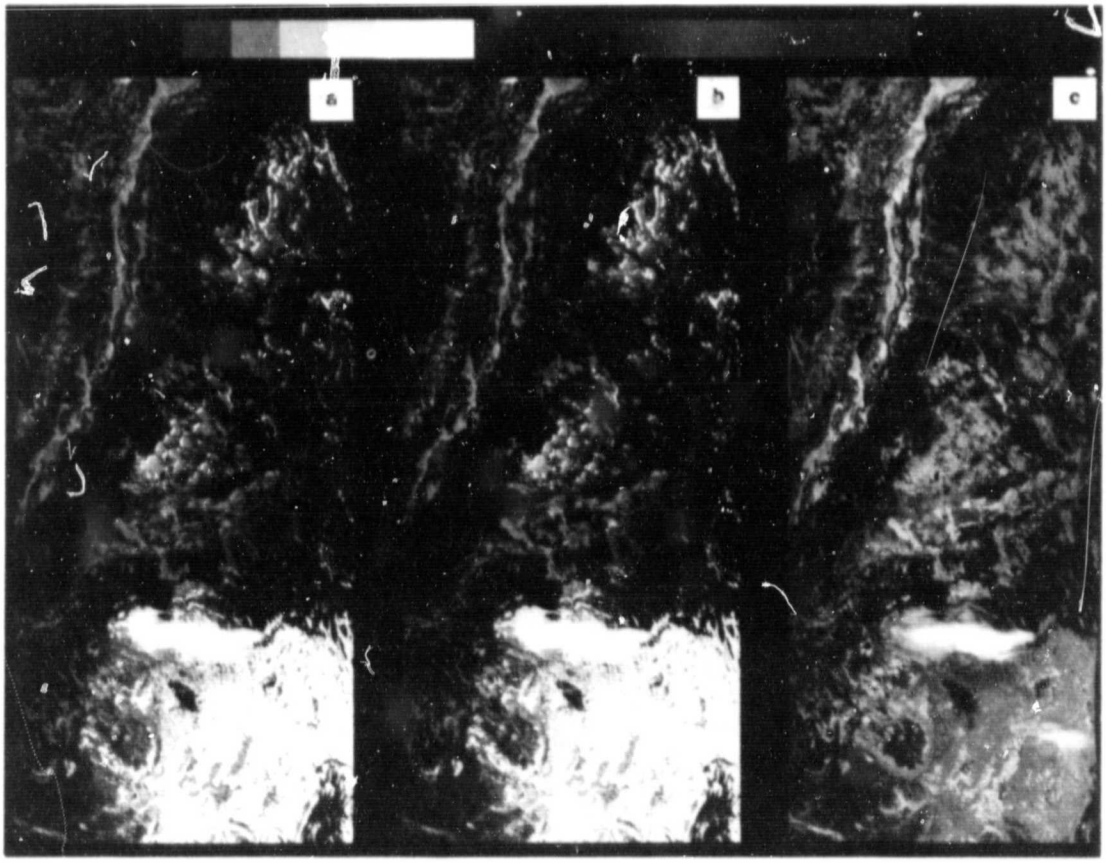


The relationship between snow depth and SMMR brightness temperature for a forested area in Michigan, with the effect of forest cover removed.

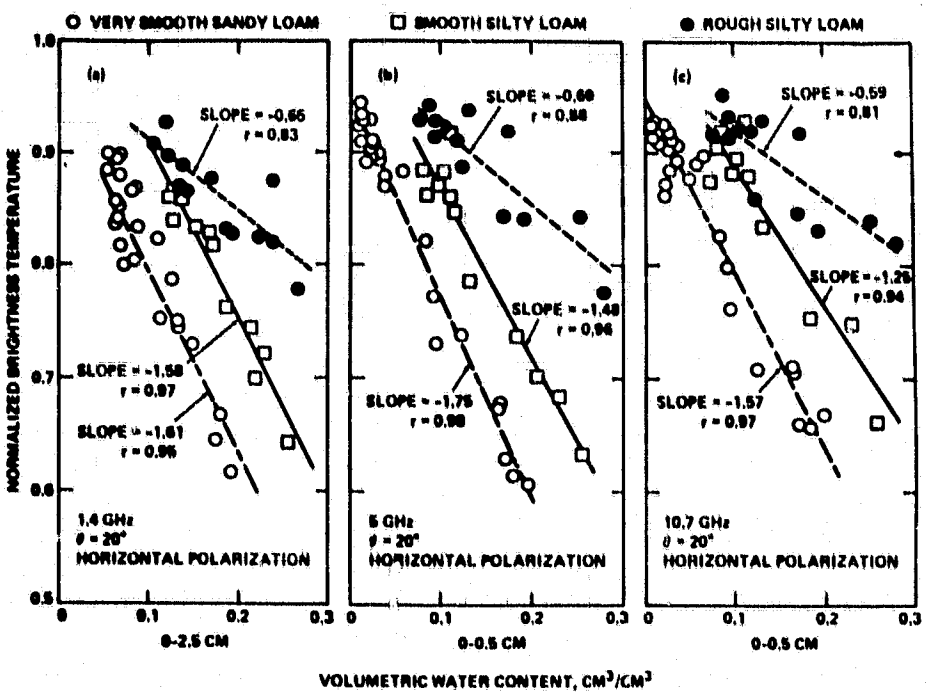
Studies of visible/infrared satellite images of mountain basins demonstrate that large variations in snow accumulation in different years cannot be detected solely from measurements of snow-covered area. To provide a means for forecasting runoff using a snowmelt runoff model, depletion curves that normally relate the areal extent of snow cover to elapsed time were successfully modified to relate snow coverage to accumulated degree-days using the South Fork basin of the Rio Grande River as an example. At the same time, data from the TM's new infrared band (1.55-1.75 μm) proved far superior to Landsat MSS data for distinguishing clouds and bare rock outcrops from snow in a given scene. This demonstrated ability of the new TM data channel to improve separation of clouds and snow will greatly increase the usefulness and accuracy of satellite images for snow cover mapping.

An important meteorological variable in many hydrological processes, such as snowmelt and evapotranspiration, is the incident solar energy (insolation). A simple and efficient physically based model of insolation under partially cloudy skies was developed to include the effects of multiple reflection between the surface and the overlying atmosphere. As compared to exact radiative transfer results, errors in calculated insolation are generally less than 1% and in calculated albedo are less than 10%. This simple insolation model can be extrapolated to a wide range of conditions, thus providing an efficient and cost-effective means of simulating observations.

Recent investigations have studied the utility of a variety of remote sensors to detect near-surface soil-moisture content. An ongoing soil moisture experiment conducted with USDA is examining the response of truck-mounted radiometers at low frequen-



TMS data showing improved separation of clouds and snowcover, Figure (a) simulates the Landsat MSS false color response while (b) is a natural color composite; (c) shows the TM response using the green, red, and new 1.55-1.75 μm bands.



Variations of normalized microwave T_B as a function of volumetric soil moisture for soils of different texture and roughness.

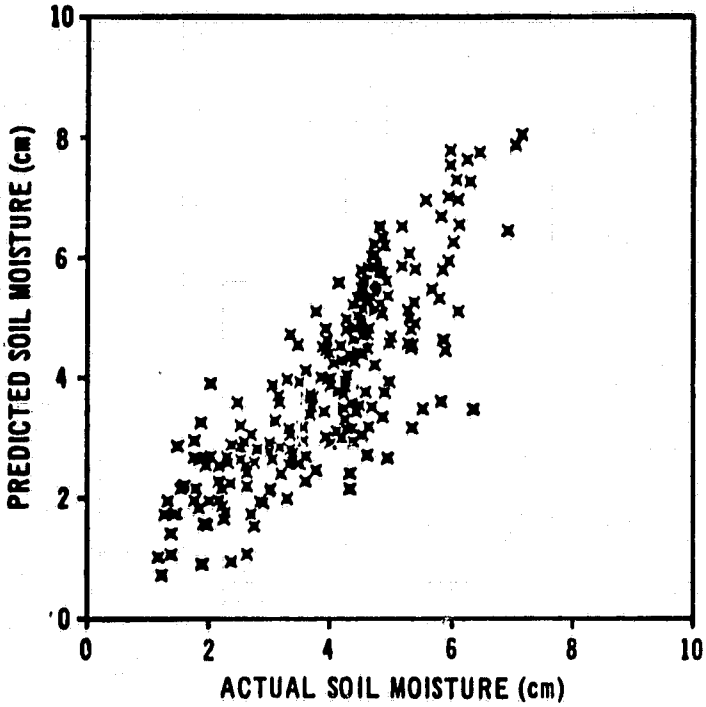
cies (0,6 to 4,99 GHz) to soil moisture under diverse conditions of vegetation cover and surface roughness. Experimental results show that the effects of surface roughness and vegetation are to increase the observed microwave emission and to decrease the microwave sensitivity to soil moisture content. To account for the roughness effect, a simple two-factor parameterization of surface roughness was added to the GSFC radiative transfer model. With this modification, the calculated microwave emissions derived from the model closely fit the observed data. Work continues to determine the impact of vegetation biomass versus plant structure and canopy geometry on the microwave response. In addition a study has been initiated to develop techniques to use time series passive microwave measurements to estimate hydraulic properties of soils. The ability to interpret and understand these effects will greatly increase the utility of microwave remote sensing for soil moisture estimation.

Examination of thermal infrared and multifrequency microwave data obtained during 3 years of aircraft experiments has verified that vegetation decreases the microwave sensitivity to soil moisture. Moreover, the sensor response to variations in surface soil moisture over targets of the same ground cover is similar in different climatic regions. Analysis indicates that the basic cause and effect relationship between the sensor measurements and soil moisture can be successfully extrapolated from theory and small scale ground-based tests to the larger resolution elements observed by aircraft instruments.

Based on multispectral data from different aircraft overflights in the Southern Great Plains, investigators have selected the 1.4 GHz microwave radiometer as the best single sensor with all-weather capabilities for estimating soil moisture. To overcome the problems associated with measuring soil moisture through vegetation, visible/infrared data were combined to produce biomass indicators, which were then used along with crop classification information to interpret the microwave data over vegetated fields. Results showed that a simple biomass indicator, the perpendicular vegetation index (PVI), could be used in linear combination with the 1.4 GHz microwave data to provide an accurate estimate of soil moisture in bare and vegetated fields.

Large-area soil-moisture measurements are needed to define the antecedent moisture condition of watershed surfaces prior to flood-producing storms and to provide objective input to a variety of hydrological and agricultural models. A recent project examined the relationship between measurements by passive microwave sensors in space and estimates of regional soil moisture in the form of an antecedent precipitation index (API) derived from surface measurements of rainfall.

NIMBUS-ESMR satellite data matched quite closely with API estimates of soil moisture. The study concluded that API algorithms can successfully



Comparison of predicted soil moisture for test grassland watersheds with measured soil moisture in the top 23 cm of the soil (assuming 3-day measurements are available). Predictions of soil moisture are based on API equations derived from ESMR satellite data.

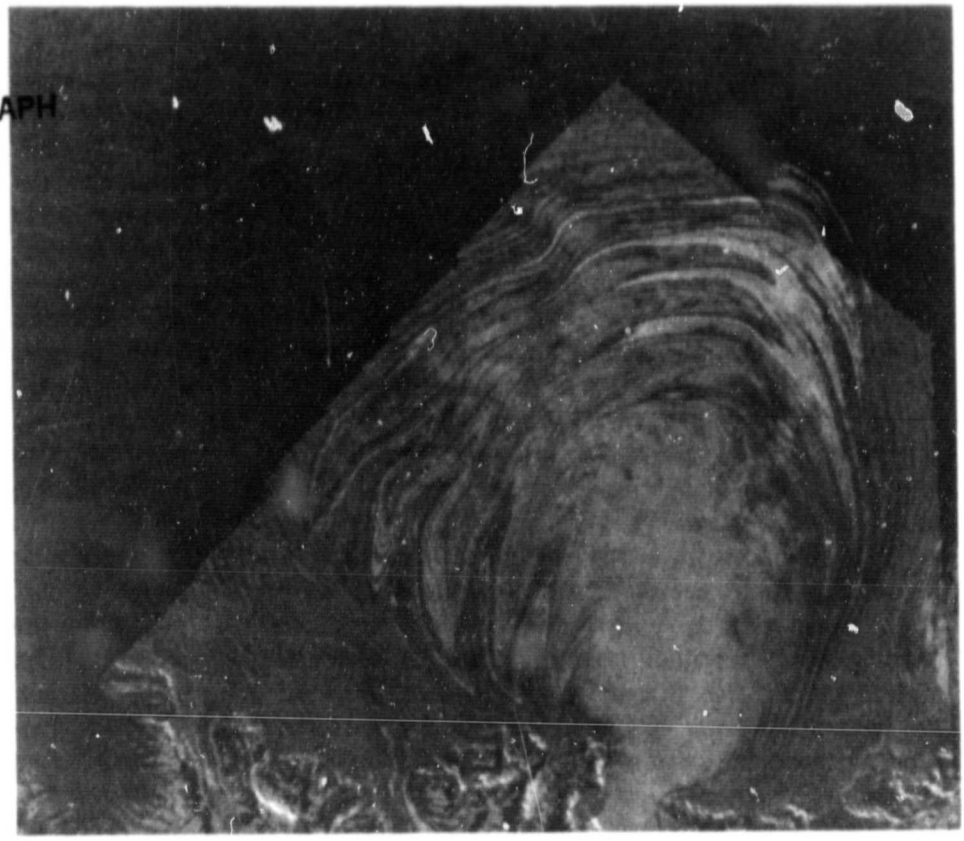
convert data from microwave radiometers to an estimate of soil moisture in relatively smooth terrain at a depth greater than the microwave system can sense, as long as repeat observations every 3 days or less are available. This result has important implications for meteorology as well as hydrology, since the moisture of the soil is a major consideration in general circulation models (GCMs) of the atmospheres. Soil moisture controls the heat/moisture exchange at the surface/air interface. Since GSFC scientists derived the API equations from the prognostic equation for soil moisture in the GCM, there is a formal basis to the API method.

A model of the energy and moisture fluxes in the soil and atmospheric boundary layer has been developed for use with remote sensing data. The model may be used to estimate evapotranspiration and soil moisture on a large-scale basis. It has been validated using data from Arizona and West Germany, and model agreement with independent estimates of evaporation and soil moisture has usually been within 1-2%.

Various types of remotely-sensed data have been applied to studies of permafrost related features and processes in Alaska. Synthetic aperture radar (SAR) and Landsat data can be merged to determine the relative depth of northern Alaskan thaw lakes. Furthermore, lakes frozen to their beds can be distinguished from lakes with just a surface ice layer. Summer melting, while dissipating the ice, can be monitored using Landsat data. Landsat data have also been used to study the distribution and variability of aufeis in North Slope streams, and to study ice break-up and spring flooding. Landsat/Seasat SAR combination prove useful in studying glacial terrain, while short-pulse radar data have been utilized experimentally to examine subsurface permafrost features. An energy-balance approach uses Heat Capacity Mapping Mission (HCMM) data to determine evapotranspiration after snowmelt over large, remote areas in the Alaskan sub-Artic, and to monitor tundra fires and subsequent recovery. As indicated by the variety of these studies, the use of remotely sensed data has substantially increased our understanding of dynamic hydrological processes operating in Artic land areas.

A pilot project with the U.S. Army Corps of Engineers Districts at Rock Island, Illinois and St. Louis, Missouri, demonstrated the potential value of MSS data for resource description, floodplain vegetation trends and dredge disposal siting. Current studies with the Detroit District in Michigan and Savannah District in Georgia compare MSS data with airborne Thematic Mapper Simulator (TMS) data for floodplain management and damage assessment. Preliminary results indicate a significant improvement in land cover classification accuracy with TMS data.

An eventual goal of much of the remote sensing work in hydrology is to provide information that permits more efficient functioning of hydrological and agricultural models. However, none of the existing models can make efficient and effective use of the remote sensing capabilities for area-wide repetitive measurements. To provide an adequate test of these capabilities, NASA and USDA have established a task force for the development of remote sensing compatible hydrological models at the University of Maryland. This cooperative project which will continue until the mid-1980s, involves developing and testing hydrological models designed to incorporate the current and anticipated capabilities of remote sensing technology.



Landsat image registered with Seasat SAR image of the Malaspina Glacier in Alaska showing detail of the crevasse and medial moraine patterns.

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Earth Observation Sensors (VIS/IR)

Sensors now operating on the Landsat Satellites use the combined effect of satellite orbital motion and oscillating mirrors to scan the earth through a telescope. The output of the telescope is coupled to small arrays of detectors to create high resolution images of the earth. Although this technique has produced high quality results with the MSS and Thematic Mapper sensors, further improvement in performance is limited because increased sensitivity is not easily attainable.

A new type of sensor now under study overcomes this problem by using linear arrays of several thousand detectors which view the earth through a telescope and use the forward motion of the spacecraft to scan the scene. A precision oscillating scan mirror is not required. This approach also provides a significant improvement in system sensitivity because each of the detectors in the large array is exposed to elements in the scene for relatively long intervals of time.

Imaging radiometers using this technology are also termed Multispectral Linear Array (MLA) sensors. Several elements of advanced technology that are critical to the future flight of such sensors are under development. The state of microelectronic technology has reached a point where linear detector arrays are considered practical for use in space sensors. Technology advances have also made possible the placement of microelectronic multiplexers adjacent to the array, on the focal plane for purpose of signal processing.

Several programs are under way to develop monolithic (i.e., all silicon) detector/multiplexer/preamplifier linear arrays in modules containing from 250 to 1,000 detectors. These modules may be butted to form arrays of any length desired. The detectors may be as small as 15 micrometers square. Parallel thrusts are directed toward developing specialized arrays for use in three wavelength regions. The visible (0.4 to 0.8 micrometers) and near IR (0.8 to 1.2 micrometer) spectral bands are covered to multiple arrays on one chip. The short wave infrared (1.2 to 2.5 micrometer) band requires separate development because of the

special detector technology required. The approaches being investigated include hybrid devices made up of mercury-cadmium-telleride detector arrays mated to silicon chip multiplexers and palladium-silicide Schottky Banier detectors.

Recently, a versatile four-band MLA airborne sensor was completed and engineering test flights are being conducted. This sensor has four linear arrays of 512 detector elements and measures reflected solar radiant energy through one of six spectral filters available to each array. The four spectral channels each view a 42.5° swath and, via the motion of the aircraft, from multispectral images of the Earth's surface. Data obtained are used to develop new remote sensing algorithms for monitoring Earth resources from space.

Other related work is also underway. The feasibility of depositing spectral filters onto linear detector arrays separated by only a few microns has been examined; a conceptual design of a beam splitter that divides radiant flux into six spatially separated spectral beams has been generated; designs for a passive radiative cooler capable of maintaining tens of thousands of detector elements at temperatures near 100K are being completed; and a design for a wide-field, wide spectral range optical system capable of imaging the Earth's surface from an altitude of 700 km with a resolution of 10 meters and a field-of-view of 185 km has been completed.

MLA technology is also being pursued for application to the thermal infrared spectral region. A program is underway to develop photovoltaic, mercury-cadmium-telluride, linear detector arrays for this spectral region. Such devices will be suitable for future spacecraft sensors and should open many new possibilities for high resolution earth and planetary thermal sensing applications.

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Multispectral Linear Array (MLA) Science Studies

A broad program of MLA supporting science studies is being conducted to examine and develop the scientific basis for selection of spatial, spectral and radiometric performance properties of spaceborne MLA remote sensing systems.

Spatial studies are examining techniques for determining the value of incremental improvements in spatial resolution, of high resolution "sharpening" bands, of texture bands, and of quantization level. Initial results have shown that a single high resolution band captures most of the spatial information in an image, and that a panchromatic band may be an acceptable compromise between a near-infrared sharpening band for vegetation and a visible band for cultural features.

Spectral studies seek to identify the boundaries and independence of reflectance bands in the 0.4-2.5 μm range, and the means of prioritizing band selection on the basis of mission objectives and constraints. Initial efforts have identified independent spectral bands based on adjacent band correlations for some crops and soils, have identified atmospheric windows, and have established a band prioritization methodology

Atmospheric studies examine the effects of real, sometimes turbid, atmospheres on the radiometric response of ground targets (including the so-called "adjacency" effect) and on the effective spatial resolution of surface scenes viewed through the atmosphere. Simulations have shown serious degradation in effective spatial resolution of targets under turbid atmospheres, and classification errors where reflectance differences between field and background are viewed through turbid atmospheres.

Bidirectional reflectance studies examine the varying information content of nadir and off-nadir views of the earth, in order to determine the feasibility of interpreting an off-nadir data set as a substitute for a nadir data set, and of extracting new information useful in scene characterization from off-nadir (including polarized) data. Initial field experiments indicate that bare soils and sparsely covered vegetation plots have stronger non-Lambertian characteristics of reflection than more densely covered plots. Off-nadir look angle measurements were found to be more powerful discriminators for crop water stress than nadir measurements, with view angles of only 15-30 degrees being appreciably better than nadir.

Reflectance differences between crop conditions, when observed through hazy atmospheres, are reduced and thus the optimum sensor view angle to maximize the differences must be determined for different atmospheres.

The results of these researches will eventually lead to a scientific performance simulation and modeling capability.

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Forestry and Land Resources

Earth resources research efforts have addressed four general areas: (1) fundamental research into the dynamical properties and processes of vegetational physical systems and the interaction of vegetation systems with other physical systems such as hydrology, atmosphere, etc.; (2) development of models to represent and revise understanding of vegetation physical systems; (3) the evaluation and use for research/applications of data from spaceborne sensors such as Landsat multispectral scanner (MSS), Thematic Mapper (TM), and Advanced Very High Resolution Radiometer (AVHRR), from aircraft scanners which simulate recently launched or proposed space sensors, and sensors employing new technologies such as multispectral linear arrays (MLA); and (4) development of systems capable of processing and analyzing high spatial resolution data.

Landsat MSS data were studied to determine target reflectance variability. Apparent target reflectance varies not only as a function of changes in illumination conditions, but also as a function of the particular sensor measuring the scene. Landsat-4 MSS responses were compared with Landsats 1, 2, 3 and D' responses (the D' MSS will become Landsat 5 after launch) using ground calibration data. The Landsat 4 and D' sensors were spectrally very similar; however, they were noticeably different from the first three Landsats, especially in the red and first near infrared bands. In-flight empirical comparisons of Landsat 1 and 2 data have shown significant response differences in all bands but the red. This intersatellite variability has implications in terms of computer-aided land-cover identification, especially in data base situations where Landsat scenes from all four scanners may be incorporated.

Researchers are investigating the utility of AVHRR data (NOAA-6 and 7) for regional or continental vegetation monitoring. The work has shown that the main physiognomic vegetation types of Africa can be separated on the basis of differences in the ratio of the red and near infrared spectral response. Also continent-wide phenological changes can be monitored using the high temporal, low spatial resolution AVHRR data.

An urban land use study has incorporated satellite and TMS data to identify the optimum sensor parameters necessary to discriminate urban land use. Seasat-SAR data (Synthetic Aperture Radar) enhanced urban class identification when combined with MSS data. Analysis of TMS data indicated that middle and thermal infrared channels improved urban land cover discrimination. TMS data have also been studied in the context of forest cover classification. Discriminant analysis of Maine boreal forest data showed that the middle infrared bands are most useful for delineating the heterogeneous cover types. The blue band proved best for discriminating different levels of coniferous defoliation.

A number of studies have made use of Thematic Mapper Simulator (TMS) data. This aircraft data simulates TM satellite data. However, radiometric and geometric variability in the TMS data induced by the large scan angle constrains users. Software to minimize those constraints has been tested. The radiometric adjustment software accounts for spectral discrepancies due to the scan angle variation and due to detector response differences. Procedures for correcting the geometry of the TMS data using existing software at GISS/GSFC has been explored. Results have shown that a global third order polynominal model of the entire flightline may leave unacceptably large, localized residuals; smaller segments may have to be registered independently.

Work has begun on the aircraft precursor of a third-generation Earth resources satellite. The second Linear Array Pushbroom Radiometer (LAPR-II) utilizes linear array technology to acquire data in the visible and near infrared spectral regions. The instrument will be used to define the engineering and operating configuration and identify potential problems associated with multispectral linear array technology.

The development of more sophisticated software and computer systems for the analysis of Thematic Mapper and other high spatial resolution data continues to be a high priority item. One major effort is in the requirements definition for the Landsat Assessment System (LAS). LAS is being used to analyze TM and MSS data from Landsat-4. A basic functional requirement document for LAS has been prepared and is being used in the development of design specifications for new LAS functions. A second major effort is the development of portable software to efficiently and accurately classify high resolution data. Both a contextual classifier that recognizes land use classes by analysis of the frequency distribution of spectral classes and a histogram based clustering procedure has been developed. Continuing research in this area will focus on the application of texture measures and other features based on local image statistics for land use classification in high resolution data.

A statewide, Landsat MSS data base has been developed for Pennsylvania to monitor forest canopy conditions over regional areas. A user-friendly front-end system allows inexperienced users to generate forest cover condition maps for any portion of the state.

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Agriculture

Researchers have addressed the problems associated with changing scan angle, sky conditions, and illumination conditions on agricultural crop target response using a variety of data collection instruments and modeling techniques. The instruments employed in the studies range from a hand-held radiometer positioned within a meter of the crop canopy to AVHRR data transmitted from a platform 36000 kilometers above the Earth's surface. A new, spherically scanning instrument has been developed which measures bidirectional reflectance in the red, near infrared, and middle infrared wavelengths (TM bands 3, 4 and 5). The instrument samples the radiance of all portions of the ground and sky hemisphere in eleven seconds. The instrument will, after field testing, be used to characterize the bidirectional reflectance characteristics of specific agricultural cover types under a variety of sky conditions at different times of the day.

Data from this instrument will also be used to test the accuracy of a three-dimensional canopy model derived to assess the effects of off-nadir viewing and changing illumination conditions on sensor response. Sensor response values predicted by the model were within 20% of the actual values using field data collected over a soybean canopy. Further modeling efforts have been directed towards quantifying the effects of row structure and sensor view angle on the thermal infrared response of a row crop with a sunlit and shaded soil vegetation components. Comparison of modeling predictions and field observations obtained over a wide variety of sensor viewing orientations yielded a root mean square deviation of only 0.96^{o}C. The affects of the atmosphere are also being studied using AVHRR data. The visible and near infrared bands and the associated vegetation indices are being tested for sensitivity to change due to the atmosphere, scan angle, and solar zenith angle. AVHRR research has shown that the high temporal frequency and low spatial resolution of the data may be used to infer large area vegetation conditions.

Plant condition may also be inferred using TM data. A water stress experiment tested the sensitivity of various Thematic Mapper bands to the degree of water stress of a soybean crop. The results indicated that TM bands 3, 4 and 5 (red, near infrared, and first middle infrared channels) provided the most information concerning canopy condition. Thermal differences also proved to be a useful discriminant.

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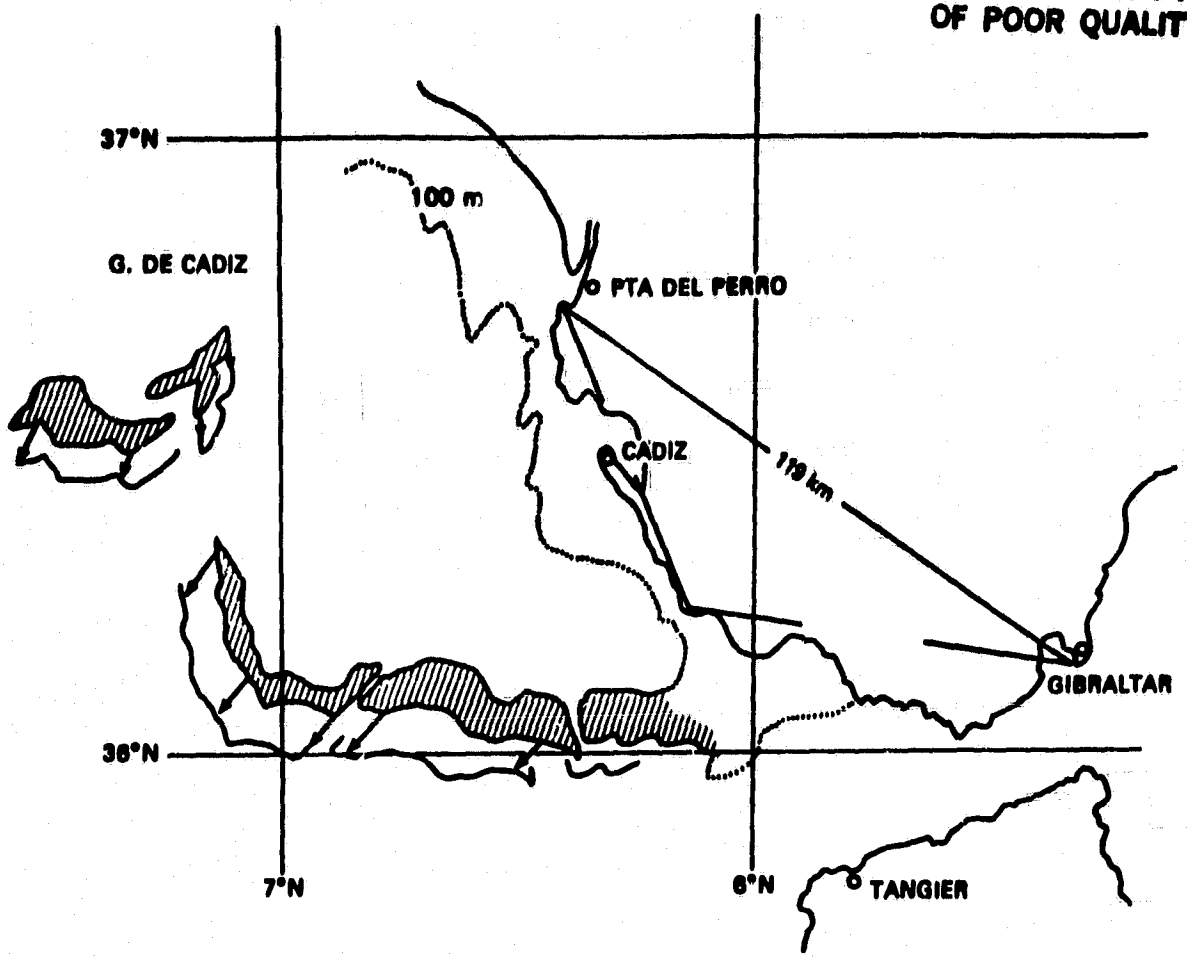
Analysis of Ocean Color Experiment Data from the Second Shuttle Flight

Visible images obtained during the Second Shuttle flight (STS-2) were used to track ocean current patterns and from this data water surface velocities were derived. An opportunity to demonstrate this new use of ocean color images occurred when the Shuttle carrying an imaging multispectral radiometer



A schematic diagram which illustrates the net motion of the chlorophyl patches with vectors exaggerated for clarity.

designated the Ocean Color Experiment (OCE) twice passed over the entrance of the Gibraltar Strait on November 14, 1981. Chlorophyll contour images of the Gulf of Cadiz were obtained as the orbiter passed over the area at 10:32 a.m. and 1:40 p.m. (GMT) on the same day. What appears in both images to be an elongated chlorophyll feature stretches from the entrance of the Gibraltar Strait to the middle of the Gulf of Cadiz and then curls north toward the southern shore of Spain. Plankton patches are natural drifters, thus careful geometric correction of the two images allowed changes in the shape and relative positions of the patches to be tracked during the 3-hour time span.

The spatial resolution of the aspect-ratio-corrected images is nominally 0.5 km. Analysis of the images showed relatively rapid plankton movement away from the Gibraltar entrance in a southeasterly direction at a rate of 5.5 km in 3:10 hours and relatively slow southwesterly flow at a rate of 2.0 km in 3:10 hours along the shallow coastal regions. The net motion indicates the presence of an anti-cyclonic circulation in the Gulf. Since visible imagery reveals only the surface and surface-layer part of the ocean, one has to construct a model and verify it against in-situ observations. Only then can one infer what is happening in the interior of the ocean. In this context, the data analysis technique described here should be seen as an indicator of what can be expected in future applications of this type of satellite data.

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Use of NOAA Advanced Very High Resolution Radiometer Data for Monitoring Terrestrial Vegetation

Several experiments have been in progress between NASA/GSFC and the Food and Agricultural Organization (FAO) scientists of the United Nations using NOAA satellite AVHRR imagery for a variety of natural resource inventory purposes. The framework of the cooperation has NASA/GSFC in charge of developing atmospheric correction routines, developing computer processing techniques, and evaluating the utility of the AVHRR 1.1km spatial resolution data. FAO provides all the ground support data and study-site expertise. Cooperative experiments include estimation of grazing biomass in West Africa for an area of 120,000 km^2; monitoring desertification processes in Baluchistan Province, Pakistan; and monitoring an area of 8,000,000 km^2 for the Desert Locust Control Project. The desert locust project is described in greater detail below.

Agricultural crops and rangeland resources over some 30 million square kilometers in 60 countries are prone to ravages by the desert locust. Successful breeding, triggered by suitable ecological conditions due to widespread rainfall and subsequent vegetation development in the desert locust recession area can result in rapid desert locust population increases, which if uncontrolled, can lead to large numbers of highly mobile and devastating swarms containing billions of locusts. Satellite remote sensing offers the only possibility for monitoring the 16 million square kilometer desert locust recession area situated largely in remote and inaccessible desert areas of Northern and Eastern Africa, the Near East, and South West Asia. Recent satellite-based research using Landsat and NOAA imagery has lead to a semi-operational monitoring program based upon NOAA Advanced Very High Resolution Radiometer data. The NOAA data are obtained and processed for an approximately 8,000,000 km^2 area every 18 days and should facilitate desert locust control for the first time since the development of recorded history for this scourge of mankind.

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CRUSTAL DYNAMICS

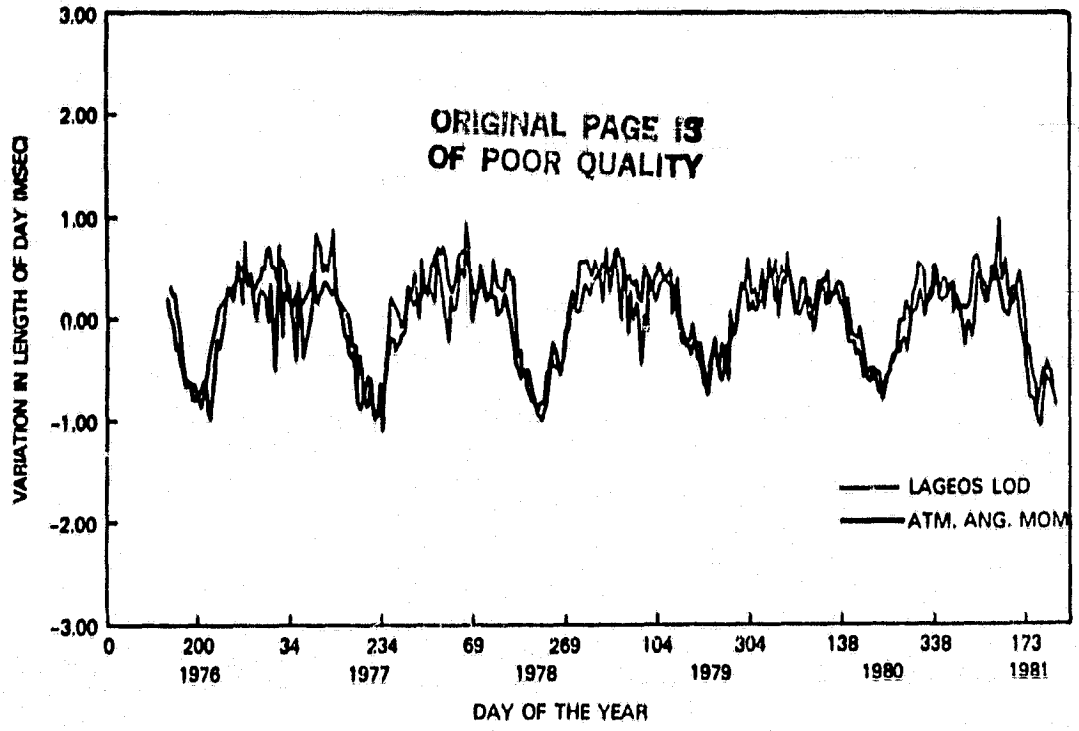
The thrust of GSFC's crustal dynamics research is to utilize space methods and technology to make precise geodetic measurements of crustal motion, deformation and Earth rotation parameters. The analysis of these data is expected to lead to an improvement in our knowledge and understanding of the Earth's dynamic motions and the forces that produce earthquakes.

Recent observations with Very Long Baseline Interferometry (VLBI) techniques have consisted of 3-7 day sessions using the Haystack and Westford, MA, Fort Davis, TX, Green Bank, WV, Owens Valley, CA (OVRO), and Onsala, Sweden radio telescopes. Analysis of these data has shown internal precision in baseline determination at the 2-3 cm rms level. Some 40 determinations of the 3928-km Haystack-OVRO baseline have been made over a five-year period. These measurements show no detectable changes in the baseline length greater than one cm/yr, indicating that the North American plate appears to be quite stable.

Epoch measurements have been made of the baselines between Onsala, Sweden and several U.S. telescopes, with formal standard errors of a few centimeters. Continuing observation of these baselines is expected to determine whether or not the European continent is moving steadily away from North America at the rate of a few cm/yr, as predicted by plate motion theories.

Measurements of small variations in the length of day (LOD) have been made on a continuous basis over the last six years, using laser ranging to the LAGEOS satellite. These measurements have been compared with predictions of changes in the LOD based on observations of the global wind structure at high altitudes. The results are shown in the accompanying figure for the period 1976-1981. The atmospheric calculations assume the conservation of angular momentum and that the atmosphere and solid Earth behave as a single system. The observed changes in wind structure can then be used to predict the corresponding changes in the angular momentum of the solid Earth, and thus changes in the LOD.

The agreement between the LAGEOS observations and the wind-based predictions is remarkable. Both data sets appear to be dominated by an annual variation, but agreement is evident even over periods as short as five to ten days. The results of these comparisons strongly suggest that variations in the



Comparison of atmospheric angular momentum with Lageos variations in LOD.

length of day for periods up to at least a year are probably of atmospheric origin.

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SENSOR DEVELOPMENT

New instruments are conceived, constructed and studied while older instruments are more fully exploited. In particular, advances have been made in understanding the requirements for the next generation of spaceborne microwave altimeters. Data from the Seasat altimeter have been analyzed over icy regions in Greenland and Antarctica to reveal topographic features obtainable through traditional methods only with great difficulty. Instruments for measuring atmospheric parameters have been studied to improve their performance. The airborne lidar has been shown to have valuable applications both over water and land as a topographic measuring instrument and for fluorescent studies of biological materials in the ocean. The surface contour radar has allowed an analysis of complex ocean wave spectra; such a capability will aid modelers in testing their results with actual conditions.

Bidirectional Reflectance Field Instrument

The Bidirectional Reflectance Field Instrument (BRFI) is a portable instrument designed to spatially scan nearly a full sphere, measuring incident (Sun and sky) and reflected (ground) radiation in three spectral bands (.6616, .8268, 1.656 μm). It will be used in agricultural research to help determine plant signatures in remote sensing operations. In use, the scan head is positioned on a horizontal boom over the crop to be scanned. During the data acquisition cycle the scan head rotates at 1 RPS about an axis parallel to the support pipe while at the same time tilting at a rate of 15^{o}/s about the orthogonal horizontal axis. The instantaneous field-of-view (FOV) is 15^{o} and the scan cycle time is 11 sec. The power source, scan controls, signal monitors, and a complete data system are located in a separate unit connected to the scanner by a cable.

The instrument was tested under normal field conditions at the USDA farm. It was calibrated and rechecked for operation with roof-top tests. The instrument was completed and delivered in July 1982.

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Short Wave Infrared Linear Array Pushbroom Radiometer

The Short Wave Infrared Linear Array Pushbroom Radiometer (SWIR) is a airborne scanning radiometer that passively measures surface reflected radiance in the 1 to 2 micrometer range. It is an experimental instrument built to examine and solve problems generic to the use of short wave IR linear array detectors in an imaging system. Goals include the development of calibration techniques to be used with linear array instruments and providing calibrated short wave IR data to users to aid in algorithm development.

A 64 element linear array is used as the detector in the instrument. The array is cooled to - 70°C using a thermo-electric cooler. The SWIR provides images with a resolution of 15 m (50 ft) when flown at an altitude of 3050 m (10,000 ft). The swath width from this altitude is 975 m (3,200 ft). The scene to be imaged is viewed through one of three selectable optical filters. The filters are located on a three position filter wheel positioned between the array and the lens.

Engineering test flights were flown with the SWIR in September 1982. The instrument operated successfully on these flights and good quality imagery was obtained. Further calibration and evaluation of the data is in progress.

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Solar Transmissometer

The Solar Transmissometer is a ground-based device which measures the apparent brightness of the Sun very accurately. The brightness varies with the condition of the atmosphere and the angle of the Sun.

From these measurements, atmospheric turbidity and optical thickness parameters can be studied. Also, atmospheric transparency data thus determined can be used to correct measurements made from instrument on aircraft or satellites which look down at the Earth's surface through the same atmosphere. This has been done for many U-2 aircraft flights of the OCS (Ocean Color Scanner), and for the Space Shuttle flight of the OCE (Ocean Color Experiment). Furthermore, accurate spectral measurements of solar flux are useful in calibrating many kinds of ground-based sensors.

Four Solar Transmissometers, each having different characteristics, have been developed. Three have 8 bands covering the visible and near-infrared spectrum, while the fourth has 6 bands covering the longer wavelengths up to about 4 micrometers. Since these instruments have narrow fields of view to avoid errors due to seeing the sky around the perimeter of the Sun, a provision for accurately pointing the instruments' input optic toward the Sun is necessary. Two of the four transmissometers have automatic trackers which incorporate a special four-quadrant sensor and drive motors to keep the sensor barrel centered on the Sun within a fraction of a degree of arc. One of these has been used on a ship, staying locked on the Sun in spite of the ship's motion. One of the non-tracking units has an electronic "peak-hold" circuit which acquires and stores the correct reading as the sensor scans across the Sun. This one, a compact, battery-operated portable, can be hand-held. The others require a tripod. These sophisticated devices have precisely temperature-controlled detectors for the utmost stability and repeatability, and can be read with a precision of four significant figures.

Sponsor: Office of Space Science and Applications

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Cloud Absorption Radiometer

The Cloud Absorption Radiometer (CAR) is now under development. Its purpose is to measure how light is scattered by clouds as a function of wavelength in order to better understand the mechanisms of radiant energy transfer in the Earth's atmosphere. This is important to Meteorology and Climate studies.

The CAR is flown directly through large clouds, measuring incoming radiation in all directions from nadir (downward) to the zenith (upward). Measurements are made in 13 spectral bands in the visible and infrared. From these data the "single scattering albedo" may be computed, without need for an absolute radiometric calibration of the instrument.

The instrument uses a scan mirror rotating continuously at 1.7 revolutions per second. Incoming light is reflected from it into a 13 cm diameter telescope, and then to a complex optical system which filters the beam into 13 different colors and spectral bands. Eight detectors of three types are required. All are temperature-controlled for optimum noise performance and stability. The six longest wave channels are read sequentially by an indium-antimonide detector cryostatically cooled to -196°C.

The CAR hardware incorporates several novel features. Since it is flown through clouds, there is a good possibility that moisture may be deposited on optical surfaces, especially the scan mirror, producing an error. The instrument is mounted outside the airplane and cannot be observed in flight. In order to check for water on the mirror, a unique monitoring system was devised. A thin beam of light is shone on the edge of the mirror, and the reflected beam is monitored by a photodiode. If any water condensation appears on the mirror the incident light starts to scatter, reducing the specular component detected by the photodiode. If the photodiode's output drops significantly, the corresponding cloud data is known to be in error and is discarded. Another novel feature maintains low offset (ensuring that zero volts at the output always corresponds to a zero radiance input) without requiring the complication and expense of a radiation chopper. It works by forcing the electrical output to zero during each backscan while the detectors are all completely darkened by means of a moveable shutter. Data taken during the active part of the scan is then measured with respect to this zero reference level.

Under the present schedule the CAR will be completed in 1983, and then flown by the University of Washington (Seattle) on their atmospheric research aircraft under a grant from the National Science Foundation.

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Pacific Area Data Collection Experiment (PADCEX)

Under a joint interagency program between NASA, NOAA, and the Department of Interior a project was created in 1980 to develop a direct readout, user-oriented satellite ground receive terminal for the GOES Data Collection Platform (DCP) system.

NASA developed the ground system and was responsible for deployment of the total system. NOAA provided a portion of the ground system for demodulating the DCP data. The Department of Interior furnished DCP's, and all their sensors, and operates the facility in Honolulu, Hawaii.

The two most important program objectives were to develop a low-cost microprocessor based terminal which is simple to build and operate, and to develop a 4 meter (13 feet) diameter antenna to replace the previously required 5 meter (16 feet) diameter antenna. The use of microprocessors, as opposed to larger mainframe computers, provides a simple, low-cost system. Because of this simplicity and resultant ease of operation, it is attractive to DCP users.

The antenna feed and Low Noise Amplier (LNA) combination developed allowed the use of 13' antenna as opposed to a 16' antenna. The increased efficiency of the feed (65% vs. 55%) yields + 15.2 db. Because of this, the antenna was compatible with rooftop installation on an office building.

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Radar Altimetry

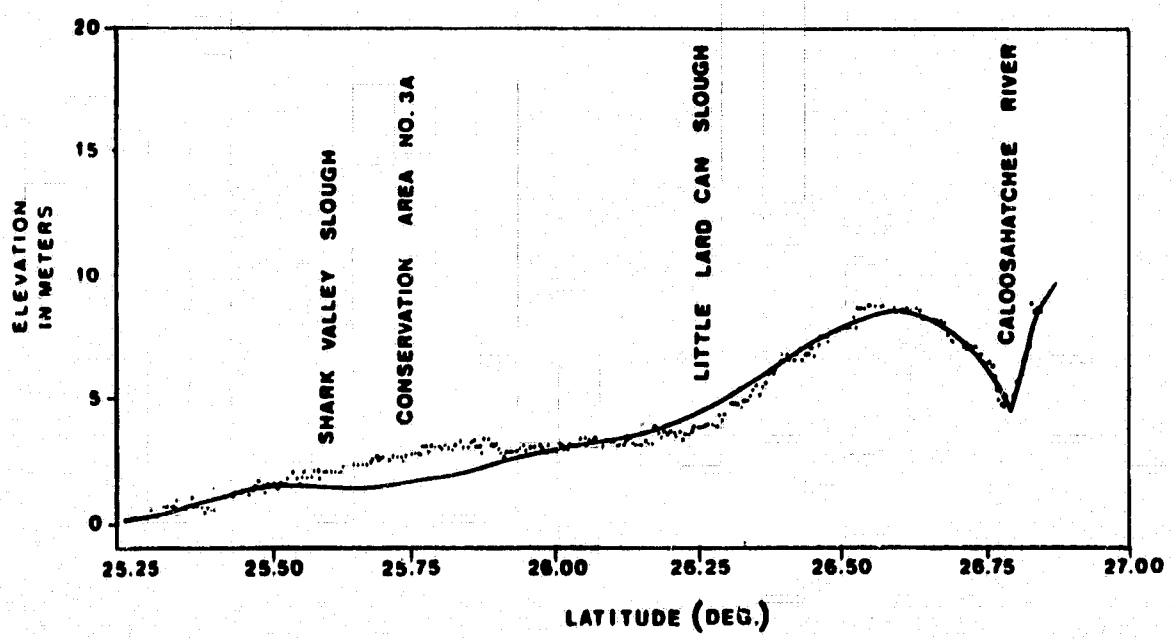
Satellite Radar altimetry began with Skylab instrumentation, then the GEOS-3 and Seasat missions showed that it was possible to detect spatial and temporal height changes (signatures) of the ocean surface. The Ocean Topography Experiment (TOPEX) altimeter is the next planned instrument in this line. Combining these measurements with ocean circulation and density models has led to significant improvement in the understanding of the dynamics of the oceans. TOPEX, therefore, offers a timely opportunity to contribute to NASA's evolving emphasis on global habitability.

The TOPEX Radar Altimeter is being designed to provide height measurements with a precision of 2 centimeters. To accomplish measurements with an uncertainty this small new design concepts have been required. One, dual frequency operation, to allow correction for the error contribution induced by the ionospheric electron content, is being investigated. Another, bandwidth enhancement, using a pulse compression technique, has been accomplished with the successful development and performance analysis of the breadboard digital chirp generator operating at 600 MHz initiated last year. A reduction in the cost of the altimeter by 40% has been shown by sacrificing some secondary capabilities.

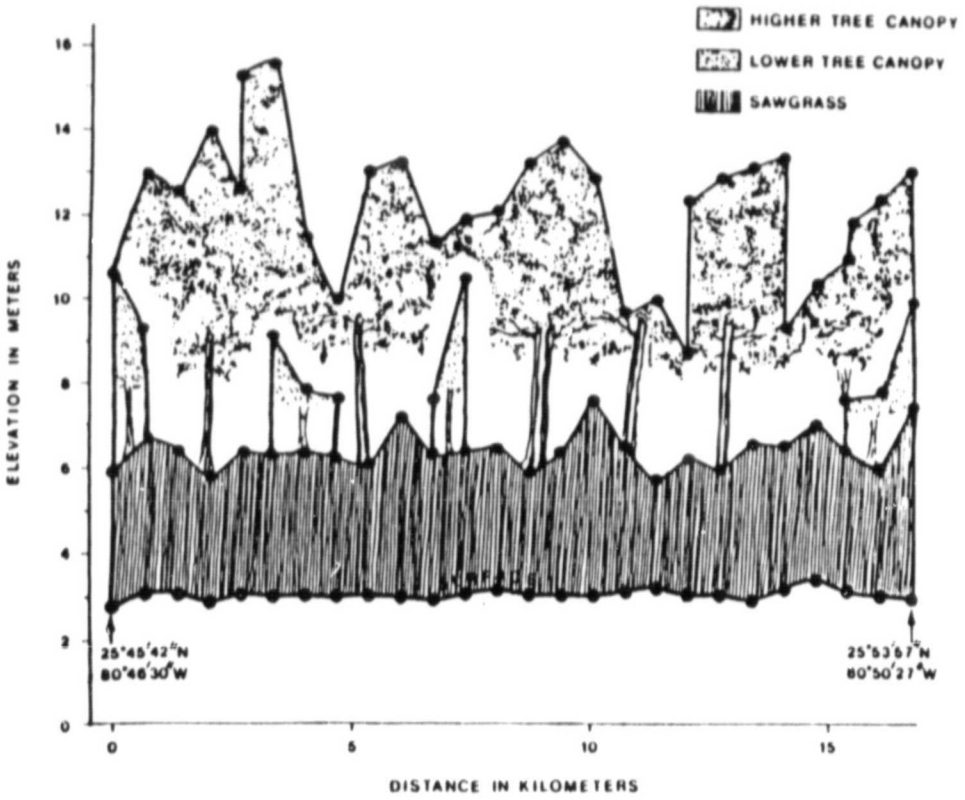
The "Advanced Ocean Sensor Long Range Plan" has been published. It sets the requirements and plans for the needed technology development for future ocean altimeter type sensors. The plan identifies the key technologies that must be advanced and the supporting studies needed to investigate the potential of new concepts.

Progress has been made on a computer simulation of satellite radar altimeters. An end-to-end simulation of surface returns, instrumentation and ground processing is under development. The program has been divided into several segments and draws upon previously isolated programs. The software is now able to produce a limited, expected altimeter instrument output. Work has been started on the ground processing segment. Input can be a surface map which is numerically integrated to give return signal characteristics that feed a surface tracking algorithm. Analytical return signals can also be generated to feed the same tracking algorithm; the purpose is to optimize tracking.

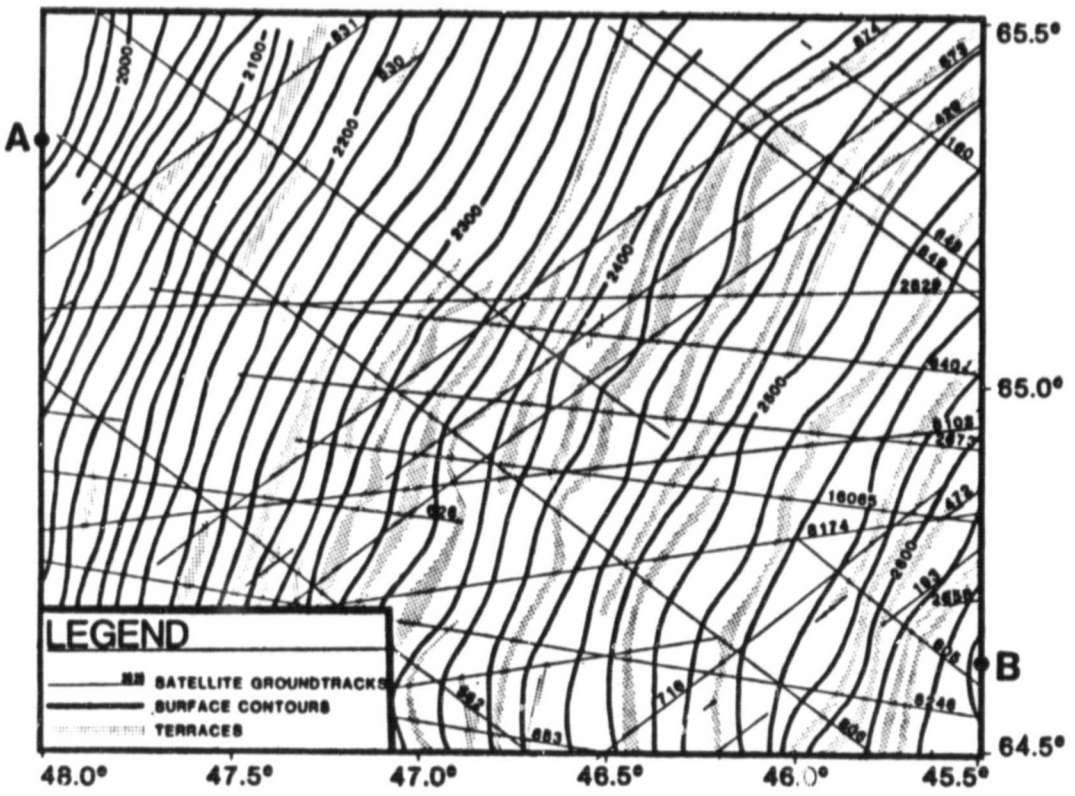
Seasat data over Antarctica, Greenland and Florida have been analyzed to provide a better understanding of the characteristics of ice sheet and land signal returns. Figure 1 is a plot of elevation data in Florida. The individual returns in some areas seem to have multiple targets; these multiple targets are vegetation layers, and are shown in Figure 2. A detailed contour



Comparison of map-derived elevations (solid line) with satellite-altimeter-derived elevations (dots).



Surface and vegetation canopy elevations from 26 consecutive waveforms over a conservation area.



Ice sheet surface features in the study area.

map (Figure 3) was developed for an icy area of Greenland. This indicated the presence of terraces across the study area which are shown as stippled areas. In Figure 4 the surface elevations are shown of the same area as a three-dimensional projection. The ice data is important in understanding ice sheet behavior. Monitoring the ice height is a method for assessing world climate change.

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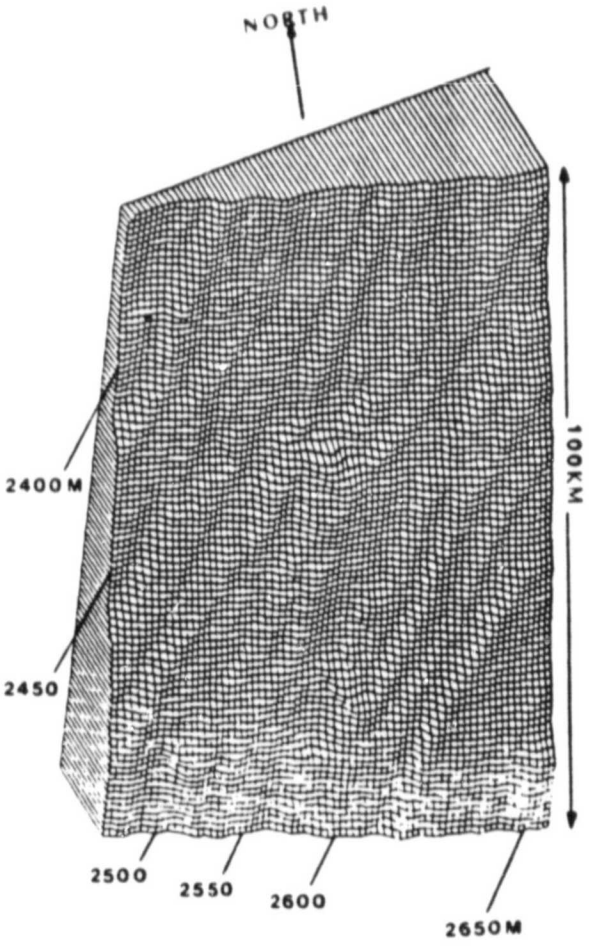

Three dimensional view of surface elevations in Eastern portion (1 degree x 1 degree) of the Greenland study area.

Minicomputer Controlled Frame Synchronizer for VAS Data

A computer controlled frame synchronizer, designed and built at the NASA Goddard Space Flight Center, has made it easier to use imagery data from the Geosynchronous Orbiting Earth Satellite (GOES). The imager is the VISSR Atmospheric Sounder (VAS). VISSR, the Visible Infrared Spin Scan Radiometer, has one visible plus twelve infrared channels with many data formats. The frame synchronizer formats VAS data under computer software control to minimize hardware complexity and cost. System flexibility is enhanced for processing data in various formats through operator selected software options. These options include selection of resolution through averaging the individual picture elements (pixels), geographic acquisition area and storage formats.

The frame synchronizer hardware is an interface between the serial spacecraft telemetry and a minicomputer memory. Synchronizer formatting options, under minicomputer control, include pixel word length selection and packing pixels in a minicomputer 16 bit word. The synchronizer signals the minicomputer at the end of each image line followed by delivery of synchronizer status, and error statistics to the minicomputer. A software algorithm monitors synchronizer status and image data for correctness and attempts to minimize or bypass errors through software commands to the frame synchronizer.

Three prototype units of the frame synchronizer are in operation. One is at the Naval Environment Research and Prediction Facility in Monterey, California. A second frame synchronizer is in use in Mexico. The third frame synchronizer is in the Direct Readout Facility at the NASA Goddard Space Flight Center, where it is supporting the NOAA North East Fisheries Center Warm Core Rings Experiment.

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Earth Sciences and Applications: Very Long Baseline Interferometry

Microwave radiation from extragalactic radio sources is an important tool for studying the dynamics of the Earth and stability of its crust. From a network of large radio telescopes, the Crustal Dynamics Project acquires Very Long Baseline Inteferometry (VLBI) data consisting of precise differences in time of arrival of the radio signals at the various telescopes. From these data the baselines between widely separated telescopes, the position of the Earth's pole, and the Earth's rotation can be inferred with great precision. Transcontinental baselines have been measured with a repeatability of 3 cm, while single day pole and rotation measurements have precisions as good as 5 cm and 0.06 millisec, respectively. Over a period of several years VLBI observations will measure the contemporary motions of the tectonic plates, which are a major factor in causing large earthquakes.

Measurement techniques have been continually improved as observations continue. The largest error source is the propagation medium. Beginning in 1979, the effect of charged particles in the line of sight, predominantly in the ionosphere, has been calibrated by observing simultaneously at two frequencies. The propagation delay from the dry atmosphere has been calibrated using local meteorological data logged during observing by the Mark III VLBI system. The delay associated with water vapor, while only one tenth that of the dry atmosphere, is much more variable and cannot be measured solely from ground data. By June 1982 all the Project VLBI stations were equipped with water vapor radiometers to measure the total line of sight water vapor directly.

VLBI data are also being used to define the celestial coordinate system. Since extragalactic objects have no detectable transverse motion, they form a fixed celestial reference frame. Source positions have been measured with uncertainties of 0.003 "sec.", the angle subtended by a quarter in Seattle as seen from Los Angeles. The radio and stellar coordinate systems will be unified using data from the Hipparchos astrometric satellite, the Large Space Telescope, and lunar occultations.

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Airborne Oceanographic Lidar

Research activities with the Airborne Oceanographic Lidar (AOL) were performed utilizing both of the basic system modes of operation, fluorosensing and bathymetry. The fluorosensing capability of the AOL was significantly upgraded through the additions of: (1) Airborne expendable bathythermograph (AXBT) launch, receiver, and data recording capability to support the ocean experiments, (2) a new multiwavelength calibration using a stepping motor driven mirror, (3) a disposable mirror exchange technique which economically allows the exchange of lower quality mirrors instead of expensive (and long downtime) recoating of usual system mirrors. The bathymetry/terrain mapping system was improved by the addition of a constant fraction discrimination system which reduces range walk errors by an order of magnitude. Ground tests are complete and a flight test is pending. The fluorosensing improvements were made operational for flight test and evaluation during a cooperative effort with aircraft flights over the NSF Warm Core Ring (WCR) experiments in the Atlantic Ocean.

Continued development of the AOL bathymetry and terrain mapping capabilities was extended to include the mapping of shallow water submarine features (> 2m) and beaches in joint NASA/U.S. Army Corps of Engineers (COE) flight experiments conducted near Wrightsville Beach, North Carolina. The analytical effort in processing data included the development of software for detailed comparison of laser scanning data with surface truth data or with laser data taken on other passes. Preliminary results indicate that the AOL has potential application for resolving a number of COE shoreline mapping problems, such as monitoring beach reconstruction.

Successful field experiments using this lidar include the airborne measurement of crude oil film thickness, ocean-dispersed tracer dye concentration and the simultaneous spectroscopic detection of the laser induced Raman return and fluorescence from chlorophyll and other naturally occurring pigment. The results of these experiments may be found in the scientific literature.

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Millimeter/Submillimeter Detector Development

Today's most sensitive heterodyne detectors for millimeter and submillimeter wavelengths use GaAs Schottky-barrier diode mixers. However, the sensitivity of these is more than a factor of 10 poorer than the ultimate quantum noise limit set by the uncertainty principle. Three factors limit the sensitivity of present Schottky diode receivers: (i) shot noise due to current flowing in the diode; (ii) loss of signal strength in the frequency conversion process; and (iii) the difficulty of providing optimum circuit impedances at the diode. Above 3 mm wavelength, item (iii) is not very significant, but below 3 mm it becomes increasingly important.

Superconducting tunnel diodes make it possible to overcome factors (i) and (ii) above. These diodes consist of a Superconductor-Insulator-Superconductor sandwich (hence "SIS" mixer) and are virtually identical in construction to the Josephson junctions being developed by the computer industry as extremely fast logic elements. In SIS heterodyne detectors we do not use the Josephson effect, but rather the single electron tunneling process, which has an extremely sharp nonlinearity. The nonlinearity is so sharp that classical mixer theory no longer applies, and the new quantum mixer theory of J.R. Tucker must be used. This theory predicts several non-classical properties for SIS mixers, including sensitivity approaching the quantum limit, and the possibility of conversion gain. Working at 115 GHz we have quantitatively verified the theory, thereby establishing it as a basis for the design of future SIS mixers. In this work we have used SIS diodes supplied by IBM Watson Research Laboratory under a joint study agreement, and by Princeton University (fabricated at NBS, Boulder) as part of an informal cooperative project. The next phase of this work will be to develop a complete 115-GHz SIS receiver for field testing on the Columbia/GISS CO Sky Survey telescope.

At submillimeter wavelengths, limitation (iii), the difficulty of providing optimum circuit impedances, becomes serious. In an effort to improve the sensitivity of submillimeter Schottky diode mixers by a factor of two or more, we are extending our earlier work on millimeter mixer circuit optimization into the submillimeter region. A computer program has been developed which allows practical mixer circuits to be analyzed accurately. This is being used with mount impedance data measured on large-scale (typically 100x) models to attempt to improve existing mixer designs.

Sponsor: Office of Aeronautics and Space Technology
Office of Space Science and Applications

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Atmospheric Chemistry

Two tasks were carried out to support the Environmental Observations Division's goal of understanding the distributions, sources, and sinks of trace atmospheric species. A study of the electrochemical concentration cell (ECC) ozonesonde under stratospheric conditions was carried out using an environmental chamber designed to simulate vertical temperature, pressure, and ozone profiles. Experimental information on the ozonesonde's accuracy and precision was obtained, and error sources were identified in order to extend its performance.

The second task involved participation in the joint NASA/University project RAVE (Research on Atmospheric Volcanic Emissions). The Wallops nitric oxide monitor was flown into volcano plumes emitted from Arenal and Poas in Costa Rica and Colima in Mexico. Information obtained from this project is being used to help evaluate the effects of volcanic emissions on tropospheric and stratospheric chemistry and on climate.

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Surface Contour Radar

The Surface Contour Radar (SCR) is a 36 GHz, computer-controlled, airborne radar which generates an elevation map of the sea surface below the aircraft in real time. After the data has been collected other programs remove the aircraft motion and compute sea surface directional wave spectra. (A two-dimensional fast Fourier transform is used.)

A detailed comparison was made between the NOAA XERB buoy and the SCR data. The angular resolution of the Surface Contour Radar directional wave spectrum is much higher than that of the pitch and roll buoys; thus only a limited number of Fourier coefficients could be computed from the buoy data. The non-directional wave spectra and limited coefficients were, however, in good agreement with those from the SCR.

This system has been used to map the evolution of the fetch-limited (that is, wind driven) directional wave spectrum off the eastern seaboard. The flight lines were both north and south of Delaware Bay following the passing of a weather front. Analysis indicating that, in addition to the waves aligned with the wind direction which grew with increasing fetch, there are other unexpected off-shore wave components whose directions significantly differ from the wind direction, and whose origin is the mouth of Delaware Bay. The surface contour radar has great potential in verifying sea surface wave generation models.

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Verification and Analysis of Satellite Derived Products

This effort, verifying temperature retrievals from TIROS N and the NOAA series of satellites, uses all available rocketsonde data between 50 mbars and 0.4 mbars. Hundreds of US rocket data reports have been paired with the TIROS Operational Vertical Sounder (TOVS) point profiles closest to the rocketsonde site. The rms differences show that the two measurements are comparable up to the 2.0 mbar level. Pairs of rocket and satellite profiles at 1.0 and 0.4 mbars show that the satellite data are colder by 5-8°C. Individual profiles and statistics which are being stratified by rocket launch sites, season, and latitudinal band do not show such clear correlation. Space/time differences are being examined as the possible cause for the large differences observed from individual pairs.

In addition, about 800 USSR rocketsonde reports are being examined in a similar manner. Measurements for nine months of 1980 and six months of 1981, have been placed in a computer-file format to obtain consistency in the data formats. About 200 measurements have already been paired with the TOVS data points showing that the satellite data are about 10°C warmer than the rocket measurements. The sum of the differences between satellite and US data and satellite and USSR data is almost equivalent to the differences observed at Wallops Island in 1977 in a direct comparison between US and USSR rocketsondes (NASA RP 1053).

Methods of obtaining representative winds from the satellite radiances are under study. Geostrophic winds obtained from analyzed fields using satellite data are being compared with direct rocketsonde and rawinsonde measurements.

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INFORMATION EXTRACTION

Information extraction refers to the manipulation, processing, and analysis of data in order to convert it into useful information. It encompasses the design, development and operation of computer-based hardware and software systems required for the extraction of information products from digital data and requires the adaptation, development and use of related disciplines, e.g. data management. The following programs exemplify the development work GSFC is undertaking in this area of engineering research.

Landsat Assessment System

The Landsat missions, through the July 1982 launch of Landsat-4, have carried various imaging sensors for observation of the Earth and its resources

in visible and infrared wavelengths. The preparation of scientifically and operationally useful data from these instruments is the prime function of the ground systems associated with the spacecraft; the critical components of such ground systems provide data geometrically and radiometrically corrected to high precision. The Landsat-4 spacecraft carries, in addition to the Multispectral Scanner (MSS) flown on previous Landsats, a new high-resolution scanning device, the Thematic Mapper (TM). This sensor presents unique complexities and possible difficulties to the ground systems. Because of the lack of experience with the TM and the requirement to maintain the quality of corrected data, a separate facility was established within the Landsat-4 ground segment to evaluate the performance of the sensor and ground processing corrections. This facility, the Landsat Assessment System (LAS), will also be used as an analysis tool to evaluate the utility of the TM data in discipline investigations, especially as quantitatively compared to MSS analyses.

The LAS, completed for initial use in July 1982, includes complete software capabilities for the evaluation of the ground segment TM image data correction from raw to geodetically and radiometrically precise outputs, as well as limited production of image scenes for evaluation both at the LAS and at other institutions. The LAS has been sized to accommodate meaningful quantities of TM data and includes equipment components for the production of high-quality film as well as digital data products. Analysis software includes classical image processing functions derived from other systems, such as enhancements, filtering, classification, and image display to three interactive image analysis stations. The data from other sensors, including the MSS, are amenable to analysis on the LAS.

During 1982 and 1983 the system will be used for discovering possible improvements to the ground system processing procedures and for better characterizing the TM data. At the same time, continuing development will be made in the analytic software in support of both Landsat and other systems.

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Transportable Applications Executive

Increasing software development costs and the difficulty of transferring programs between computer systems motivated an effort in 1980 to design a common executive to be used in software systems currently under development for remote sensing applications. This Transportable Applications Executive (TAE) will provide systems services commonly required by data analysis software, including interactive user control through menus, commands and command procedures, input parameter processing, error handling, and image and file management. Machine and operating system dependencies will be isolated in interface sub-routines to facilitate conversion of the executive to other systems. Because of the common interface provided by the executive, analysis programs written to use its services can be installed and run on other computer systems operating under TAE.

Following completion of a conceptual design in November 1980, a prototype version of the system was completed in August 1981 which operates on Digital Equipment Corporation VAX 11/780 computers.

During FY82, the prototype was converted to run on the DEC PDP-11 computer system. The prototype has been modified and extended through version 4.0 and distributed to 23 installations both inside and outside of NASA. The operational system will be delivered in 1983.

One of the first software packages to run under TAE is the General Meteorological Package (GEMPAK) currently under development to analyze temperature, humidity, and other parameters which are derived from satellite observations. This system of analysis programs provides capabilities for the mathematical analysis of observations and the ability to produce gridded fields and the display of contour maps, vertical soundings and cross-sections. GEMPAK includes device-independent graphics subroutines that will be generalized for use in TAE to provide a common, transportable interface to a variety of color and monochrome display devices and plotters.

Sponsor: Office of Space Science and Applications

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Pilot Atmospheres Data System

The Pilot Atmospheres Data System (PADS) program is directed toward the development and demonstration of effective data system capabilities, including the interconnection of applications data systems, to provide space application researchers and others with improved access to readily useable data and data products. Major technological concepts currently being evaluated relate to computer network interfaces, data system interconnection, and interactive catalog and data set access/exchange in a distributed system environment. Application of developed data system capabilities is directed in support of selected OSSA weather, climate, and upper atmospheres research programs.

During 1982, the PADS program has completed the second phase in the development of a System of Networked Applications Processors (SNAP), a distributed network supporting packet communications and both catalog and data set access among heterogeneous processing systems. At present, the SNAP includes the interconnection of five separate data analysis/management systems at GSFC and a configuration of eight processors at the University of Wisconsin, all involved in severe storms, local weather or climate-related research. These processors consist of 16-, 24-, and 32-bit minicomputer architectures from two different computer vendors (DEC and Harris) and an IBM-compatible mainframe.

The user-oriented network services presently provided within the SNAP enable an interactive terminal user of any computer system in the SNAP to make queries for and access data sets from any other computer system in the network. A uniform user interface to all network services has been provided to all GSFC hosts even though different data inventories and data management systems are used on each host. The network interfaces and the multilayered communication and application level protocols of the SNAP have been designed in cognizance of the evolving standards for system interconnection.

Extension of the SNAP to incorporate at least two additional GSFC processors and the installation of a high speed (1-10 Mbps) local cable network at GSFC to improve user-oriented distributed data access service functions are planned for 1983.

Sponsor: Office of Space Science and Applications

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Pilot Climate Data Base Management System

The Pilot Climate Data Base Management System (PCDBMS) will serve as a focal point for managing NASA's large collection of climate-related satellite data. The PCDBMS will provide uniform data catalogs, inventories, and access methods for selected NASA data sets. It will also provide appropriate data manipulation facilities so that research users can easily combine or compare data sets, and can acquire data that is compatible with other computer facilities where the data will be used. This pilot system will focus current data management activities, demonstrate the capabilities of an automated data base management system, provide limited but useful support for climate research, and carry out related data management research and development directed toward the evolution of a comprehensive, fully automated data management system. In FY82 a comprehensive catalog was developed and is available on-line and in hardcopy form, and a Demonstration System consisting of inventories and data selection capabilities for ten data sets was made available. In FY83, an additional six data sets will be added to the Demonstration System, as well as new capabilities to support statistics and graphics using these data sets.

Sponsor: Office of Space Science and Applications

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Crustal Dynamics Data Information System

The Data Information System (DIS) for the Crustal Dynamics Project provides for cataloging of all Project acquired data from 1974-1981 as well as new data to be acquired during the lifetime of the Project through 1988. The collection of the various types of data includes a large selection of analyzed geodetic data products, such as geodetic baselines, positioning of the observing stations, Earth polar motion data,

and other ancillary geodetic products. The information will be stored in a Crustal Dynamics Data Base and is directly accessible via a menu-driven user language. The DIS utilizes commercial data base management techniques to enable the user to query and cross-reference the information for the preparation of data requests and for providing project management reports.

After the completion of a conceptual design of the DIS in July 1981, the system implementation was started in FY82 with the design of the data base and the subsequent cataloging of the data products. Shared utilization of a VAX 11/780 computer with the Pilot Climate Data Base Management System enabled a rapid implementation of the system including menu-driven procedures and user Help functions. Pilot operations for outside users through dial-up telephone lines were started in May 1982 and the system became fully operational on September 15, 1982. The DIS is expected to become part of a data base for the National Geodetic Reference System at the conclusion of the Project.

Sponsor: Office of Space Science and Applications

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Massively Parallel Processor - Custom VLSI Circuit

The Massively Parallel Processor (MPP) uses a custom-designed very large scale integrated (VLSI) circuit to implement the Single Instruction Multiple Data Stream (SIMD) architecture of the MPP.

This high speed complementary metal oxide silicon (HCMOS) VLSI circuit is used as the basic building block to form the 128 x 128 array of bit serial processors. Each custom circuit contains eight processing elements (PEs).

Each PE has six 1 bit registers, a shift register with a programmable length, a data bus, a full adder, control logic and connection to random-access memory.

The MPP chip contains 8500 transistors and requires 300 milliwatts of power at 7 volts. The basic clock rate is 10 MHz. All inputs and outputs are TTL compatible to allow interfacing to high speed external memory chips, which provide 1024 bits of memory per PE.

Sponsor: Office of Aeronautics and Space Technology

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Data System Technology Program

As part of the NASA Data System Technology Program, GSFC is conducting various applied R&D activities in data base management systems (DBMS). The purpose of these activities is to assess, develop, and demonstrate techniques for applying DBMS technology to NASA's satellite data management problems and to transfer this technology to current and future missions. Fiscal Year 1982 activities included:

- Comparative analysis, evaluation, and performance testing of DBMS systems to determine the effects of varying data base designs and computer operating system parameters.
- Detailed design and configuration management of a Packet Management System (PMS) utilizing a DBMS to catalog, store, and retrieve packetized satellite data ingested at rates up to 50 million bits per second.
- Applied research in the development of a common user interface to distributed, heterogeneous databases, including preliminary development of methodology based on formal logic theory.

In Fiscal Year 1983, DBMS test and evaluation will continue, the PMS will be implemented and tested, and further research will be done in access methods to distributed heterogeneous data bases and architectures for large volume data bases.

Sponsor: Office of Aeronautics and Space Technology

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SPACE APPLICATIONS

Remote sensing applications development and transfer activities are conducted at GSFC primarily by the Eastern Regional Remote Sensing Applications Center (ERRSAC). Technology transfer has been accomplished through the Regional Remote Sensing Applications Program and through the related Applications Systems Verification and Transfer (ASVT) program. Remote sensing technique and application development and testing is being conducted under the Experimental Test and Evaluation Program, the successor to the Regional Application Program. GSFC objectives and recent accomplishments in these areas are summarized in the following paragraphs.

Experimental Test and Evaluation

The Experimental Test and Evaluation Program (ET&E) was initiated in FY82. The objectives are to determine the technical viability of remote sensing techniques through test and evaluation projects in a variety of applications environments, and specifically to improve interpretation of remotely sensed data, and to improve interpretation of georeferenced data sets incorporating remotely sensed data. Several test and evaluation projects are in progress in a variety of applications environments, in the areas of renewable and nonrenewable resources.

Initial results using normalization techniques have shown significant convergence in spectral values and variances for signatures associated with major land cover types by 1) converting digital brightness counts to relative radiances and 2) performing a 1/sin0 adjustment to account for solar elevation effects.

Additional projects now in progress compare AVHRR, MSS and TM level 1 land cover classification accuracies; examine the capabilities of HCMM thermal data in conjunction with MSS data to distinguish urban from rural land covers; and establish a Washington, D.C., area full-scene (185x185km) data base for controlled studies of techniques and data combinations.

Sponsor: Office of Space Science and Applications

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Regional Applications Program

The ERRSAC Regional Applications Program successfully completed cooperative demonstration programs with Ohio, Delaware, and New York. Final workshops communicated accomplishments to other state resource managers and legislators. Ten states in the north central/northeast area now have successfully completed programs and have operational capabilities for using satellite remote sensing data in environmental and natural resource management. Programs in six additional states are underway now, with completion expected in FY83.

In Delaware a statewide Landsat land cover data base was developed for monitoring agricultural land conversion. In Ohio, land cover changes were determined from Landsat data over 4-year period for incorporation into a wildfowl habitat model, in order to assess causes of wildfowl population decline. In another Ohio project, Heat Capacity Mapping Mission (HCMM) day time thermal data were combined with Landsat MSS data to improve separability of urban and agricultural land cover classes. Landsat derived forest type information in Virginia was incorporated into natural hydrocarbon emission models, demonstrating that both forest and anthropogenic hydrocarbon sources were needed to simulate summer peak ozone levels. Landsat classification results, incorporated into the Maryland Automated Geographic Information (MAGI) system, not only provided accurate cover information, but led to improved strategies for use of the MAGI data base as well. Merging of Landsat MSS and RBV data in Maine yielded improved delineation of logging roads and clearcutting activities.

The Appalachian Lineaments ASVT project was completed. Technical papers describing the relationship between Landsat-derived lineaments and hydrocarbon accumulation in three Appalachian test sites were reported at professional meetings, and the findings of two states were published as state reports for wider dissemination.

Sponsor: Office of Space Science and Applications

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Flight Projects and Mission Definition Studies

During Fiscal Year 1982, engineers at GSFC have been involved in planning and development of a number of new satellite programs and projects directed toward obtaining maximum use of space-derived data.

GSFC

Space Telescope

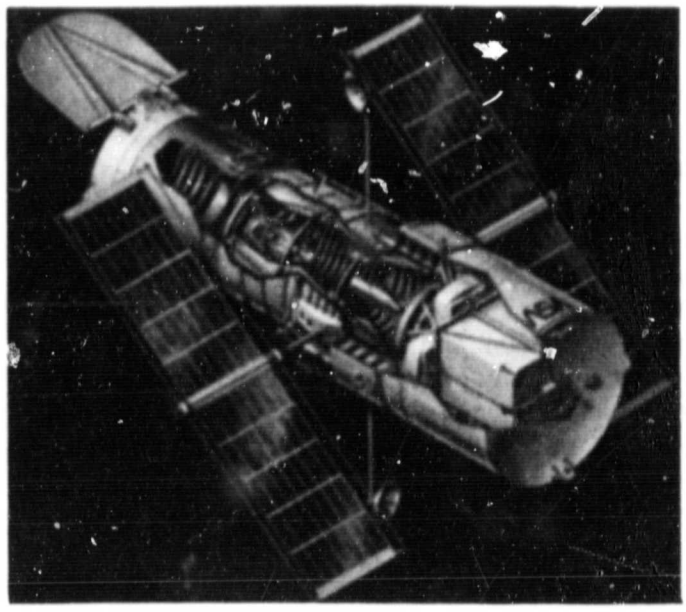
The objective of the Space Telescope (ST) Program is to establish and operate an astronomical facility consisting of an orbiting observatory and a ground system which will greatly exceed the capability of even the best ground-based observatory, and to make it available for research in optical astronomy by scientists from the United States and abroad.

Above the obscuring atmosphere of the Earth, the Space Telescope's 2.4 meter mirror will allow it to observe 350 times the volume now visible from ground-based telescopes as well as to study the ultraviolet (UV) region of the spectrum which is mostly absorbed by Earth's atmosphere. Its combination of increased detector sensitivity, relatively large aperture, high-quality optics, and extremely precise pointing should allow it to "see" and resolve extremely faint stellar objects up to about the 27th visual magnitude, which is 50 times fainter than can be seen from the Earth.

The Space Telescope is the most ambitious space astronomy program yet conceived. It will be the most significant research tool in optical astronomy from its launch in 1985 to the end of this century. It will be maintained though several cycles of in-orbit and ground refurbishment. The total requirements for the ST are awesome in their scope and complexity. Two NASA field centers share the responsibility of meeting these requirements under an arrangement set up by NASA Headquarters.

Under the overall program management overview of the Office of Space Science (OSS), the Marshall Space Flight Center (MSFC) has been designated the lead ST Project Management Center. In addition, the MSFC ST Project Office manages two large contracts: one with Perkin-Elmer (P-E) for the design and development of the Optical Telescope Assembly (OTA) which includes the Fine Guidance Sensors (FGS) to be used for pointing control as well as for astrometry, and another with the Lockheed Missile and Space Company (LMSC) for ST systems engineering and integration, and for the design and development of the Support System Module (SSM) which includes the attitude control system, the command and data handling system, the power system, the thermal system, and the structure. The OTA operates the spectral range of 1200 Å° 1000 m, the 2.4 meter primary mirror is ground to an accuracy approaching $\lambda/60$ at visible wavelengths. The pointing control accuracy is 0.01 seconds of arc in each of 2 axes, and the stability is 0.007 seconds of arc.

An artist's concept of the Space Telescope



The Goddard Space Flight Center (GSFC) is responsible for the science and operations aspects of the Space Telescope. Specifically, the Space Telescope Science and Operations Project (STSOP) at the GSFC is responsible for managing the following:

- design and development of the five Scientific Instruments (SI's) for use on the first of the ST;
- design and development of the SI Control and Data Handling (SI C&DH) system;
- Verification and Acceptance Program (VAP) to integrate and test the SI's and the SI C&DH;
- system engineering of the total ground systems;
- design and development of the Science Operations Ground System (SOGS);
- establishment and operation of the Space Telescope Science Institute (ST ScI) which will conduct the science operations; and,
- operation of the total observatory.

In addition, the GSFC Mission and Data Operations Directorate (M&DOD) is responsible for the design, development and maintenance of the Data Capture Facility (DCF), the Payload Operations Control Center (POCC), and other institutional support, jointly called the ST Observatory Management System (STOMS).

The European Space Agency (ESA) is providing the ST solar array, one scientific instrument, and participation in science operations.

Sponors: Office of Space Science and Applications

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Solar Optical Telescope Observatory

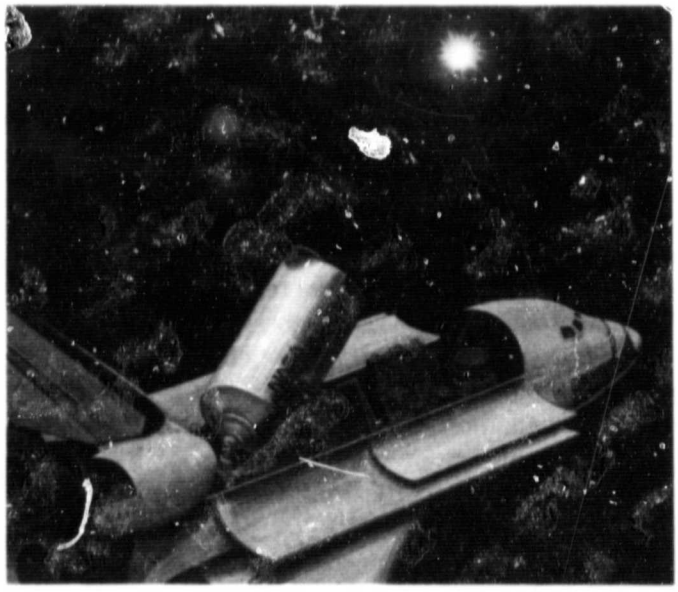
The Solar Optical Telescope (SOT) Observatory will conduct detailed solar observations in space in order to solve a number of fundamental problems in solar magnetism and in atmospheric heating and dynamics. Many problems of solar atmospheric structure and dynamics that have been discovered, but not solved, by ground-based observations and earlier space missions will become amendable to solutions with the data the SOT would acquire.

The SOT will be the first payload ever launched that satisfies all the necessary criteria to quantify solar phenomena and processes. These criteria include the capability to make measurements simultaneously over many spectral bands from the deep UV thru the visible, not only with sufficient angular resolution (approximately 0.1 arc-seconds) to study the solar features on the scale which many basic physical processes occur, but also with high spectral and temporal resolution fine enough to track the changes in short-lived phenomena.

The SOT observatory will be at a 463 km circular orbit. The space shuttle enables returning the observatory to the ground for refurbishment between observations (currently planned for every 18 months) to further enhance the study of the Sun.

The SOT observatory consists of a telescope facility, various complements of scientific instruments (depending on the mission) and the necessary ground equipment and facilities to fabricate, integrate, verify, and operate the observatory. The heart of the facility is an f/25 Gregorian optical telescope with a 1.3 meter diffraction limited primary mirror. This mirror is also articulated in six (6) degrees of freedom to allow for pointing and tracking on solar features anywhere over a ±30 minute field around the telescope axis.

The Science Instruments observe solar images provided by the Gregorian optics of the SOT Facility or by collecting optics internal to the instruments, for concurrent viewing of solar areas of interest over long periods of time. Because the solar images will be



The Solar Optical Telescope Observatory launched from the Shuttle Payload will conduct detailed solar observation in space.

displayed on the ground in real time, the scientists conducting the observations will be in a position to quickly zero in on solar features that rapidly change in an unpredictable fashion. Observations presently made on the ground with great difficulty over many months will be made from space in a few hours with spatial resolutions approximately three times better. The SOT Observatory will also permit recording high-resolution synoptic sequences over a period of several days from space, as opposed to minutes or seconds from ground-based observations. In summary, the SOT Observatory incorporates all the advantages of a ground-based telescope in addition to yielding more accurate solar data than was ever possible.

Sponsor: Solar Optical Telescope Project

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Search and Rescue Satellite-Aided Tracking (SARSAT) Project

During Fiscal Year 1982, the TIROS Project successfully integrated the SARSAT flight hardware into operational TIROS spacecraft. The spacecraft, NOAA-E, is scheduled for launch in the first half of Fiscal Year 1983.

SARSAT will provide a demonstration of aerospace technology to the Search and Rescue (SAR) community by detection and location of downed aircraft and ships in distress. The Search and Rescue Mission of the TIROS Project at the GSFC is responsible for the U.S. portion of the SARSAT Project, an international cooperative project involving the U.S., Canada, and France. NASA is the system manager of the U.S. participation which included NOAA, DOT, and DOD. Canada provides the spaceborne repeater for relay of the 121.5 and 234 MHz signals from Emergency Locator Transmitters (ELT's) carried by approximately 200,000 U.S. aircraft and Emergency Position Indicating Radio Beacons (EPIRB's) carried by some ships. France provides a spaceborne processor for experimental ELT's and EPIRB's operating at 406 MHz. The U.S. integrates these two instruments onboard the TIROS Series of NOAA environmental satellites. Each country provides its own Local User Terminals (LUT's) and test beacons as well as strong participation by the SAR users in the demonstration of the system. The location of the ELT's and EPIRB's is accomplished with the same doppler location principal demonstrated by satellite data collection systems such as the Nimbus RAMS and the ARGOS system. The Soviet Union is also cooperating with the SARSAT partners by making its own SAR satellite system, COSPAS, interoperable with the SARSAT system.

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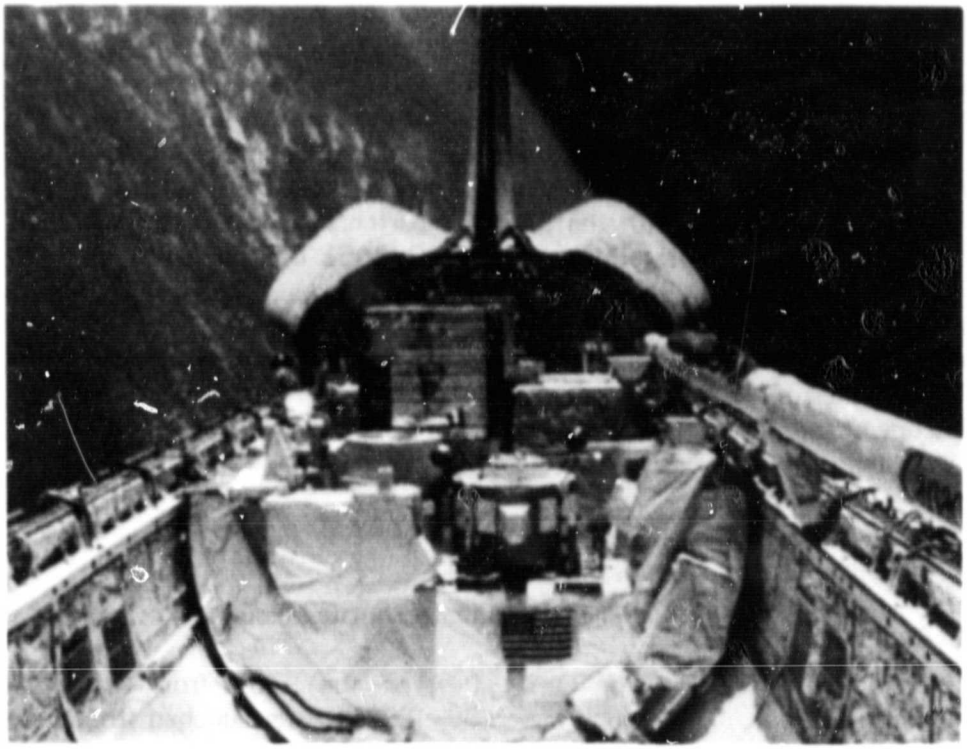
OSS-1 First Goddard Shuttle Mission

The OSS-1 flew on the STS-3 from March 22 through March 30, 1982. It was launched from Cape Kennedy and landed at White Sands. Subsequently it was ferried back to the KSC, and the Payload was trucked to the GSFC for deintegration.

The STS-3 mission, part of the Orbital Flight Test series was designed to test the temperature extremes that could be encountered during a Shuttle flight. It was divided in exposure for significant periods in tail-to-sun, nose-to-sun, and bay-to-sun orientations.

The Payload consisted of nine investigations, eight of which were carried on an ESA Pallet in the cargo bay exposed to space, while the ninth, a life-sciences Plant Growth Unit, was housed in the mid-deck of the Shuttle. The paller-mounted experiments, representing the disciplines of Space Plasma Physics, Astronomy, Planetology, Solar Physics, and Technology, were selected primarily to conduct their investigations while characterizing the Shuttle environment for suitability as an experiment base.

Preliminary results of interest to future users are the quantization of such phenomena as EMI, particulate, and molecular contamination, shuttle distortion and stability, and Shuttle-plasma interactions. The OSS-1 also demonstrated, for the first time, the use of the RMS and associated hardware-software systems to grapple, unstow, and restow an experiment in the cargo bay. The thermal canister was demonstrated as an enclosure for temperature control of a spaceborne device via heat pipe technology. The feasibility for further study of induced electromechanical effects using electron emitters was shown.



The shuttle payload bay is shown here where experiments from many different disciplines are mounted for flight on the shuttle.

Most dramatic was the planned and serendipitous contributions of the man in conjunction with the experiment in space exploration.

The anomalies encountered were the failure of one of two tape recorders (redundant) caused by a loose washer causing a break in a tape drive belt, an inoperative scanner drive in one of the experiments, and degradation in one of three sensors in another. There were several "hits" experienced in two of the eleven microprocessors used by the payload. These are under investigation, but it appears that conducted susceptibility is the most likely suspect.

The OSS-1 "Pathfinder" Mission, though not completely representative of future operational missions, did serve as a testing and proving ground for what is involved in accommodating a payload to the Shuttle. As such, a considerable number of important "lessons learned" were garnered. It is a notable successful first in the developing Shuttle area.

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Advanced Land Observing Systems Studies (ALOSS)

During Fiscal Year 1982, the GSFC ALOSS Office conducted multiple studies for the definition of a remote land observing instrument that would use linear arrays of solid-state detectors operating in the "push-broom" scan mode. This instrument would offer very sensitive multispectral image data at high ground resolution, on-board detector calibration, and cross-track and stereoscopic viewing modes. The design definition of the Multispectral Linear Array (MLA) instrument has resulted in five design approaches with unique solutions to the MLA instrument requirements. Design definition studies were completed for both free-flyer instruments and shuttle-attached instruments. Results substantiate the feasibility of instrument designs to provide high resolution, radiometrically-calibrated imagery over a 15^{o} field-of-view with four bands in the visible and near-infrared spectrum, and two bands in the short wave infrared region.

In addition, a low-cost, reduced field-of-view (5^{o}) six-band instrument has been evaluated and is being proposed as a near-term development for a shuttle flight in late 1986.

A comprehensive list of mission technology objectives that are considered key to the successful development and flight of an MLA instrument have been formulated and published. Preliminary mission

science objectives have been formulated by the Multispectral Imaging Science Working Group.

These studies have provided design, schedule, and cost information that can be used in preparation of MLA instrument performance specifications for hardware development, and for definition of system parameters for a Land Observing System mission in the late 1980s.

Sponsor: Flight Projects Directorate

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Geopotential Research Mission (GRM)

The GSFC is currently in the planning stages for a Geopotential Research Mission (GRM) formerly known as GRAVSAT/MAGSAT. This mission is to consist of two low altitude (160 km) spacecraft in essentially the same polar orbit with a following distance of 100-300 km. The objective of the mission is to model the fine-scale ($1^{o} \times 1^{o}$) variations in the Earth's gravitational and magnetic fields. The fundamental measurement to be used in this analysis will be the range rate between the two satellites recorded at 4-sec time intervals. With a 6-month mission lifetime, over 3.6×10^{6} measurements would be obtained to estimate the approximately 40,000 $1^{o} \times 1^{o}$ mean gravity and magnetic anomalies covering the surface of the Earth.

Each spacecraft contains a DISCOS system. This is a 140 mm ball inside a cavity that senses the position of the ball. In orbit, the balls are essentially affected by nothing but the Earth's gravity field, which they follow. The spacecrafts are forced to keep the cavities centered around the ball, in all 6^{o} of freedom. The force is provided by reaction wheels and gas jets, especially jets to compensate for air drag at this low altitude. About half the weight of each spacecraft is rocket fuel. A rigid boom attached to one of the spacecraft houses scalar and vector magnetometers.

The GRM is to substantially improve knowledge of the fine structure of the Earth's gravitational and magnetic fields. The Earth's gravitational field contains information about the Earth's distribution of mass and can be used to construct a model of the geoid, which is the equipotential surface that would coincide with sea level if the oceans had not tides or currents and there were no interaction with the atmosphere. Satellite altimetry, in combination with the geoid, which can provide the instantaneous height of the ocean surface, can be used to study global ocean circulation. This is an important factor in meteorological and climatological research. Because the Earth's gravity field reflects the distribution of mass within the Earth, it can be used to explore the existence, form, and scale of convection in the Earth's mantle. Mantle convection is thought to play a major role in the driving of the plates; how and why the tectonic plates move is a fundamental, but unsolved, question in geophysics with important implications for our understanding of the occurrence of earthquakes. In addition, gravity can also be used to study continental and oceanic lithospheric features (such as mountains and ocean trenches) caused by collision of plates, and to study the mechanical properties of the plates themselves.

The Earth's magnetic field is of vital interest in four areas. One is the general orientation of the magnetic field lines as utilized for navigational purposes. Secondly is the temporal variations in the magnetic field that are as much as 7 percent over a ten year period. Third, the anomalies in the field distribution which are related to the geological structure of the anomalous region. Fourth, the temporal magnetic variations in localized regions that have occurred since the Magsat-A Mission that will provide information on the characteristics of the Earth's core.

The simultaneous measurement of the gravitational and magnetic fields produced by the Earth's structure will provide information never before available. On a global scale, this time-correlated information combined with the expected resolution will provide new knowledge of the Earth's structure. Use of data obtained from the GRM is expected to lead to regional identification of non-renewable resources such as petroleum and mineral ores.

Sponsor: Office of Applications

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Solar Maximum Repair Mission (SMRM)

Congress has given NASA approval to conduct rendevous and repair/retrieval of the Solar Maximum Mission (SMM) Observatory after more than four years of on-orbit operation using the Space Transportation System (STS) and the Multimission Modular Spacecraft (MMS) Flight Support System (FSS). The mission is currently manifested with the Long Duration Exposure Facility (LDEF) for STS-13 on April 17, 1984.

The SMM payload consists of seven instruments whose prime objective was the coordinated observation of solar flares in the solar corona during a period of high solar activity. The SMM, which was launched on a Delta expendable launch vehicle on February 14, 1980, was declared a success after more than 7 months of satisfactory scientific observations during which the scientific model of the Sun was greatly enhanced. Around 10 months after launch, underrated fuses in the Attitude Control Subsystem (ACS) Module blew on three of four attitude control momentum storage wheels which caused loss of the precision three-axis stabilization. Since that time, the spacecraft has been placed in a slow spin, approximately 1 degree/second, using a magnetic control mode which permits continued operation of three of the payload instruments while coarsely pointing at the Sun.

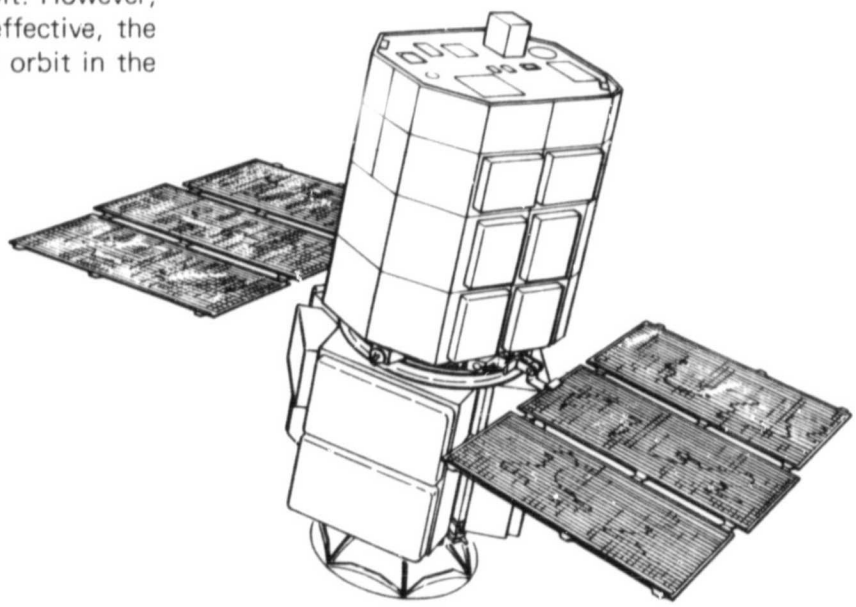
The objective of the Solar Maximum Repair Mission is to return the Solar Maximum Mission Observatory to full operational status and to determine the Space Transportation System capability to retrieve and repair the spacecraft on orbit. However, in event the planned repairs are not effective, the entire observatory will be returned from orbit in the F.S.S.

The pointing repair will be achieved by on-orbit replacement of the MMS ACS Module with a Landsat-D/SMM flight spare. This capability is provided by the modular design of the MMS spacecraft which was the first application of this technique for free-flyer/STS interface compatibility. Replacement of the ACS Module by Extravehicular Activity (EVA) will restore full scientific operation to six out of seven instruments in the SMM payload.

The elimination of operating instrument anomalies is planned by EVA installation of a plasma baffle over the Soft X-Ray Polychromator (XRP) propane bleed port, and replacement of the failed Coronagraph/Polarimeter (C/P) Main Electronics Box (MEB). This will return the SMM Observatory to full operation.

Before the ACS on SMM malfunctioned, the mission had been declared a scientific success. Unique observations of solar flares had been made. A number of these observations have provided new insights into the physics of flares.

Investigators from each of the SMM instrument teams continue working in collaboration with the Goddard Space Flight Center, which operates the SMM Observatory, to understand the full significance of the data thus far collected. Approximately 100 papers have been published or have been submitted for publication on the SMM results to referenced journals. Three of the seven instruments continue to collect significant data. They are the Solar Constant, Gamma-Ray, and Hard X-Ray Burst experiments.



The Solar Maximum Mission (SMM) Observatory on-orbit configuration is to be repaired/retrieved by the Solar Maximum Repair Mission (SMRM)

As impressive as the SMM results have been thus far, one must realize that the investigators were still not yet using the full observing power of the mission when the ACS malfunctioned. This untapped potential should be fully realizable with the renewed mission that will result from the repair activity. Following activation of the Tracking and Data Relay Satellite System (TDRSS), scheduled for STS-6 and -8, the repaired SMM will be capable of supplying high-quality near real-time solar observations on sunside passes. This will give investigators unprecedented capabilities for immediate participation in the conduct of their experiments.

The hiatus, between the first phase of the mission and that which will result from the repair activity, offers two major advantages to the scientific community. First, detailed understanding of the early SMM results will spur the generation of highly refined and well-focussed observing programs for the renewed mission. Second, considering the time in the solar cycle, the payload will be able to pursue several interesting quiet-Sun scientific objectives. Among these will be the investigation of coronal holes, monitoring of solar constant as the cycle approaches minimum and the monitoring of the evolution of the solar corona during the minimum period.

The Solar Maximum Repair Mission is the first practical demonstration of the STS capability to rendezvous and service a free-flyer satellite. Numerous missions, such as Landsat-4, Landsat-D' (LSD'), Long Duration Exposure Facility (LDEF), Upper Atmosphere Research Satellite (UARS), Gamma-Ray Observatory (GRO), Advanced X-Ray Astrophysics Facility (AXAF), and the Space Telescope (ST) have baselined or are considering retrieval and/or servicing for the purpose of refurbishment and reuse.

After the landing, an assessment of long-term space environmental effects on the recovered hardware will be performed and the SMM ACS Module will be reworked to support the requirements of the LSD Program. The magnitude of rework and associated cost of refurbishment will help establish guidelines in planning future reuse of free-flyer spacecraft components and the FSS by other missions. The lessons learned in the course of this mission and in postlanding analyses will help generate improved techniques for the design of future shuttle compatible spacecraft.

The Solar Maximum Repair Mission is planned as a five-day operation with the STS dropping its external tanks in the Pacific Ocean as the Orbiter ascends to the SMM operational orbit by direct injection. The LDEF deployment and STS rendezvous with the SMM Observatory will be at an altitude of 500 + 37 km (270 + 20 n.m.) and inclination of 28.5°. The mission will be launched from Kennedy Space Center (KSC) during the first half of CY 1984. The Orbiter will carry a crew of four and a repair cargo consisting of the full FSS employing Cradles A, B, & A' and its avionics, a replacement MMS ACS Module, two experiment repair kits, two Module Service Tools (MST's), two Extravehicular Maneuvering Units (EMU's), Portable Foot Restraints, Manipulator Foot Restraints on the end of the RMS, and a Manned Maneuvering Unit (MMU).

Phasing of the STS launch window and subsequent STS OMS burns are such that the Orbiter will rendezvous and station keep at a safe distance of about 90 m (300 feet) from the SSM. An astronaut will approach the SMM by untethered flight using a Manned Maneuvering Unit (MMU) equipped with a special trunnion grapple to capture and stabilize the SMM. The Orbiter will then maneuver to within about 9 m (30 feet) of the SMM, where the 15 m (50 feet) long Remote Manipulator System (RMS) will capture the Observatory. The RMS will then berth the SMM to the FSS in the Shuttle payload bay, the MMS umbilical connectors will be remotely engaged, and the spacecraft will be powered off and the batteries taken off line.

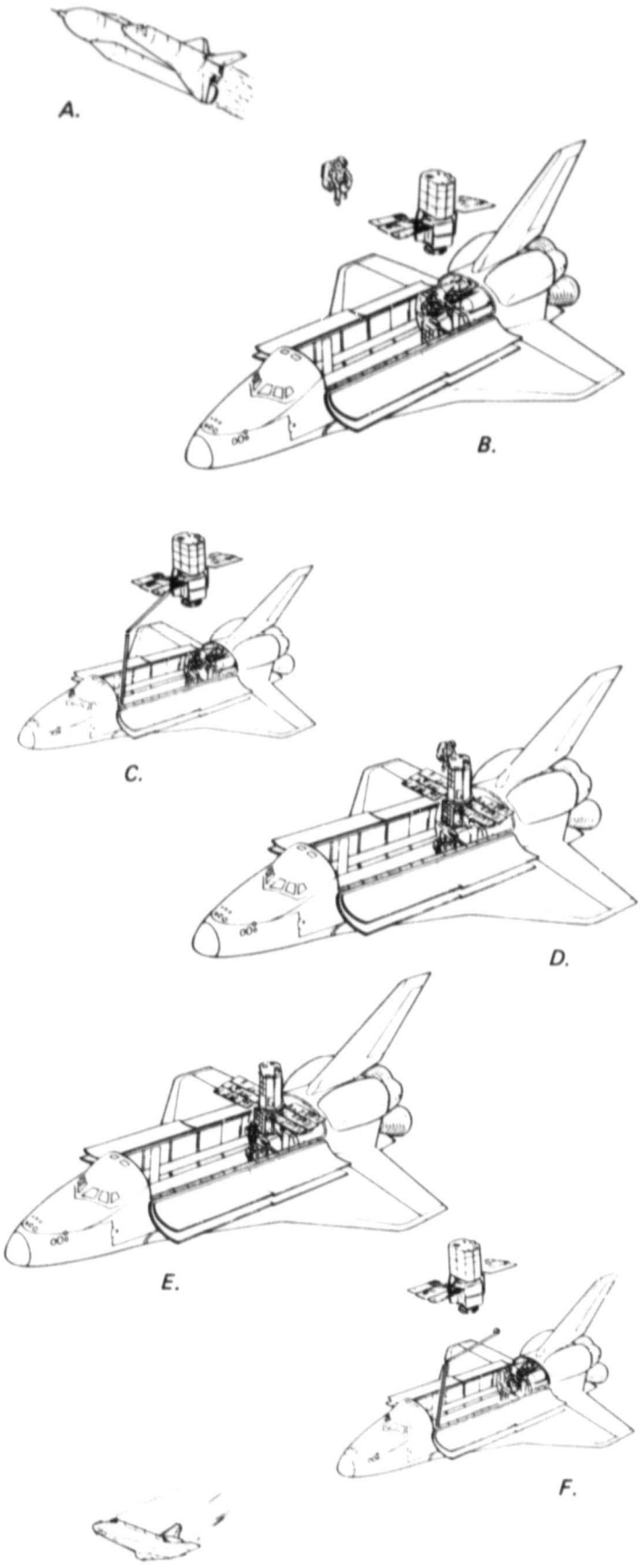
The untethered astronaut with the MMU will next maneuver to a location over one of the solar arrays to install a plasma deflection cover over the XRP propane exhaust port. He will then stow his MMU and join a companion to exchange the ACS module using Manipulator Foot Restraints on the RMS and Portable Foot Restraints and a MST.

The final repair operation performed during the second EVA day will consist of removing and replacing the Main Electronics Box of the Coronagraph/Polarimeter and the panel on which it is mounted. This entails the removal and reinstallation of eleven common "D" cable connectors. The same major EVA service aids will be used. This will conclude EVA activities.

The crew will then reactivate the spacecraft from the Aft Flight Deck. A functional checkout of the SMM will be performed remotely from the GSFC SMM Project Operations Control Center (POCC) as the mission specialists rest.

If sufficient OMS propellant remains, the Orbiter will reboost the SMM towards its initial 575 km (310 n.m.) altitude to provide for extended operations.

Following a final observatory functional check, the RMS will then be used to deploy the observatory



to orbit. The Orbiter will then back away from the SMM, prepare for deorbit, and land at KSC.

Consideration is being given to deployment of the SMM's TDRSS High-Gain Antenna System (HGAS) either just prior to or sometime following the Observatory redeployment.

After landing, the failed Coronagraph/Polarimeter Main Electronics Box, the FSS, and retrieved ACS Module will be removed from the Orbiter, and transported to a hangar for inspection. The ACS module will then be returned to the Module Contractor for testing and refurbishment as a Landsat-D spare. This will allow the first hands-on detailed engineering assessment of the effects of extended spaceflight on satellite hardware. The FSS will be brought back to GSFC and placed in storage until required for the next missions.

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The Solar Maximum Mission (SMM) Repair Sequence of Events.

A. Launch from Kennedy Space Center
B. Rendezvous, MMU Capture, and Altitude Stabilization
C. RMS Grapple
D. SMM Berthing and Experiment Repair
E. SMM ACS Module Exchange
F. SMM Redeployment
G. Deorbit and Landing at Kennedy Space Center

Cosmic Background Explorer (COBE)

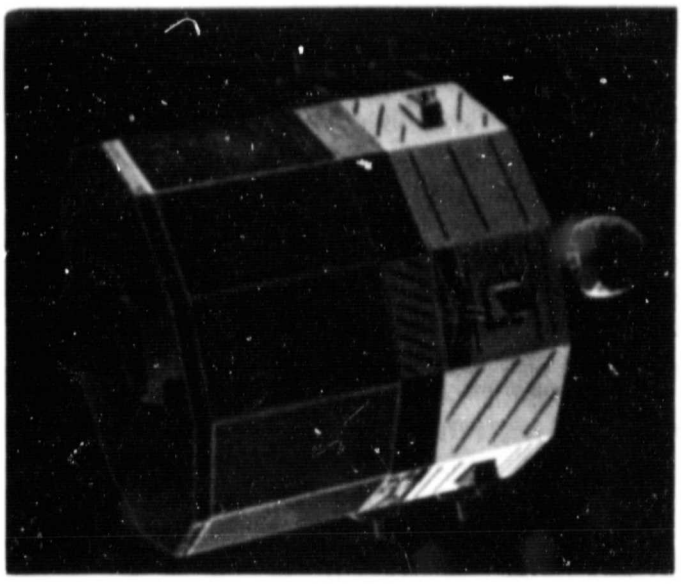
The Cosmic Background Expolorer Satellite (COBE), under study since 1976, is the result of three proposals submitted to NASA in 1974, following Announcement of Opportunity numbers 6 and 7.

The COBE is the first satellite designed specifically for cosmological studies. It will measure diffuse radiations, which can be detected from much greater distances than discrete objects. The most famous diffuse radiation is the 3 K cosmic background radiation, discovered in 1965 by Penzias and Wilson, who were awarded the Nobel Prize in Physics in 1978. This radiation is now believed to be the relic to the big bang, the primeval explosion which began the present phase of the expanding universe. It is known to have a spectrum not far from that of a 3 K blackbody over the range from 70 cm to 0.5 mm wavelength. It is also known to be almost perfectly uniform, as expected from the idea that the universe as a whole is uniform on sufficiently large scales. This idea is a fundamental assumption of cosmology, and the uniformity of the background radiation is its best test. The cosmic background radiation was once the dominant constituent of the universe, controlling the motion and state of the matter. We now observe the same photons, red shifted and diluted by the expansion of the universe.

The Cobe, including the scientific instruments, will be handled in the in-house subsystem procurement mode at the NASA/Goddard Space Flight Center.

Cobe, a single observatory mission, will be launched from the Western Test Range (WTR) by the Space Transportation System (STS) into a parking orbit of about 300-km, with a 99-degree inclination. Cobe will then be placed into a 900-km altitude, Sunsynchronous orbit by an intergral hydrazine propulsion system.

Three Cobe instruments will be operated in a survey mode and the science and ancillary data will be time-division multiplexed to form a single data stream. This data stream will be recorded continuously onboard the observatory and transmitted directly to a ground receiving station once each day. The Tracking and Data Relay Satellite System (TDRSS) will be used to support the mission from launch through shuttle separation, and a multiple access TDRSS S-band link will be used to provide tracking, command, and realtime telemetry capability throughout the mission lifetime. The operation and control functions will be provided using one of the GSFC Multi-Satellite Operational Control Centers. A Cobe Science Data Room will be used to provide each of the experimenters with direct access to all of the observatory data (ancillary and science) for the purpose of data reduction, analysis, and experiment mission planning.



The Cosmic Background Explorer (COBE) designed specifically for Cosmological studies.

During fiscal year 1982, definition studies were completed on the observatory subsystem and the Instrument Engineering Development unit program was initiated on all three instruments.

A second quarter fiscal year 1989 launch is presently planned for Cobe, followed by one year of flight operations and two years of data analysis.

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Multimission Modular Spacecraft

The first production Multimission Modular Spacecraft was successfully launched from the WTR with the Landsat-D Thematic Mapper and Multispectral Scanner payload on July 16, 1982. Early orbit performance of this Landsat-4 spacecraft and instrument

complement has been highly successful.

In addition to the usual three MMS modules, a new PM-IA Propulsion Module, providing 510 lbs. of hydrazene, has successfully raised the orbit from the planned Delta 3920 injection parameters to the operational orbit parameters. In addition, orbit drag makeup burns have been made retaining the desired orbital ground track. This unit has sufficient propellant to permit Landsat-4 to operate for a number of years and then burn back to the Shuttles parking orbit for possible retrieval and ground refurbishment.

The Landsat-D Prime spacecraft has been delivered from the Spacecraft Integration Contractor, Fairchild Space and Electronics Company (FSEC). to the Payload Integration Contractor, General Electric. When this I&T effort is completed, the spacecraft and payload will be canned until needed for a backup mission.

and Co-Investigators. Computer-based remote terminals will be located at each of the Principal Investigators facilities for communication with the CDHF and for performing data analysis.

During Fiscal Year 1982, the flight instrument development phase of the mission was initiated. This new start effort included definition of the Observatory, the ground data processing system, and flight operations support system. During this period, definition of the instruments was finalized and decisions were made to use the Multimission Modular Spacecraft for flight, to implement a dedicated facility for data processing and analysis, and to use institutional facilities for flight operations.

Current project planning is based on launch of the Observatory in the fall of 1988 with 18 months of flight operations and 12 additional months of data processing and analysis.

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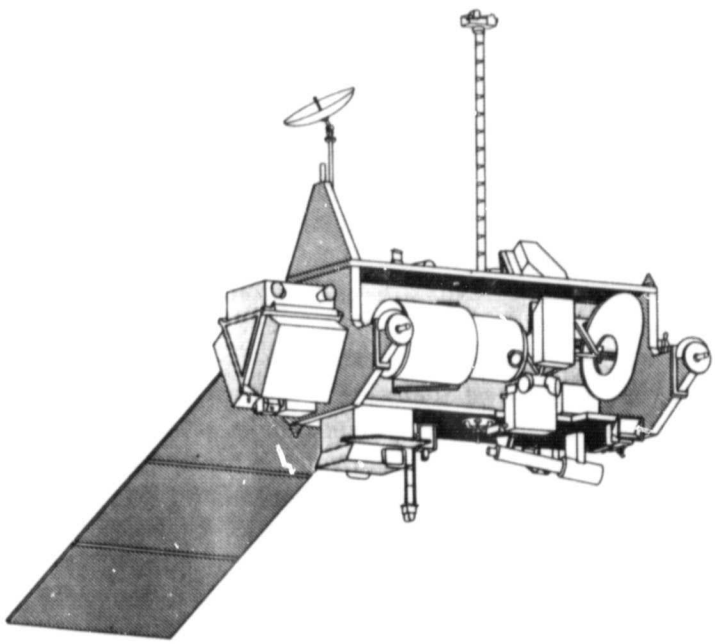
Upper Atmosphere Research Satellite (UARS) Mission

The objectives of the Upper Atmosphere Research Satellite (UARS) mission are to understand the mechanisms that control upper atmosphere structure and variability, assess man's impact on the earth's ozone layer, assess the potential effect of stratospheric change on weather and climate, and develop an effective strategy for stratospheric monitoring.

Meeting these objectives requires coordinated measurements on a global scale of atmospheric chemistry, winds, and energy input. These data will be acquired by a single Observatory containing 11 scientific instruments and orbiting the earth at an altitude of 600 km and an inclination of 57°. Since analysis of coordinated measurements is essential to the mission, a Central Data Handling Facility (CDHF) will be implemented at the Goddard Space Flight Center for data processing and storage. Various levels of processed data will be available for analysis by all members of the UARS Science Team which is formed by a total of 19 Principal Instrument and Theoretical Investigators and a large community of Collaborators



Schematic drawing of the Upper Atmosphere Research Satellite (UARS)

Flight Support System

The Flight Support System (FSS), used for transporting to orbit and for on-orbit servicing and retrieving the Multimission Modular Spacecraft (MMS), is nearing completion and will be systems integrated and tested in CY 1982. This system consists of two major subsystems, the A, B, and A' Retention Cradles and the Payload Berthing and Positioning Platform for adaptation of Cradle A' and the supporting avionics. When completed, these major configuration elements can be operated independently or used collectively as a unified system in the STS orbiter, depending upon the specific mission requirements.

The first application of the FSS will be the recently approved Solar Maximum Repair Mission (SMRM) when the Space Shuttle will service or retrieve the SMM Observatory at an altitude of about 500 km (270 Nautical Miles) in CY 1984.

Also planned is the use of the FSS Cradle A', Berthing and Positioning System and avionics for the servicing of the Space Telescope some three years following its launch.

Other FSS applications under consideration include Landsat-D' deployment and Landsat-D retrieval, GRO, UARS, and AXAF.

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Origins of Plasmas in the Earth's Neighborhood (OPEN)

The OPEN Program is a major new thrust in the study of Sun-Earth relationships. Its goal is to obtain the first quantitative assessment of the global flow of energy through the Earth's space environment above the upper atmosphere. This goal will be accomplished with a network of four spacecraft orbiting strategically in four key locations around the Earth. These space laboratories will provide simultaneous measurements of the charged particle radiation and magnetic and electric forces that transfer, store and dissipate energy throughout the Earth's dynamic space environment.

The OPEN Program will use measurements of the flow of electrically charged gases, called plasmas, between the two principal sources and the two major storage regions in the magnetosphere. One spacecraft, placed sunward of the Earth outside of the magnetosphere, will sample the solar wind gas flowing into the Earth's neighborhood. A second spacecraft, in a high orbit over the poles, will measure the entry of plasma from the second plasma source--the ionosphere--into the magnetosphere. This satellite will also obtain global pictures of the aurora to provide a direct, quantitative measure of plasma energy deposited into the upper atmosphere. A third spacecraft, placed in an elongated equatorial orbit, will measure plasmas and high-energy particles in one of the major magnetospheric reservoirs--a region called the equatorial ring current. The fourth spacecraft will utilize occasional gravitational "kicks" from near encounters with the Moon to keep its orbit in the second major plasma and energy storage region--the long, comet-like magnetospheric tail on the nighttime side of the Earth.

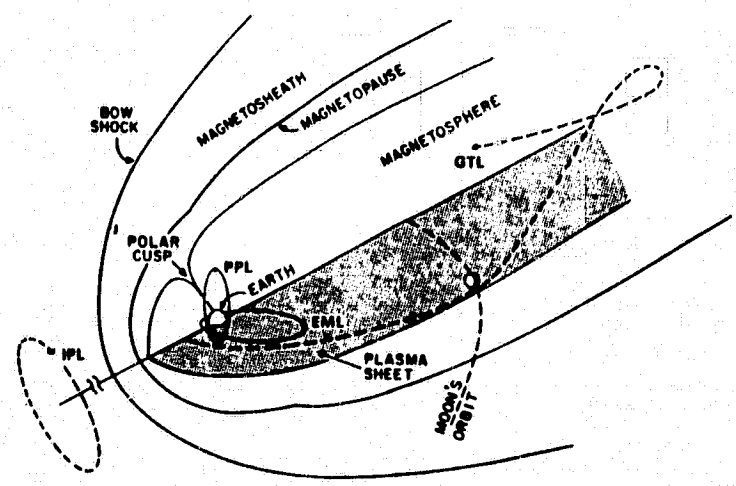

Diagram of how the Origins of Plasmas in the Earth's Neighborhood (OPEN) is designed to operate to achieve maximum results.

During the past year a Science Working Group was formed comprised of the thirty-seven spacecraft instrument, ground-based and theory team principal investigators who were formally selected to participate in the OPEN Program. Working under direction of the GSFC Project Office, this group initiated a series of science instrument and mission definition studies that will culminate in a specific set of science mission requirements and plans. Concurrent with the establishment of the science definition activities, the Project Office completed a study of mission concepts that meet realistic cost constraints without compromising major science requirements, and it initiated a detailed definition phase study of the science data analysis segment of the OPEN Project.

Exploration of the Earth's space environment in the 1960's and 1970's successfully provided a picture of the average shape, size, and structure of the magnetosphere and its boundaries. But there exists no comprehensive, quantitative description of how the various parts of this vast system affect one another as a whole. Earlier studies have produced an essentially static anatomical survey of the Earth's neighborhood. Now, for the first time, the possibility exists to obtain an understanding of the large-scale dynamics--the physiology--of the solar-terrestrial environment. The OPEN Program is designed to accomplish that major step forward.

Sponsor: Office of Space Science and Applications

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Space Tracking and Data Systems

Efficent and reliable tracking, data acquisition and communications are essential for all NASA flight operations if they are to meet their specific objectives. GSFC is pursuing several programs to develop new techniques necessary for the tracking, acquisition, and handling of data from future flight programs.

GSFC

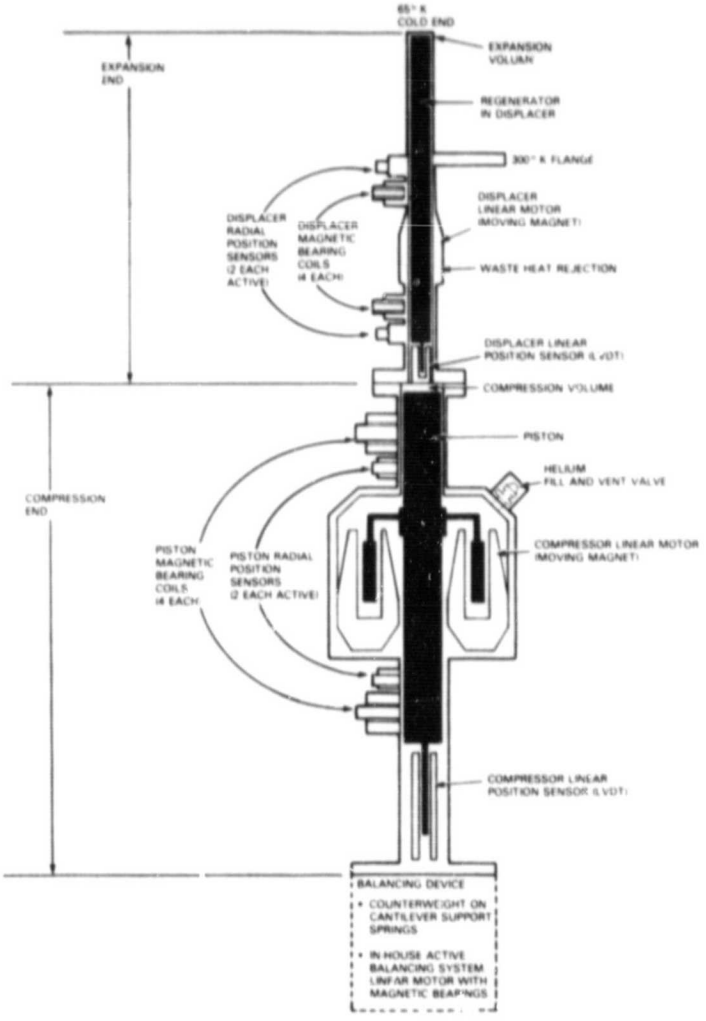
Long-Lifetime Cryogenic Refrigerator

Many space instruments require ultralow temperature cooling to perform their measurements. The Goddard Space Flight Center technology programs are underway to fulfill this need. Of particular importance is the development of an ultralow temperature (cryogenic) refrigerator that will operate in space for 3 to 5 years without maintenance.

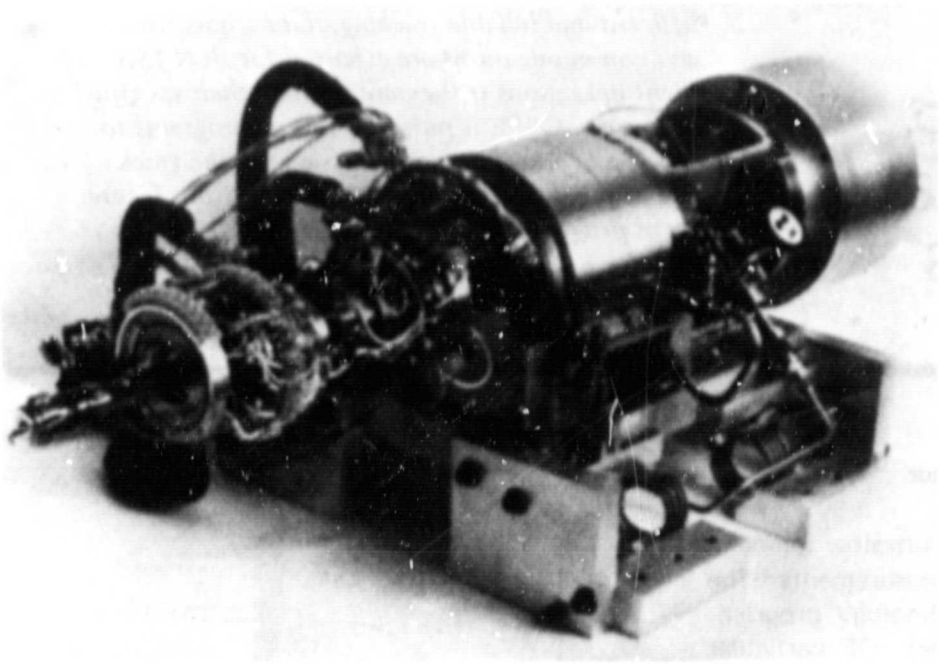
The new refrigerator could be the precursor to future commercial development of pumps, motors, compressors, and other mechanical devices with longer, wear-proof lives less susceptible to failure. It overcomes frictional wear by substituting electronically controlled linear magnetic bearings for conventional sliding or ball bearings so that the refrigerator's components remain levitated and centered in magnetic fields and move without touching the sides of their housing. It also minimizes the chance of mechanical failure by employing a direct linear drive motor to drive its piston and displacer, eliminating the mechanical linkages and drive shaft required by more commonplace rotary motors.

The first unit of the new refrigerator has been tested for over 300 hours. It produces 5 watts of cooling at 65°K (-343°F) while requiring 200 watts of drive power. The magnetic bearings, linear drives, and electronics control are performing in an excellent manner, resulting in a machine that essentially operates without friction and mechanical wear.

The development of a second model of the refrigerator, with improved components, is underway. This unit will take the technology to a flight status. Future work will include the extrapolation of this technology to lower temperature machines.



Single Expansion Cryogenic Cooler with Linear Magnetic Suspension



The Cryogenic Refrigerator developed by GSFC to operate for 3 to 5 years maintenance free

Sponsor: Office of Aeronautics and Space Technology

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Integrated Circuits with Infrared Detector Elements

A new integrated circuit structure consisting of transistors and infrared detectors has been developed. The circuit is a monolithic assembly of signal processing electronics directly coupled to an array of lead sulfide detectors. The detectors are .002" x .002" in dimension or approximately 250,000 elements per square inch. Each detector has at least 2 transistors to control signal flow. The application for this new chip is in infrared imaging primarily in the 1-3 micrometer wavelength region. This wavelength corresponds to thermal imaging that is sensing targets at an elevated temperature relative to the background. Such applications exist in earth observations from space, smoke and fire alarms, military targeting (jet fuselages), and specific wavelength sensing such as the absorption of all but the 1-3 micron light passing through a substance and sensed at the other side.

The technology developed is based on the IC technology used to fabricate sophisticated custom chips for the satellite data control systems. The chips have, until now, been implemented exclusively as miniaturized electronic circuitry. Any imaging experiments (such as the Landsat) would utilize a separate assembly for the detectors. These IC chips would then be used to not only interpret detector signals, but also to control satellite functions such as guidance, data formatting, telemetry, and housekeeping in general. By incorporating detectors directly on the chip, hundreds of interconnecting and generally unreliable wire connections are eliminated. The number of elements and resolution can be dramatically increased and detector quality can be improved.

Current work is now underway to increase the integration of detectors and circuit complexity to achieve a scaled magnitude of 10^6 elements per square inch and 10-20 transistors per element for highly sophisticated signal conditioning and processing.

Sponsor: Goddard Space Flight Center
Director's Discretionary Fund

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IR Detector Arrays - (ARC/GSFC)

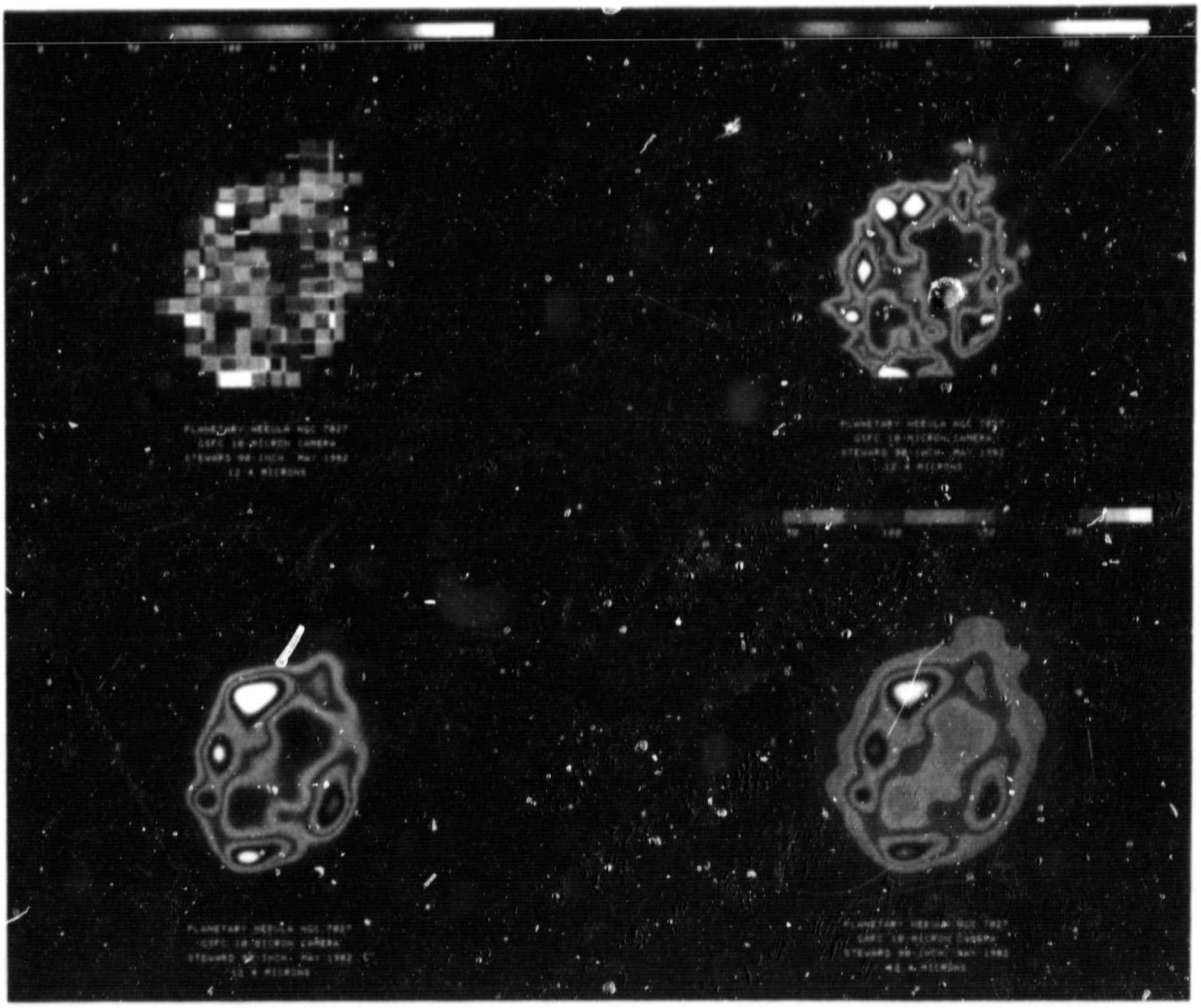
Advanced concepts for space telescope platforms now employ arrays of sensors for image observations. From space, images in wavelength bands outside atmospheric windows will then be possible. The reduced background flux in space will allow observations of many much weaker sources than is possible from comparable ground-based instruments operating in comparable observing time. At shorter wavelengths the spatial resolution will be improved for an instrument of equal aperture due to the removal of atmospheric effects.

In the past year we have developed and operated an imaging infrared camera system designed to address the practical aspects of such advanced concepts in the thermal infrared. This system operated at the telescope Cassegrain focus across a wavelength range of 6 to 13 micrometers.

A possible instrument configuration would place the dewar and electronics up to the microcomputer and mass storage in the spacecraft. The operator in a ground installation controls the instrument at the minicomputer through a user-transparent satellite link.

The present camera operating system allows near real-time image analysis, quick look data check, image data gathering, and preprocessing modes. Current mapping data is stored on a floppy disk for future processing and storage. Optional mass storage is possible with the installation of a suitable system.

The data was processed by team coinvestigators at the Smithsonian Astrophysical Observatory, from data tapes generated during a field test in November 1981. Recently we have implemented AIPS software on a VAX 11/780 computer. AIPS allows similar image analysis, display, and tape file generation to a FTIS format allowing wide distribution to potential



A photograph of a Planetary Nebula (NGC 7027) taken with the 3-meter RTF Camera.

system users. Currently our attention is concentrated on the development of focal plane arrays and high-yield reliable hybrid assembly techniques fo focal plane electronics.

Sponsor: Office of Aeronautics and Space Technology

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Microwave/Optical Components and Techniques

Technology is being developed that will result in space communication systems capable of transferring data at rates of thousands of megabits (gigabits) per second. Such systems will be necessary to relay large quantities of data from earth orbiting instruments to the data user. To develop such systems, hardware is being developed in the areas of spacecraft frequency sources, modulator/exciters, high power transmitter amplifiers, low noise receivers, and other advanced subsystems including antennas.

In the area of frequency sources, five hybrid microwave circuit Shallow Bulk Acoustic Wave (SBAW) oscillators have been developed. SBAW oscillators show promise for spacecraft applications as they are not as bulky as conventional crystal oscillators followed by multiplier chains.

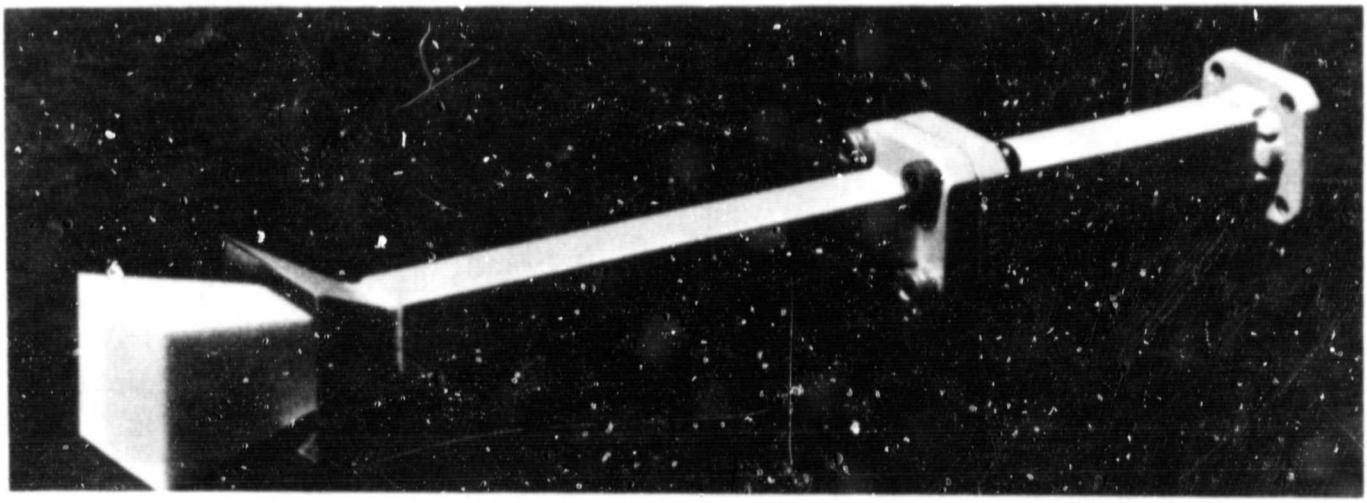
A breadboard feasibility model 60 gigahertz (GHz) modulator/exciter has been completed. This unit is capable of transmitting digital data at rates of up to 4 gigabits per second.

High power solid-state amplifiers for transmitter applications are also being developed. An amplifier operating at 15 GHz using Gallium Arsenide field effect transistors has been completed. A high power amplifier to operate at 60 GHz has been designed using the IMPATT (Impact Avalanche Transit Time) device.

Low noise, wide band receivers have been developed for operation at 15 and 30 GHz using Gallium Arsenide field effect transistors. These receivers exhibit state-of-the-art performance in terms of their sensitivity. At 60 GHz, where field effect transistors exhibit poor performance, an integrated receiver using a mixer has been developed. To develop extremely low noise receivers, several superconducting tunnel junction devices have been produced, and RF mixing at 115 GHz has been achieved. Theory and recent experimental results show that such devices can have a sensitivity approaching the fundamental quantum noise level.

In the area of high technology antenna development, a computer model has been generated and a series of dielectric waveguide horns have been mathematically modeled and fabricated. Such antennas should be small in physical size and also less expensive to fabricate than those made of conventional horn materials.

Finally, some preliminary work was completed which should result in the development of optical (laser) high data rate communications systems for space flight applications. Investigations were conducted in power combining techniques and methods of coupling semiconductor lasers to single mode fibers.



Assembled 30 GHz Dielectric Horn with metallic waveguide transition and launcher.

Sponsor: Office of Aeronautics and Space Technology

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Advanced Heat Transport Devices

Heat transport in space with the absence of gravity and natural convection presents difficulties when trying to maintain adequate temperature control of spacecraft and their components. As in the case of the Space Shuttle, pumps, consuming large amounts of power and susceptible to breakdown, are used to transfer coolant between user stations. In addition, these systems use liquids in single phase, well below their saturation temperature. The disadvantage of this system is that temperature rises in the loop as more and more heat is added. This change in temperature from point to point presents problems to users who want to be held at a constant temperature regardless of location in the system. Also, single-phase systems preclude both heating and cooling provisions.

To answer future needs in space stations of higher power transport at constant temperature with high reliability, low power, and the ability to heat and cool, two phase systems are being researched at GSFC. By taking advantage of the heat of vaporization of refrigerants, such as freon and a small pump to overcome the lack of gravity, these goals can be attained. The power of several kilowatts can be transferred into the heated section or out through cooled sections over 20 meters (64 ft.) in length with little or no change in temperature. Another system uses the capillary forces of a wick and offers the same capabilities with no moving parts. Both of these systems show promise for ground base application where the cost of maintenance of large pumped systems and the associated energy to run them becomes a factor.

Sponsor: Office of Aeronautics and Space Technology

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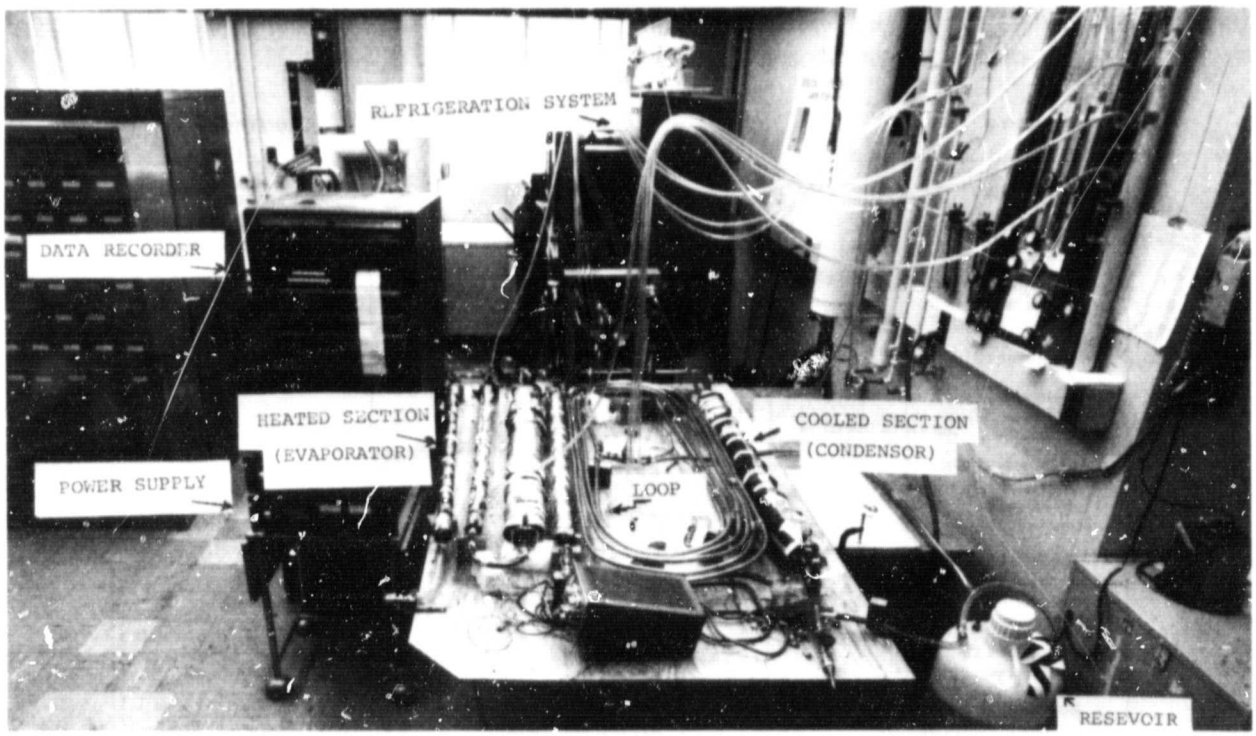

A pumped two-phase system with both heating and cooling sections currently being investigated.

MISSION AND DATA OPERATIONS

The objectives of the GSFC's work in this area are to provide the new concepts and design base required for the effective implementation and operation of near-Earth mission control and data processing systems during the 1980s. Principal related activities during the past year addressed systems management, software development, man/machine interfaces, attitude/orbit determination, image processing, and mission control.

Systems Management

The Systems Management research activity is addressing a number of different problem areas with respect to system planning, cost estimating, implementation, and modeling. Its objectives are to develop an understanding of system problems and to develop appropriate tools to aid in the resolution of system planning, cost estimating, implementation, and modeling problems.

In the system planning area this research activity has developed a methodology for designing and assessing ground system configuration concepts. During the last year, the basic methodology was exercised on several different flight project scenarios resulting in the generation of an "ideal" system model. Presently, an overall transition plan for the incorporation of the appropriate aspects of the model into mission and data operations is being developed.

In the system cost estimating area, research activity is focusing on the development of a simplified cost and time model which facilitates the study of ground system alternatives for new spacecraft, permits cost-requirement trade-off analysis, and aids in risk assessment. This system tool focuses on optimizing the decision-making process for the design of new space/ground systems.

In the system implementation area, research activity is focusing upon the development of automated requirements generation tools. Initial work is proceeding on the automation of feasibility study generation which will be expanded to a more general requirements generator capability.

In the modeling area, research activity is focusing on Local Area Network (LAN) modeling and mission planning modeling. These two areas are key to large system automation activities in future mission and data operations support.

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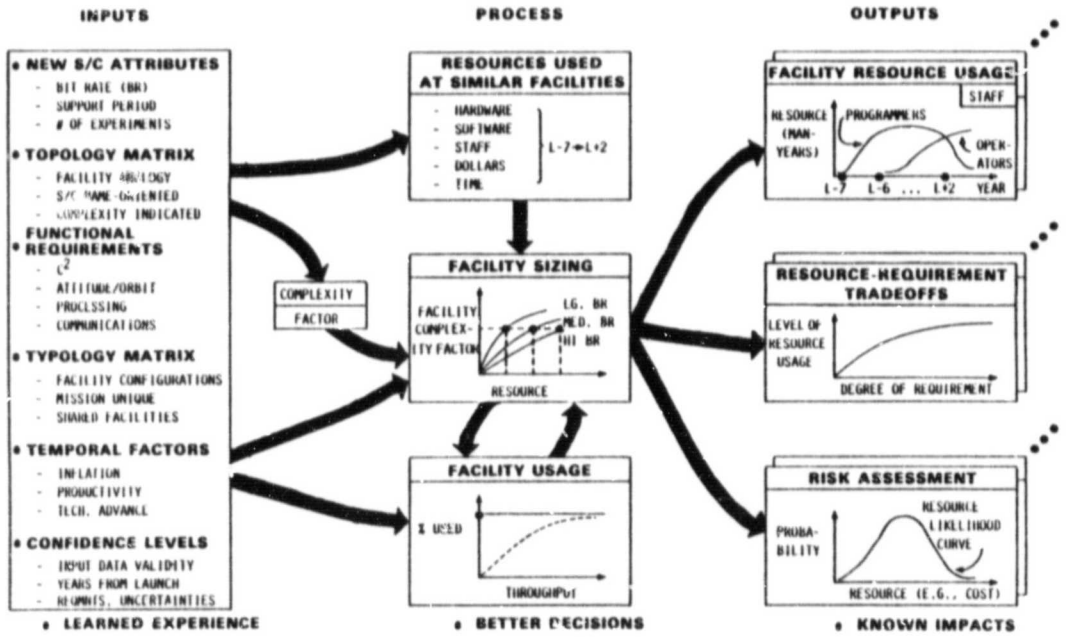

Simplified Cost and Time Model (SCAT) facilitates the study of ground system alternatives, permits cost-requirements track-off analysis, and aids in the risk assessment.

Software Development

One concern that must be continually addressed for software development environments is to determine which (if any) software approaches or methodologies favorably impact the development process. During this past year, continued experiments within the Software Engineering Laboratory (SEL) led to a major upgrade of the document "Recommended Approach to Software Development." This document is now the standard followed by all software development for flight dynamics, and the favorable impact of these standards is evidenced by a significant productivity increase during development as well as the increased reliability of completed projects.

In addition, several other documents which report the impact (both favorable and unfavorable) of various software approaches have been completed or are under development. These include the evaluation of independent verification and validation to support the software development measures for flight dynamics project. The measures analysis will provide the basis for assessing software quality early in the development process.

During the coming year several new experiments will be conducted. One will utilize the approach of rapid prototyping which has become a very publicized technique for developing medium to large-scale software systems. A detailed set of measures and software probes will be developed so that a realistic assessment of the usefulness of this approach can be made. It is anticipated that guidelines for applying (or avoiding) the technique of rapid prototyping will then be developed.

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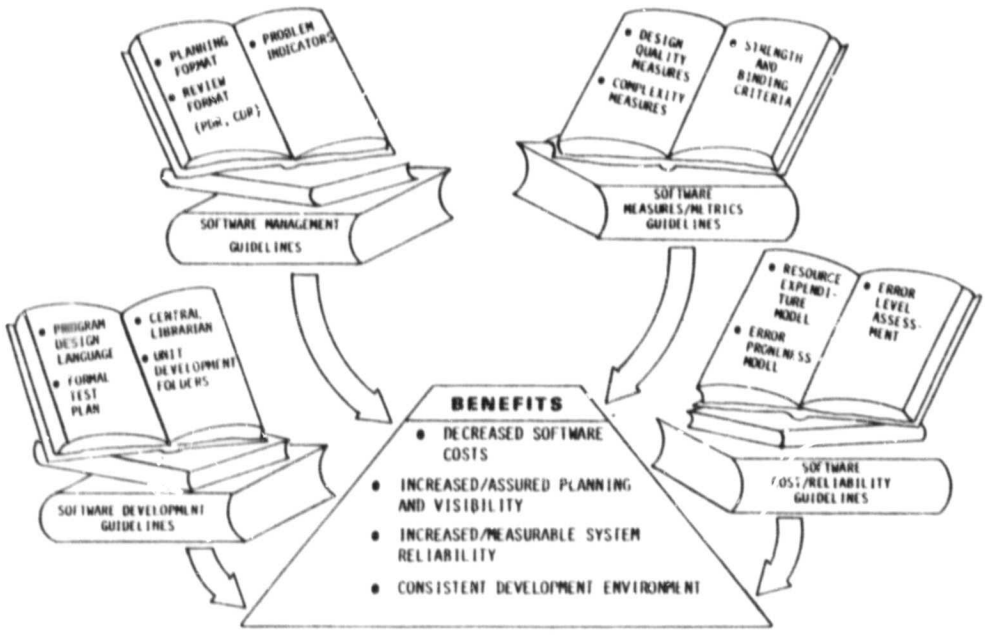
Man/Machine Interfaces

The two major objectives of the current man/machine interface research activities are to (a) develop and apply "natural" man/machine interfaces for space payload and ground control systems and (b) develop a methodology and guidelines, emphasizing human factors issues, which will be used in the design and implementation of such interfaces.

To support these objectives three major thrusts have been identified. These are voice/touchtone input/output machine mechanisms to support a natural user/computer dialog with mission and data operations systems; development of man/machine interface mechanisms stressing human factors considerations for large-scale real-time information storage and access for mission and data operations systems; and the implementation of a human factors laboratory to



Planned Software Guidelines aid users in selection of appropriate management, development, and measurement methodologies and techniques.

perform feasibility experiments, demonstrate interface concepts, and establish cost and performance parameters for application-directed, near-term operational concepts earmarked for incorporation into mission and data operations systems.

Subsequent to the development of the microprocessor-based audio and touchtone interface system, a management message generation/retrieval system will be developed. This system will integrate a voice storage and retrieval system into the GSFC electronic mail system. This management message generation/retrieval system will give managers mobility in that the managers will be able to access this management generation/retrieval system from any touchtone telephone.

The continued development and transfer of human factors technology and standardized information storage/access/manipulation mechanisms into the mission and data operations environment will represent a major improvement in man/machine interfaces with the numerous operational data/information bases required for efficient and effective operations.

The human factors laboratory will provide the appropriate workbench environment to support the research and development efforts needed to facilitate the implementation of advanced man/machine interfaces for near-term application in the mission and data operations environment.

Sponsor: Office of Aeronautics and Space Technology

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Attitude/Orbit Technology

Orbit and attitude computations have traditionally been performed on large, mainframe computers primarily due to the large data bases and the complex models required in the computations. Recent advances in microelectronics hardware have opened the door to performing these computations in distributed mini and microcomputers which may be onboard the spacecraft or at distributed locations on the ground.

To take advantage of these hardware technology breakthroughs, the GSFC engineers are developing data processing techniques and breadboard orbit and attitude systems which may be placed onboard the satellites or at distributed ground locations such as the control centers. During 1982, such microprocessor-based orbit and attitude systems were developed. An evaluation of the timing, accuracy, and applicability of these systems is underway.

Improved attitude determination accuracies driven by advanced image processing requirements and Charge-Coupled Device (CCD) star trackers leads to the investigation of star identification algorithms and processing requirements necessary to meet the accuracy constraints.

The above technology advances are also applicable to the attitude determination and control of a space platform and the precise pointing of multiple independent instruments.

Sponsor: Office of Space Tracking and Data Systems

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Image Processing

By the late 1980s or early 1990s, sensors of the Multispectral Linear Array (MLA) type may produce 10^{10} or more bits of data per Landsat size (185 km x 185 km) scene. Approximately 15 2400-foot reels of standard 1/2-inch wide computer tape recorded at 6250 bpi would be required to store a single scene containing this much data. Handling data files this large represents a major data storage problem both for NASA's image processing and archival storage systems and for the end user.

In order to provide a solution for this problem, NASA is supporting the development of computer-compatible digital optical disk recorder/reproducers. These devices use laser light to record more than 10^{10} bits of data on a single surface of a 12-inch (or 14-inch) disk coated with a thin layer of optically sensitive material. Cost projections indicate that digital optical disk recorder/reproducers will be similar in cost to the High-Density Digital Tape Recorder/Reproducers (HDDTR) currently used in NASA's image processing systems and that media cost will be significantly less. In addition, read-only digital optical disk units are projected to be similar in cost to standard computer magnetic tape units, thus

providing data users reasonably priced data retrieval devices capable of handling 10^{10} bit files of data.

A detailed systems design for such a computer-compatible optical disk system optimized for use in an image processing environment is being defined under a current NASA contract. Particular emphasis is placed on developing a "smart" optical disk controller which will minimize the complexity of the hardware and software interface between a host computer and the optical disk system. The system design resulting from this effort will be used to implement a prototype optical disk system to be demonstrated on a research and development image processing system at NASA/Goddard Space Flight Center. Delivery of the prototype is scheduled for late 1984.

Sponsor: Office of Space Tracking and Data System

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Mission Control

The Multisatellite Operations Control Center (MSOCC-1) at the GSFC is the control center facility for many near-Earth flight programs. The control center uses several computer systems and display devices that must be rapidly reconfigured from one spacecraft support configuration to another, as required for associated spacecraft passes. During the past year, related research activities have been directed toward both the display changes and the automation involved in the reconfiguration of support equipment. Up until now, all displays have been in black and white and without graphics capability. Research has been undertaken to assess advantages and problems of color displays along with techniques for presenting data in different ways using the graphics capability of the new MSOCC equipment.

A selected Command Management System (CMS), a large mainframe computer, aggregates investigators requests for mission control and merges and tests these requests against spacecraft and communications constraints to evolve one uniform uplink to an onboard spacecraft computer. Due to hardware limitations, this approach allowed little user-oriented software which operated in an on-line interactive mode. With the advent of inexpensive general-purpose microcomputers, it is possible to provide the end user of the CMS many on-line preprocessing functions without the need for a large mainframe computer to support the on-line processing. During the past year, a prototype distributed CMS system has been developed and tested linking a micro with a mainframe computer. Such a system has the potential not only to offload many of the mainframe computer functions but can also optimize the response time and performance of processing tasks required for user decisions.

Sponsor: Office of Space Tracking and Data Systems

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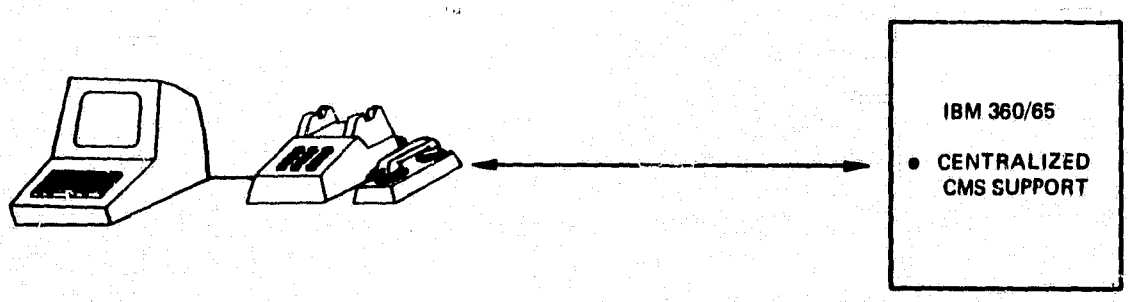

Distributed Command Management Illustration

TDRS-A Spacecraft

The TDRS-A spacecraft, being developed under a Telecommunications Service contract with Spacecom, is being readied for a Shuttle launch on January 20, 1983. This constitutes the first of four planned launches that will produce a Tracking and Data Relay Satellite System network capable of supporting STS and free flyers over the next 10-year period. The ground element of this telecommunications service is located at White Sands, New Mexico, and will constitute one of the most advanced computer automated switching centers in existence. The TDRSS Network Control Center, located at the GSFC, will provide the most sophisticated computer automated scheduling and monitoring capability ever produced by NASA.

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Network Support of the Shuttle Orbital Flight Tests (OFT)

With the precision landing of Columbia on July 4, 1982, the GSTDN completed nearly flawless support of the OFT program. This support was in addition to the normal support provided to satellites already in orbit. It was necessary to make some Shuttle-unique augmentation to the network primarily in the voice and command area. It was necessary to augment geographic coverage before STS-1 with the addition of UHF voice facilities at Dakar on the west coast of Africa, Seychelles in the Indian Ocean, Botswana and Yarragadee in Australia. The Dakar station was upgraded to full S-band capability just prior to STS-4 because of the due east launch azimuth.

A major challenge to the Network was the requirement to attain and maintain angle tracking precision and accuracies on fairly old antennas equal to or even better than original performance. This performance had not been required since Apollo days. This was attained by carefully modeling the errors of each antenna and correcting angle data in real-time with the computer in the tracking data processor.

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The Communications Link Analysis and Simulation System (CLASS)

The Networks Directorate's Communications Link Analysis and Simulation System (CLASS) is an end-to-end communications link analysis tool for evaluating user link performance as well as TDRSS user toll/or TDRSS system or subsystem performance. To perform an analysis, the system simulates all user and TDRSS communications system elements, user vehicle dynamics (orbital and attitude variations), and the communications environment (including radio frequency interference (RFI)), atmosphere effects and self interference from other system users. The atmospheric and launch dynamics analysis capabilities of the CLASS are expected within the next year. These analyses can be performed for all TDRSS user links, forward (command) and return (telemetry), including links which are not fully compatible with the TDRSS requirements.

To facilitate the operation of the CLASS, which is a large software system, and to provide timely analysis of TDRSS user links, a dedicated computer facility has been implemented. The CLASS computer system is built around a Perkin-Elmer 3244 supermini central processor unit with four megabytes of directly accessible solid-state memory. Interfaced with the 3244 is a 300 megabyte disc drive, a magnetic tape drive, a medium speed line printer, and ten remote terminals. The entire system is operator controlled via a master video display unit. Application programs can be written in FORTRAN, COBOL, PASCAL, and Assembly language.

The CLASS system is currently being utilized to evaluate communications system performance for TDRSS users such as Landsat-D, Space Telescope, and Shuttle. The system is also being employed to evaluate the potential performance of TDRSS user system components which are currently under development. These components include switched beam antennas, the NASA standard transponder, and Ku-band transmitters. Other types of analysis for which the CLASS system is currently being employed

are: the development of revised user signal distortion limits, evaluation of the TDRSS user coding techniques, and evaluation of TDRSS system performance test data.

Sponsor: Office of Space Tracking and Data Systems

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Automated Documentation Center

The Documentation Section of the Networks Directorate has designed and implemented an Automated Documentation Center (ADC) to facilitate the timely cost-effective production of the engineering, operations, and management documentation required for GSFC programs. The ADC integrates turn-key word processing, computer-aided design and drafting systems, and telecommunication technologies to provide the following services.

- Interactive design and production of fabrication drawings for electromechanical equipment
- Automated design of printed circuit boards
- Creation and modification of document illustrations including exploded views
- Access through telecommunications to existing documentation data bases
- Linkage of contractors and government agencies through telecommunications to a central documentation production facility ensuring consistant presentation of all documents
- Electronic merging of text and illustrations to provide a single data base suitable for output on electronic laser printers or phototypesetters
- Dissemination of documents and management information through telecommunications.

This integration of technologies, unique within NASA, ensures that data processing and telecommunication technologies utilized by the Documentation Section improve the delivery of services and quality of program management as mandated by the Paperwork Reduction Act of 1980. Expanded capabilities will include the direct telecommunication of complete documents including complex drawings to the point of need including the printing of paper copies only in quantities needed. It is clear that the role of paper is changing from that of a continuous information exchange medium to only a medium of input and output. In many cases, intermediate steps can be pursued more effectively through electronic systems and telecommunications. Today paper is necessary as the final product; the concept of demand printing assures that even for complex documents, the paper output will be created only when needed and in the quantities required.

Sponsor: Networks Directorate

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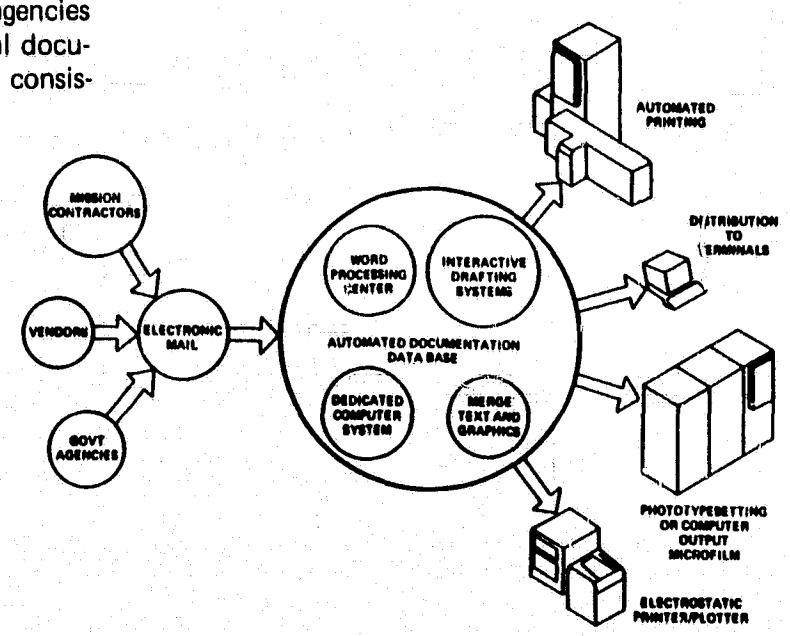

The Automated Documentation Center was designed to facilitate cost effective production of the engineering, operations, and management documentation required for GSFC programs.

The Radio Frequency (RF) Simulations Operations Center (SOC)

A major limiting factor for conducting simulations is that the Project Operations Control Center (POCC) and the Ground Spaceflight Tracking and Data Network (GSTDN) are not available for early premission testing. The Simulation Operations Center (SOC) was established to alleviate the problems that occur in scheduling the simulations required to debug software and to train personnel on the GSTDN and in the POCCs on mission procedures.

When the SOC is required to simulate a POCC, a unique program is developed for the SOC's minicomputers to formulate command, control, and TLM verification and display-system operations. The simulated POCC usually works with the portable simulation system (PSS) located at a GSTDN station, representing the spacecraft, to obtain a complete exercise of POCC/GSTDN interface.

Simulating the POCC achieves the following objectives:

- Fault isolation and detection.
- Monitoring network support performance during mission simulations.
- Mission simulations exercises without interference to the POCC real-time operations.
- GSTDN personnel training.

The same type of computer used for the POCC simulations is programmed to simulate a GSTDN station's telemetry and command-data interface. The simulator, an integral part of the SOC, has the capability to conduct data flow simulations via NASCOM with any network user organization having a communication interface with the GSFC.

A significant new capability, the RF SOC, has been developed during this year. The RF SOC is a fully instrumented spacecraft transponder designed to communicate directly with two of the Tracking and Data Relay Satellite System (TDRSS) satellites. This transponder and its antenna is located at the Goddard Space Flight Center (GSFC). When an RF connection is established with the TDRS, the SOC and the RF SOC systems work as an integrated system, exercising the entire data path for the simulated mission. This path is up through the TDRS in synchronous orbit, down through the White Sands Ground Station, and then through the NASCOM circuits back to the GSFC and into the SOC. The system can receive any standard forward link and transmit any return link, simulating any response that the TDRSS era spacecraft is capable of producing. These simulated telemetry responses are generated by the minicomputers located in the SOC. The signals emitted by the RF SOC can be controlled, varied, and verified to a greater extent than is possible with an actual spacecraft. These simulations can be performed prior to launch to aid software development and to prove system integrity. Simulations performed after launch will provide a direct basis of performance comparison.

Sponsor: Networks Directorate

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High-Density Digital Magnetic Tape Recording for Mission Support

The technology of magnetic tape recording of scientific data has evolved from the recording of analog signals at frequencies up to 250 Hz in the early sixties, to the present day systems able to record digital data signals at rates exceeding 200 million bits per second (MBS).

The real challenge to the evolution of high data rate recording came about with the need to record very high data bit streams such as those generated by Seasat and Landsat scientific experiments. Seasat required 120 MBS record rate and Landsat required a record rate from 15 MBS to 85 MBS. NASA personnel, working with industry, developed specifications that led to the development of reliable High-Density Digital Recorder (HDDR) systems, capable of recording data rates satisfying all anticipated requirements through the 1980s.

High-density digital recording offers several significant advantages over conventional analog recording methods. The data is recorded in a format that is compatible with electronic data processing equipment, and the data is reproduced with a high degree of accuracy, with little degradation due to the effects of tape flutter and time base error. With the use of an appropriate error correction system, bit error rates less than one error per ten million bits can be achieved. The most significant advantage of the HDDR system is its ability to record extremely high packing densities up to 45,000 bits per inch per track.

The HDDR systems currently supporting Landsat and those installed at the White Sands Network

Ground Terminal (WSNGT) in support of TDRSS are configured in a parallel format. The high data rate serial bit stream to be recorded is electronically converted within the HDDR to parallel streams of bits and is recorded on a number of tracks across the tape width. In the reproduce process, the data is reassembled and output as a serial data stream representing the original input data.

HDDR magnetic tape recorders will be the principal recording systems of the eighties. Data transfer rates in excess of 450 MBS are practical. Advanced recorder systems have been demonstrated with data transfer rates as high as 600 MBS. Magnetic tape and recorder technology have not yet reached the practical limits of their capability.

Sponsor: Office of Space Technology and Data Systems

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In-Flight IFR Procedures Simulator

A desktop flight simulation device was modified and installed in a Cessna 172 aircraft for use in training student pilots in the performance of instrument flight rule procedures. The pilot and simulator performance were recorded in-flight for later ground-based analysis. This effort conspicuously demonstrated both the technical feasibility and operational practicability of such a training innovation in significantly reducing costs and hazards inherent in conducting this training by conventional means. The activity was recently completed with the issuance of NASA TM-73292, which describes the equipment and summarizes the results.

Sponsor: Wallops Flight Center,
Director's Discretionary Fund

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Global Positioning System (GPS) Timing Receiver

In support of NASA's Crustal Dynamics Program to increase knowledge of the dynamics of the Earth's crust, the Goddard Space Flight Center, in a joint program with the Naval Research Laboratory has developed a GPS timing receiver to synchronize the clocks of worldwide remote laser ranging stations to within several hundred nanoseconds for correlation of laser data with time.

The GPS is a Department of Defense satellite navigation system which will consist of a constellation of 18 space vehicles, 6 in each of the 3 orbital planes.

The GPS timing receiver is a microcomputer based system that receives, processes and displays GPS time data from any satellite in the GPS constellation. To perform a satellite time transfer with GPS, pseudo-range measurements are made that consist of the signal propagation delay plus the difference between the GPS satellite clock and the GPS ground station receiver reference clock. Data from the satellite are automatically processed to obtain satellite position and satellite clock information.

Use of these timing receivers at the laser tracking sites will essentially remove timing errors from the analysis of the Earth's crustal motion.

Sponsor: Office of Space Tracking and Data Systems, and the Office of Space Science and Applications

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Severe Storm Dynamics

An investigation into the nature and structure of severe convective storms is underway at the Wallops Flight Center facility. Two separate high-power, high-precision, ultra-sensitive radars are being used to measure precipitation levels and line-of-sight velocities within storm cells. One of the radars, operating in the UHF frequency band, is particularly well-suited to detect the presence of lightning channels within the storm. This information, combined with data from instrumentation which measures the location of cloud-to-ground, as well as cloud-to-cloud and intra-cloud lightning activity, gives an unprecedented picture of the relationships among the various elements

of a storm. Other instrumentation measures the changes in the electric field of the Earth during thunderstorms and electrical signature of individual lightning strokes at several different frequencies.

Information collected is already being used to identify regions within storms that might be particularly hazardous to aircraft operations.

Sponsor: Goddard Space Flight Center, Director's Discretionary Fund

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Aeronautical In-Flight Data Processing Systems

A research activity has been initiated to demonstrate the feasibility and utility of an airborne digital flight data processing system for improved safety and cost savings in applications in the NASA aircraft inventory. The effort will utilize advanced technology developed in related NASA research to monitor in real-time aircraft performance parameters to evaluate engine and airframe performance characteristics. The data will be analyzed and evaluated to assess the safety, practicability, and economic benefits of such a system compared to the traditional operational and maintenance techniques.

Sponsor: Office of the Chief Engineer

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Effects of Heavy Rain on Aircraft Aerodynamics

A research project has been initiated to investigate the characteristics of water films on aerodynamic surfaces and to evaluate the effects of the moisture generated roughness on the performance of lifting surfaces. The project involves both experimental aircraft water film measurements along with wind tunnel testing of airfoil elements in a simulated rain environment.

Sponsor: Office of Aeronautics and Space Technology

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Automated Pilot Advisory System (APAS)

An experimental APAS was developed and operated by Wallops personnel to demonstrate the feasibility of using a low-cost completely automated system to provide airport and air traffic advisory information at uncontrolled airports. Successful demonstration activities were conducted both at Wallops and at Manassas, Virginia, in a high-density general aviation situation. This activity was recently completed with the results published in NASA TM-73296.

Sponsor: Office of Aeronautics and Space Technology

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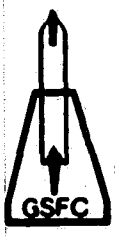
Space Technology

The Space Technology Program at GSFC is directed toward providing advanced technology for handling data from future space missions and for making maximum use of space technology for the benefit of mankind. Programs have been focusing on long range requirements in data systems technology and new technology development.



SPACE TECHNOLOGY

The Space Technology Program at GSFC is directed toward providing advanced technology for handling data from future space missions and for making maximum use of space technology for the benefit of mankind. Programs have been focussing on long-range requirements in data system technology and automation and related new technology developments.

Data Systems

Several projects were initiated in FY81 for the development of technology for advanced data systems to improve NASA's data handling and mission operations capabilities in future flight missions.

Data Systems Research and Technology

The Data Systems Research and Technology Program develops and demonstrates systems technology and techniques which can enable more efficient and effective transfer of useful data from the sensor to the user, extraction of information by the user, and exchange of information between users.

In the area of systems studies, two major activities were initiated in FY82. The first addresses data system concepts for the Origin of Plasmas in the Earth's Neighborhood (OPEN) and Upper Atmosphere Research Satellite (UARS) missions with the goal of identifying areas where costs could be reduced by using a common design. The second study area is examining alternate data system concepts for a manned space station in order to identify key technology needs.

Development continued in FY82 on the Massively Parallel Processor (MPP), a special-purpose computer with an architecture of 16,384 processing elements arranged in a 128-by-128 array. The MPP is a single-instruction multiple-data stream system operated by an array control unit which provides identical control signals and memory addressing to all processing elements. Processing speeds of up to a billion operations per second will afford rapid and economical extraction of information from data, especially data in the form of an image. Custom-designed Very Large Scale Integrated (VLSI) circuitry forms the building blocks of the processing array. Each MPP VLSI chip contains eight processing elements composed of 8,500 transistors requiring 300 milliwatts of power at 7 volts. During FY82, the processing-element chips have been produced, and the system is being assembled. In FY83, the resultant prototype processor will undergo testing as a demonstration and research system for government, academic, and industry use to verify new applications and algorithmic approaches in large-scale parallel computing.

Research and development in Data Base Management Systems (DBMS) also continues in FY82. DBMS systems underwent comparative analysis, evaluation, and performance testing to determine the effects of varying data base designs and computer operating system parameters. Detailed design was completed for a Packet Management System (PMS) to catalog, store, and retrieve packetized spacecraft data ingested into a data system configuration at rates up to 50 million bits per second. The PMS will be implemented and tested in FY83.

Sponsor: Office of Aeronautics and Space Technology

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Automation

An Automation Program has been established tc help provide NASA with a full understanding of knowledge-based systems technology and to provide, via prototype applications, a demonstration of its potential in the area of command and control system. Basic technology is required in automated planning, decision making and problem-solving, knowledge-based systems, machine perception, and machine learning to expand the applications of computer-based automation in the space program. Specific targets include demonstration of the feasibility of knowledge-based approaches for automating major command and control functions and to demonstrate the feasibility of improving mission operations productivity and effectiveness by application of expert-system technology.

Establishing a knowledge base and the corresponding inference mechanisms that use it are two basic capabilities that are required for any successful application of expert systems. There is growing interest in the use of expert systems within NASA; and in order to provide support for the appropriate introduction of these systems in various operational environments, an overall methodology will be developed for establishing the feasibility of using knowledge-based concepts, and for defining an approach to determine what type and extent of information is required to support future automated functions.

Not all system functions may be amenable to knowledge engineering. An attempt will be made, in the command and control environment, to establish the practicability of utilizing knowledge-based concepts. Command and control functions within the areas of command generation, validation, and real-time operations will be evaluated to derive those functions that can be automated through usage to knowledge-based systems. Data that can be used to validate knowledge-based systems concepts and to develop a prototype system to be utilized by command and control will also be defined.

The two major results expected from this research activity are a validated methodology for the incorporation of knowledge-based technology in NASA ground systems and prototypes that demonstrate the effectiveness of the methodology in the command and control environment.

Sponsor: Office of Aeronautics and Space Technology

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The Autocuer Speech-Analyzing Aid for the Deaf

The objective of the Autocuer project is to develop and field test an eyeglass-mounted display to aid deaf people in communicating with the hearing community. The display is based on principles of "cued speech," a phoneme-oriented sign language familiar to many deaf people. The display operates in real-time, substituting for cued speech traditionally performed with one hand of the deaf speaker. The unit generates a virtual image the deaf person sees superimposed over his normal vision as one of 28 symbols related to the vowel-consonant combinations which cannot easily be distinguished by lip reading. The unit may even allow conversation over the telephone, a communications link that is difficult for the deaf to use.

The present emphasis is on building many field test units that can be used to test the hardware in real-life situations and to measure the performance of the system, particularly with adults. A prototype is nearing completion.

The Autocuer project is a multi-way collaboration effort. Research Triangle Institute is providing project coordination and building the hardware and software needed for the task. Gallaudet College is providing laboratory training and laboratory and field testing capability. The Veterans Adminstration and NASA are providing funding for the three-year project. Goddard Space Flight Center is providing technical assistance and coordination.

Sponsor: Technology Utilization

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A New Look at Speech Recognition

In the 1976 to 1979 timeframe, the Goddard Space Flight Center Technology Utilization Program supported the development of a real-time speech display unit which had many similarities to the processing performed in the human ear and nerve system. Recent evaluations by phoneticians and audiologists substantiate that the unit faithfully follows phonetic theory very closely and can be of significant use in training deaf people. The unit appears to correct for the effects of coarticulation, a slurring or running together, and blurring phonemes as seen by traditional displays such as spectragrams. The units built in that time frame were analog to a large degree and too expensive to commercialize in that form.

In the period of 1978 to 1982, an algorithm for processing signals was developed for processing plasma waves and will be flown on the Solar Polar "STO" instrument. There now is evidence that this algorithm can be simplified and adapted to processing speech in real-time using one or two microprocessors in an almost completely digital form.

Goddard Space Flight Center no longer funds this effort. However plans are underway to develop a prototype of this concept with commercial entities which it is believed, can tap and profit from a multi-million dollar demand for a low-cost, speaker-independent speech recognition system that can be plugged into most home computers as well as many consumer products.

Sponsor: Technology Utilization

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