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1996 Annual BAAS Obseratory Report

NASA Goddard Space Flight Center

Laboratory for Extraterrestrial Physics

Greenbelt, MD 20771

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INTRODUCTION

The Laboratory for Extraterrestrial Physics (LEP) performs experimentaland theoretical research on the properties and dynamics of theheliosphere, the interstellar medium, and the magnetospheres andupper atmospheres of the planets, including the Earth. In addition,LEP members study the chemistry and physics of planetary stratospheresand tropospheres and of condensed solar system matter includingmeteorites, asteroids, comets and planets. The LEP conducts afocused program in astronomy, particularly in the infrared andin short as well as very long radio wavelengths. We also performan extensive program of laboratory research, including spectroscopyand physical chemistry related to astronomical objects.

The Laboratory proposes, develops, fabricates, and integratesexperiments on Earth-orbiting, planetary, and heliospheric spacecraftto measure the characteristics of magnetic fields, electric fields,and plasmas in space. We design and develop spectrometric instrumentationfor continuum and spectral line observations in the X-ray, γ-ray,infrared, and radio regimes; these are flown on spacecraft tostudy the interplanetary medium, asteroids, comets, and planets.Studies are conducted to investigate electric and magnetic fieldsand plasma-dynamic phenomena in the near-Earth space environmentto determine the temporal and spatial variations influencing themotion and composition of plasma and neutral gases in the Earth'satmosphere and magnetosphere. Suborbital sounding rockets andground based observing platforms form an integral part of theseresearch activities.

This report covers roughly the period from August, 1995 to September,1996.

I. PERSONNEL

Dr. Richard Vondrak, appointed last year, continues as Chief ofthe Laboratory for Extraterrestrial Physics. Before joining theLEP, he was Director of Space Physics, Lockheed Palo Alto ResearchLaboratory, Lockheed Research and Development Division. Mr. FranklinOttens is Assistant Chief. The Laboratory Senior Scientists areDrs. Richard Goldberg, John Hillman, Michael Mumma, Louis Stief,and Robert Stone. The Branch Heads are: Dr. Joseph Nuth (Astrochemistry);Dr. Keith Ogilvie (Interplanetary Physics); Dr. Drake Deming (PlanetarySystems); Dr. Steven Curtis (Planetary Magnetospheres), and Dr.James Slavin (Electrodynamics). The Information Analysis and DisplayOffice is headed by Mr. William Mish.

The Civil Service scientific staff consists of: Dr. Mario Acuña,Dr. John Allen, Dr. Robert Benson, Dr. Thomas Birmingham, Dr.Gordon Bjoraker, Dr. John Brasunas, Dr. David Buhl, Dr. LeonardBurlaga, Dr. Gordon Chin, Dr. Regina Cody, Dr. John Connerney,Dr. Michael Desch, Mr. Fred Espenak, Dr. Joseph Fainberg, Dr.Donald Fairfield, Dr. William Farrell, Dr. Richard Fitzenreiter,Dr. Michael Flasar, Dr. Melvyn Goldstein, Dr. Joseph Grebowsky,Dr. Fred Herrero, Dr. Michael Hesse, Dr. Robert Hoffman, Dr. DonaldJennings, Mr. Michael Kaiser, Dr. John Keller, Dr. Alexander Klimas,Dr. Theodor Kostiuk, Mr. Virgil Kunde, Dr. Ronald Lepping, Dr.Robert MacDowall, Dr. William Maguire, Dr. Marla Moore, Dr. DavidNava, Dr. Walter Payne, Dr. John Pearl, Dr. Robert Pfaff, Dr.Dennis Reuter, Dr. D. Aaron Roberts, Dr. Paul Romani, Dr. RobertSamuelson, Dr. Edward Sittler, Dr. Mark Smith, Dr. David Stern,D r. Jacob Trombka, Dr. Aldofo Figueroa-Viñas, and Dr.Peter Wasilewski.

The following are National Research Council Associates: Dr.Richard Achterberg, Dr. James Clemmons, Dr. Michael Collier, Dr.Neil DelloRusso, Dr. Frank Ferguson, Dr. Nicola Fox, Dr. RyoichiFujii, Dr. Robert Glinski, Dr. Susan Hallenbeck, Dr. Joseph Harrington,Dr. Vladimir Krasnopolsky, Dr. Giovanni Laneve, Dr. Thomas Moran,Dr. Pedro Sada, Dr. Michael Smith, Dr. Peyton Thorn, Dr. MarkWeber, and Dr. Xingfa Xie.

Personnel on contract to GSFC or in the LEPas long-term visiting faculty include: (Hughes/STX) Dr. AshrafAli, Dr. Daniel Bedichevsky, Dr. Scott Boardsen, Mr. Mark Cushman,Dr. Roger Hess, Dr. Shrikanth Kanekal, Dr. Masha Kuznetsova, Dr.Brook Lakew, Dr. Carey Lisse, Dr. Paul Marionni, Dr. Nitya Nath,Mr. George McCabe, Dr. Vladimir Osherovich, Dr. Mauricio Peredo,Dr. Michael Reiner, Dr. Takehiko Satoh, Dr. Pamela Solomon, Dr.Adinarayan Sundaram, Dr. Adam Szabo, and Dr. Nikolai Tsyganenko;(Universities Space Research Assoociation) Dr. Dimitris Vassiliadis,Dr. Jesper Gjerloev, and Dr. Valeriia Troitskaia, Dr. Hung KitWong; (Applied Research Corporation) Dr. Sanjoy Ghosh, Dr. MichaelGoodman, Dr. Thomas Moran, and Dr. Edouard Siregar; (ComputerSciences Corporation) Dr. Larry Evans; (Catholic University) Dr.Pamela Clark, Dr. Tamara Dickinson, Dr. Michael DiSanti, Dr. FredNesbitt, and Dr. Richard Starr; (University of Maryland BaltimoreCounty) Dr. Marcos Sirota; (Georgia Southern University) Dr. RobertNelson; (University of Maryland College Park)

Dr. Dennis Chornay,Ms. Kelly Fast, Dr. Denise Lengyl-Frey, Dr. Thejappa Golla, andDr. Timothy Livengood; (Charles County Community College) Dr.George Kraus; (Cornell University) Dr. Barney Conrath, and Dr.Paul Schinder; (Rowan College) Dr. Karen Magee-Sauer; and (Universityof Virginia) Dr. Lembit Lilleleht, and Dr. Patrick Michael

II. PLANETARY & COMETARY RESEARCH

Jupiter

Planetary-Scale Thermal Waves. D. Deming and collaboratorscompleted an analysis of infrared observations of planetary-scalethermal waves on Jupiter. They concluded that these low-amplitude(Å0.3 Kelvin) waves are likely to be Rossby waves, representedby small latitude excursions in the zonal winds. These latitudeexcursions produce temperature fluctuations via "vortex stretching,"a consequence of vorticity conservation. The necessary latitudedeviations in the zonal wind streamlines were calculated to beof order 1°. The small System III phase velocity of the wavesindicates that they are forced by structure which rotates at nearlythe same rate as the Jovian interior. Specific possibilities forsuch forcing include the interaction of the deep zonal winds withinterior structure, and forcing by stable vortices such as theGreat Red Spot.

Ethane Emission. T. Kostiuk, D. Buhl, and K. Fast, of theLEP, with colleagues J. Goldstein and T. Hewagama (NationalAir and Space Museum), measured auroral 12 µm ethaneemission from the north pole of Jupiter in September 1996 at theNASA Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii.These infrared heterodyne line measurements are additional datain a set obtained since 1981 to be used in the study of long termvariability and correlation with solar cycle and seasonal effectsof the Jovian infrared hydrocarbon aurora.

Ultraviolet Emission. T. Livengood was co-PI with R. Prangé(IAS, Paris, France) of the final Guest Observer program withthe International Ultraviolet Explorer satellite. A multi-nationalteam traveled to the European Space Agency ground facility atVillafranca del Castillo, Spain in August-September 1996 for sixfull weeks of observations of nearly all significant ultravioletemissions yet identified from the Jovian system. Targets observedinclude variability monitoring of the aurorae and the equatorialLyman-α bulge emission, high signal-to-noise,wide-bandwidth, zonally-averaged measurements of the stratosphericalbedo in the equatorial and Shoemaker-Levy 9 impact-latituderegions on Jupiter, the Io plasma torus, and albedo measurementsof three of the four Galilean satellites. Over 650 spectra resultedfrom this program, sampling Jovian phenomena on time scales andwith detail not previously achieved.

Jupiter, Shoemaker-Levy 9 impact event. T. Kostiuk,D. Buhl, F. Espenak, P. Romani, G. Bjoraker,K. Fast, and T. Livengood, with D. Zipoy (UMD), publishedan analysis of high-resolution spectra of two Shoemaker-Levy 9impact regions on Jupiter, obtained using the GSFC Infrared HeterodyneSpectrometer. These observations measured emission of ammoniainjected into Jupiter's stratosphere after the impacts and provideevidence that the emission was isolated to the upper stratosphere.These data are currently being compared with similar observationsobtained by A. Betz (U of Colorado) to investigate the time-developmentof ammonia emission at the Shoemaker-Levy 9 impact sites. Theseresults will be used to develop improved models for ammonia chemistryin the stratosphere of Jupiter.

T. Livengood, T. Kostiuk and H. Käufl (EuropeanSouthern Observatory) are continuing the calibration and analysisof mid-infrared imaging of Jupiter taken through the Shoemaker-Levy9 impacts and the week following, investigating the morphologicaland broadband spectrophotometric development of the impact sites'stratospheric signature. The data set in hand includes observationsseveral months prior to the impacts as well as several monthsfollowing the impact.

Models of NH_3 Spectra. P. Romani collaboratedwith other LEP members in interpreting infrared heterodyne observationsof NH_3 emission lines in the stratosphere of Jupiterfollowing the Shoemaker-Levy 9 impact. Several 1-D NH_3photochemical models were constructed. The simplest model is a"rapid decay" model. It assumes 100% loss of NH_3following photolysis and includes only NH_3 self-shielding.However, even from this simple model it was possible to draw somepreliminary conclusions. If the Q1 impact produced the same initialamount of NH_3 as K/G then horizontal spreading alongwith photochemical loss must be considered in modeling the NH_3spectra as a function of time. Alternatively, since Q1 was a smallerimpact than K/G it is consistent that Q1 produced less NH_3than the K/G impacts. Inclusion of other shielding sources willstrengthen these conclusions. For longer periods (months) afterthe impacts the retrieved stratospheric NH_3 abundanceis too high to be explained by this simple photochemical modeland horizontal spreading. Additional shielding or substantialrecycling (80%) of NH_3 post photolysis is required.

Observation and Modeling of Hydrocarbon Spectra. In late1994 and early 1995 D. Jennings and P. Sada observed CH_4,C_2H_6, and C_2H_2 emissionfeatures on Jupiter with a cryogenic echelle spectrometer (CELESTE).A preliminary run (by P. Romani) with a 1-D CH_4 photochemicalmodel resulted in a case that was too rich in $C_2H_2$and too poor in C_2H_6 by approximately thesame amount (a factor of about 2). This is similar to the problemencountered previously in modeling the hydrocarbon photochemistryon Neptune with a *K*, eddy diffusion coefficient, profilesimilar to the one used in the Jupiter model (one that variesas the inverse of the atmospheric number density to some power).In the case of Neptune it was found that the model could reproduceeither the C_2H_2 or C_2H_6emission features to within observational uncertainties, but whenit was attempted to fit both features with the model the bestthat could be done was a case that was too rich in $C_2H_2$and too poor in C_2H_6 by about a factor oftwo. For Neptune the solution was to use a *K* profile thatrapidly increased with declining pressure in the lower stratosphereto a value which remained constant with pressure until the methanehomopause and then decreased at lower pressures. However, beforesuch a *K* profile is invoked for Jupiter the effects ofrecent laboratory rate measurements and branching ratios on themodel predicted C_2H_6 and C_2H_2mixing ratios need to be assessed.

Io Flux Tube Footpoints. Dr. J. E. P. Connerney and colleaguesT. Satoh, and R. Baron (U Hawaii) have imaged Jupiter at 3.40m wavelength using the NSFCAM infrared camera and NASA's IRTFat Mauna Kea, Hawaii. The technique exploits a set of emissionlines of the H_3^+ ion (3.40 m) within a strongabsorption band of methane, to image the distribution of $H_3^+$with high spatial and temporal resolution. These images evidenceintense and omnipresent auroral emissions at both magnetic polesand emission at the foot of the Io Flux Tube (IFT). The latterappears as an isolated, sub-arcsecond spot which moves acrossJupiter's disc in concert with the orbital motion of Io; it isexcited by the electrodynamic interaction of Jupiter's magneticfield with Io. June 1995 and July 1995 NSFCAM images capturedIo's signature in both polar regions with greatly improved spatialand time resolution. Emission extending well downstream (60 degrees)of the IFT footprint along Io's L shell can be seen in the southernhemisphere. High time resolution imagery of the IFT footprint,conducted in 1995 and 1996, is used to further our understandingof the electromagnetic interaction between Jupiter and Io. A catalogof observed surface locations of the IFT footprint is being assembledand used to refine models of Jupiter's magnetic field.

H_3^+ Aurorae. T. Satoh and colleaguesJ. Connerney, and R. Baron (U Hawaii) use NSFCAM infrared imagesof Jupiter to model the distribution of Jovian H_3^+emissions in the auroral regions and to monitor the dynamic stateof the Jovian magnetosphere. A linearized inverse method is usedto extract an emission model from many images of the aurora, obtainedat different Central Meridian Longitudes. Evidence is found forenhanced emissions at longitudes marked by weaker surface magneticfield magnitudes, and there appears to be a local time enhancementin emissions poleward of the auroral oval in the dusk sector.The auroral intensity has two principal components of time variability:a short-term variability (days) which correlates well with thesolar wind ram pressure arriving at Jupiter, and a longer-termvariability (months) which is believed to be related to the energizationand transport of magnetospheric plasma in Jupiter's magnetosphere.A continued program of observation of the aurora is conductedto monitor the state of the magnetosphere in support of the GalileoMission.

Magnetic Field. J. Connerney, M. Acuña, and N. Ness(Bartol) have obtained a spherical harmonic model of Jupiter'smagnetic field from the Ulysses magnetic field observations. Themagnetic field in the Jovian magnetosphere was represented usinga third degree and order spherical harmonic expansion for theplanetary (internal) field, and an explicit model of the magnetodiscfor the field (external) due to distributed currents (e.g., ringcurrents). The model was obtained by partial solution of the underdeterminedinverse problem using generalized inverse techniques. The modelfits the Ulysses fluxgate magnetometer observations well, witha RMS residual that is comfortably less than the estimated errorof the measurement. Dipole, quadrupole, and a subset of the octupolecoefficients were determined and found to compare reasonably wellwith those obtained from the earlier Voyager and Pioneer encounters.The model requires a less intense magnetodisc current in early1992 compared with that observed during the Voyager 1 encounterin 1979 and the Pioneer 11 encounters of 1973 and 1974.

*Jovian Decametric Radio Emission.*The Wind/WAVES experiment (M. Kaiser, PI) provides surprisinglygood observations of Jupiter's decametric (DAM) radio emissionsin the 2 to 14 MHz band. It is in this band that (a) Jupiter hasits peak spectral flux, (b) the organization of DAM as a functionof Jovian central meridian longitude seem to stop, (c) hectometerwavelength emissions from high above the auroral zones seems toreach a frequency above which they cease to exist, and (d) thereis a polarization transition from predominantly right hand athigher frequencies to at least equal right and left. WAVES iscurrently making DAM observation from very low Jovigraphic latitudesnot probed by the Voyager spacecraft. Emissions from Jupiter'ssouthern auroral region dominate the WAVES data to date.

Galileo Radio Observations. F. M. Flasar and P. J. Schinderwith colleagues D. P. Hinson (Stanford) and A. Kliore (JPL) haveanalyzed the data from the first Galileo radio-occultation experimentof Jupiter, using the spacecraft's low-gain antenna. They haveretrieved vertical profiles of electron density that attest tothe extreme heterogeneity of Jupiter's ionosphere. At ingress(24° S, near the evening terminator) they have identifiedseveral density peaks. The topmost is located 900 km above the1-bar level, has a maximum density of 1∞105 cm-3,and a full width at half maximum of 200 km. That at egress (43°S, near the morning terminator) is lower, at 2000 km altitude,weaker, having a peak density of 2∞104 cm-3,and much broader, with width ~1000 km. Comparison with previousoccultations by Jupiter of Voyager and Pioneer spacecraft indicatesno clear correlation with time of day or solar cycle. The Galileoegress location is proximate to the latitude of the SL-9 cometimpacts, and the residual debris from these may account for thelower density observed. Below the main broad peak at the Galileoingress location, two thin electron density layers have been identifiedin the retrievals, with vertical separation 80 km and verticalwidths <50 km. They may be evidence of electron and ion motionsthat are forced by gravity waves propagating from lower altitudesand that are constrained by Jupiter's magnetic field, analogousto the sporadic-E layers in Earth's ionosphere.

Wave Propagation. M. Reiner and J. D. Menietti (Iowa) competedthe first ray tracing calculation that uses as input the measuredarrival direction of the Jovian hectometric (HOM) radio emission.The results demonstrate that wave refraction due to the Io torusand the magnetic field can significantly influence the HOM sourcelocation.

Jupiter Waves. R. Achterberg, F. M. Flasar, and B. Conrathhave continued their search for thermal waves in Voyager IRISdata. For Jupiter, they find a strong signature of a wave in theupper troposphere with zonal wavenumber 1, whose amplitude varieswith latitude on the scale of Jupiter's zonal currents, and whichappears to be nearly stationary with respect to the System IIIlongitudes. Surprisingly, the zonal phase of this wave remainsnearly constant with latitude, except for a ~180° phase shiftwhen the latitudes of the Great Red Spot are traversed. As theSpot itself is nearly stationary in System III, this behaviorsuggests that it may be responsible for forcing the observed wave.

Titan

Supersaturated Methane. Using Voyager 1 IRIS spectra, R.Samuelson and N. Nath have completed a study of the supersaturationof methane in Titan's atmosphere. The maximum degrees of supersaturationin the upper troposphere appear to range from about 1.6 at lowlatitudes to 1.3 or so at high latitudes, and the correspondingmethane mole fractions near the surface are about 0.06 and 0.02,respectively. These results are consistent with predictions froma steady-state methane condensation model developed by R. Samuelsonand L. Mayo, after modification for seasonal variations. Thismodification is compatible with another study by Samuelson andMayo, which indicates that the observed condensate/vapor ratioof C_4N_2 in Titan's north polar hood is atleast two orders of magnitude larger than that predicted fromsteady-state theory, unless cyclic seasonal effects are included.A logical consequence of these studies is that liquid ethane maybe more concentrated at the surface (or in surface regolith) inpolar regions than at low latitudes.

Global Zonal Winds. T. Kostiuk, D. Buhl, K. Fast,and T. Livengood of the LEP with colleagues J. Goldstein,T. Hewagama, and K. Ro (National Air and Space Museum)observed Titan in October 1995 and in September 1996 using theGSFC Infrared Heterodyne Spectrometer (IRHS) at the NASA InfraredTelescope Facility on Mauna Kea, Hawaii. Using the IRHS's frequencysensitivity of approximately one part in 108, these observationsattempt to determine the direction and magnitude of Titan's globalzonal wind flow by comparing the frequency retrieved for known12 µm transitions of the ethane molecule on the east andwest limbs of Titan. Initial results obtained from these and aprevious run are consistent with prograde zonal winds of

~100 m/s.Improved analytical software is under development to reduce thesedata more accurately, and improved source tracking and laser-stabilizationhardware are being developed to support future observations. TheCassini Huygens Probe team has been kept apprised of this projectfor its relevance to planning the Huygens Probe mission. Ethaneabundance in Titan's stratosphere is also determined in thesemeasurements, and has been found to differ from Voyager results.

Neptune

W. Maguire continued his research on the atmospheric compositionof the outer planets. He previously identified a new constituentin the Neptune atmosphere, dicyanoacetylene (C_4N_2).He is now modeling its IR spectrum in the 25 μmregion to determine its abundance in Neptune's atmosphere.

Mars

Many LEP members are involved in future Mars missions; these effortsare described in Section VI below.

Comets

T. Kostiuk and T. Livengood have initiated a cooperativeprogram of cometary research with C. Lisse and colleaguesat University of Maryland, to study mid-infrared emission fromcomets and its relationship to other observed phenomena. Mid-infraredsources within a comet include thermal continuum emission of dustin the coma, dust in the tail, and the surface of the nucleus,and possible molecular emission by species in the coma. Mid-infraredmeasurements offer a new method to determine a comet's nuclearsize and dimensions from the rotational light curve, as the observedemission flux is directly related to the cross-sectional areapresented to the observer. Initial measurements were made on CometHyakutake in March 1996 under the NASA Infrared Telescope Facilitycampaign. C. Lisse was a member of the Science Team for theIRTF campaign. He was the PI on X-ray observations with the ROSATsatellite and led or participated in related observations in theEUV, visible, and radio regions. The X-ray observations revealedan extraordinary and unexpectedly strong emission on the comet'ssunward side. Results were published in October 1996 by the journalScience. Observing time has been allocated at the European SouthernObservatory for T. Kostiuk and C. Lisse to make mid-IRimaging observations of comet Hale-Bopp in November 1996, andat the NASA IRTF for mid-IR imaging in February 1997.

Comet Shoemaker-Levy 9

D. Deming and J. Harrington are conducting a ballistic and radiativehydrodynamic simulation of the plume infall from the collisionof comet Shoemaker-Levy 9 with Jupiter. It is currently believedthat fall-back of the plume ejecta produced large shock-heatingof the upper atmosphere over an extended region on Jupiter. Thisheating was responsible for the very bright infrared emissionseen by terrestrial observers and referred to as the "mainevent." A ballistic "toy plume" model is used byHarrington to define the spatial distribution of the infallingplume mass and momentum. The free parameters of the toy plumeare adjusted to maximize the agreement with HST observations ofthe plumes on the limb and the debris crescent on the Jovian disk.The ballistic computations are then used by Deming as input fora series of 1-D radiativehydrodynamic computations of the atmosphericresponse at each point of the plume infall. The radiative emissionfrom each point is spatially integrated to yield a synthetic lightcurve for comparison to observations. This comparison indicatesthat the series of secondary maxima following the main peak ofthe light curve is produced by a rebound ("bounce")of the infalling plume material and the upper atmospheric layers.Both the amplitude, and to a lesser extent the period, of thisbounce are influenced by the opacity of the plume material becauseof radiative damping. These calculations also define the heightprofiles of the atmospheric heating at each point, and could beused as input for analysis of infrared spectra of this event.

III. ASTROCHEMISTRY

Circumstellar and Interstellar Chemistry. Using ultravioletspectrographs aboard the Hubble Space Telescope, R. Glinski andcoworkers observed the spin-forbidden Cameron Bands of CO as wellas the spin-allowed Fourth Positive system in the Red Rectanglenebula. These results suggest that a charged-particle impact mechanismis responsible for the excitation of the CO (a3_) state commonto both systems. R. Glinski and J. Nuth demonstrated that thehomonuclear diatomic molecules and ions of H, N, O and C foundin diffuse cloud environments will display highly non-Boltzmann(essentially flat) vibrational-state distributions and that insome instances (e.g. H_2/H_2+) the absoluteabundances in excited vibrational levels (*v*=1-5) of themolecular ion approach abundances in the equivalent neutral state.This could be very significant in derivations of molecular abundancesbased on observations of only a single vibrational level.

G. Kraus, J. Nuth, and R. Nelson measured the infrared spectraof a wide range of commercially available samples of $SiS_2$for comparison with observations of stellar spectra displayinga 21 micron emission feature but that are not known to be oxygenrich. All samples display features in the 17-18 and 20-21 micronregions as well as strong individual bands from 7-13 microns thatmight serve as additional observational parameters to confirm/refutethe hypothesis that SiS_2 is responsible for the observed21 micron feature in dust shells around some oxygen deficientproto-planetary stars. Preliminary measurements of the rate atwhich the infrared spectra of amorphous silicate smokes (analogousto condensates around oxygen-rich stars) change as a functionof temperature appear to indicate that magnesium silicates annealmuch more rapidly than do iron silicates: experiments to quantifythis difference are currently in progress. Follow-up studies ofpreviously reported experiments that demonstrated that volatilegases condensing on amorphous silicate grains at temperaturesas low as 20K form crystalline solids rather than amorphous iceshave shown that this effect only occurs when the silicates areprepared in a hydrogen-rich atmosphere, despite the fact thatthe size distribution and infrared spectra of grains formed ina helium-rich atmosphere appear to be identical in all respects.Additional studies of these materials are in progress.

*Outer Planets and Satellites of Jupiter, Saturn and Titan.*L. Stief, W. Payne, F. Nesbitt (Coppin State), P. Monks, R. Thornand D. Tardy (U. Iowa) have measured rate constants and productyields for reactions of the vinyl radical C_2H_3.The C_2H_3 radical is one of the most abundantC_2 radical species in photochemical models of the atmospheresof the outer planets and satellites. The reaction N+$C_2H_3$is important as a potential source of prebiotic molecules containingthe C=N group in the atmospheres of Titan, Neptune and Triton.The present work represents the first experimental study of theN+C_2H_3 reaction. The reaction is rapid,as expected for an atom-radical reaction, and occurs at aboutone-half the rigid sphere collision rate. Three reaction channelswere observed: $N+C_2H_3$-> C_2H_3+NH(Γ=0.16), C_2H_2N+H(Γ=0.80) and C_2H_3N(Γ=0.04) where Γrepresents the fractional yield of each reaction channel.The lowest energy isomers of C_2H_2N and $C_2H_3N$are the CH_2CN radical and the CH_3CN moleculerespectively. The CH_3CN molecule was recently detectedfor the first time in the atmosphere of Titan. The reaction $C_2H_3+C_2H_3$is a minor loss process for C_2H_3 in outerplanetary atmospheres but a major side reaction in planned laboratorystudies of the reaction $CH_3+C_2H_3$which is one of the most important C_2H_3reactions in outer planet atmospheres. The present work representsthe first study of the $C_2H_3+C_2H_3$reaction at low pressures appropriate for atmospheric chemistry.The reaction was shown to occur at the rigid sphere collisionrate limit, consistent with higher pressure studies. However,the adduct molecule C_4H_6(1,3-butadiene),which is the major product at higher pressure, was not observedat all (Γ<0.0l) in the low pressureexperiments. The yield Γ of the channel$2C_2H_3$ -> $C_2H_2+C_2H_4$was unity. Thus C_4H_6 is not expected tobe a product of C_2H_3 chemistry in outerplanet atmospheres. A quantitative study of the rate and productsof the reaction $CH_3+C_2H_3$ is nowunderway.

Construction has been completed on a system designed to measurethe thermodynamic properties of pure substances and mixtures atlow temperatures; the apparatus represents the joint effort ofJ. E. Allen, Jr. and R. N. Nelson (Georgia Southern). The systemis capable of covering over nine orders of magnitude in pressurefrom a base pressure of 10-7 Torr by combining instruments whosepressure ranges overlap. The sample cell is connected to a heliumcryogenic cooler and temperatures as low as 80 K have been achieved.Care was taken in the design to accurately account for the effectsof thermal transpiration and a residual gas analyzer was incorporatedboth to monitor sample purity and to follow the evolution of individualspecies in binary and tertiary mixtures as a function of temperature.The system is currently being calibrated with propane, after whichlow-temperature measurements will be made on a series of lighthydrocarbons. These studies are needed to accurately predict thelocation and chemical composition of the various cloud layersin the atmospheres of the giant planets.

Cosmic Ices. Laboratory studies of the infrared spectralproperties of cosmic ices before and after proton irradiationare conducted using a unique set-up designed specifically forthe ion bombardment of thin films of low temperature ices. Thefocus of these investigations is to understand physical-chemicaland radiation-chemical processes and identify products in irradiatedicy materials thought to exist in cometary ices, in interstellaricy grain mantles, and in some cases on the surfaces of icy satellites.M. H. Moore and R. L. Hudson (Eckerd College) have completed irradiationstudies of both H_2O+CH_4, and $H_2O+C_2H_2$ ice mixtures. In the H_2O+CH_4ice, the formation of C_2H_6 at the expenseof CH_4 results in a $C_2H_6:CH_4$ratio between 0.3 to 0.03 depending the initial CH_4concentration. In the $H_2O+C_2H_2$ice, the formation of C_2H_4 and C_2H_2,by H-atom addition reactions is observed. A $C_2H_6:C_2H_2$ratio of ~0.8 is obtained. Other molecules identified in bothmixtures include methanol, ethanol, acetaldehyde, and formaldehyde.Analysis of the entire data set is currently in progress. Resultsare directly applicable to understanding the $C_2H_6:CH_4$ratio found in Comet Hyakutake of about 0.6 and can beused to suggest new observations of future comets.

Conditions in the Primitive Solar Nebula. Karner and coworkerscompleted a study of the properties of particulates produced viavapor-phase condensation following lightning-induced vaporizationof magnetite and alumino-silicate glass that may have some parallelsto the production of chondrules in the primitive solar nebula.The samples contained both crystalline and glassy material whilethe chemical compositions of the phases were consistent with predictionsbased on eutectics in the equilibrium Fe-Al-Si phase diagram,thus indicating a kinetically controlled approach to equilibriumin this very rapidly evolving chemical system. Studies of theremnant magnetization of the samples is in progress. A relatedstudy of shock-induced magnetization in fine-particle iron suchas that found in meteoritic chondrules has been completed anddelineates the information (shock strength, ambient magnetic field,etc.) that might be extracted from magnetic measurements of suchparticles.

X-ray and Gamma-ray Measurements of Solid Bodies. Duringthe calibration of the x-ray solar monitor (J. Trombka, P.I.)of the NEAR spacecraft (see below), a number of solar flares occurred.The two solar monitor detectors, a solid state PIN detector anda proportional counter measured line and continuumemissions during both quiet sun and flare periods. Temperaturesand emission measures were inferred and discrepancies with temperaturesinferred from the GOES data for the same time period were noted.A detailed discussion of the measurements and the discrepancieshave been carried out and submitted for publication.

Terrestrial research. On a per atom basis, bromine is considerablymore destructive of stratospheric ozone than is chlorine. Whilethere have been several studies of the reaction OH + ClO, thereare none for the related reaction OH + BrO which is importantin the parititioning of stratospheric bromine. The first experimentalmeasurement of the rate constant for the reaction $OH+BrO->Br+HO_2$was made by D. Bogan and coworkers. The reaction was found tooccur at one-half the limiting collision rate and is some seventimes larger than an estimate in a widely used data compilationfor modeling stratospheric chemistry. The magnitude of the rateconstant, although previously unexpected, was shown to be supportedby theoretical considerations.

An infrared sunphotometer that covers the spectral range from1.2 to 4.5 microns has been developed to measure trace atmosphericgases and aerosols by J. Allen, Jr., in collaboration with R.Nelson (Georgia Southern) and R. Halthore (Brookhaven). A circularvariable filter is used for spectral tuning andthe signal is detected with a thermoelectrically cooled short-wavelengthmercury cadmium telluride detector that spans the range from 1to 5 microns; suntracking is achieved with a portable equatorialmount. The instrument was field tested in late September at theNational Solar Observatory in Sunspot, NM. Although the data arestill being analyzed, preliminary spectral plots are noticeablydifferent than those obtained at GSFC. Besides the obvious differencein water vapor concentrations, there appear to be variations inother spectral features which may reflect differences in the abundancesof other trace gases

In a continuing effort to understand the magnetic anomalies detectedby POGO and MagSat, P. Wasilewski and R. Warner completed studiesto magnetically characterize subduction zone mafic xenoliths fromJapan and the Aleutian Islands, while Wasilewski and K. Nazarovacompleted a study of the magnetic petrology of Harzburgites fromthe Islas Orcas fracture zone. These studies are aimed at determiningspecific metamorphic changes that occur during subduction andthat result in a magnetic boundary layer at the Mohorivicic Discontinuity.

Gas-Phase Spectroscopy. D. Reuter, J. M. Sirota, J. Hillmanand D. Jennings conduct high-resolution laboratory infrared spectroscopyof gaseous molecular species. The research focuses primarily onmolecules of planetary and astrophysical interest, and supportsNASA flight missions in both these areas. The work also supportsground-based astronomy and terrestrial atmospheric studies. Particularemphasis is placed on obtaining reliable intensities, self- andforeign-gas pressure broadening coefficients and line-mixing effects.The group also measures tunable diode laser (TDL) and Fouriertransform (FTS) spectra at wavelengths greater than 10 μm.Supporting laboratory measurements are scarce for these wavelengths,but are crucial for the analysis of data from upcoming space missionssuch as Cassini, where CIRS will obtain spectra of Saturn andTitan from 7 to 1000 μm. Recent activitiesof the group have included obtaining and/or analyzing spectraldata for excited state and fundamental transitions in H_2,$^{13}C^{12}CH_6$, C_2H_4,C_2H_2, N_2O, CO_2, C_3H_4(both the methylacetylene and allene isomers) and HNO_3.This recent work has been carried out in collaboration with W.E. Blass (U Tenn.), J. M. Frye (Howard), J. W. C. Johns (NRC,Canada), A. Perrin (C.N.R.S., Paris), D. W. Steyert (Wabash College),and L. L. Strow (UMBC). These measurements have already impactedplanetary studies. For example, the ν12^{13}C ethane ($^{13}C^{12}CH_6$)intensities have been used in conjunction with ground-based observationsto infer an essentially terrestrial $^{13}C/^{12}C$ratio on Jupiter and Saturn, while the intensities of the ethylene(C_2H_4) transitions have been used to obtainconcentrations of this species in the upper atmosphere of Saturn.The low temperature line intensity and self- and nitrogen broadenedmeasurements of the ν9 band of allenenear 28μm are the first such measurementsof this band, and are among the longest wavelength TDL data everobtained. The parameters obtained from these experiments are crucialto the proper interpretation of the upcoming CIRS measurementsof the atmosphere of Titan.

IV. SUN-EARTH CONNECTIONS

Heliospheric Physics

Interplanetary Field Structure. M. Reiner, J. Fainbergand R. G. Stone used the unique location of Ulysses over the southpole of the sun to demonstrate unequivocally that interplanetarytype III radio bursts trajectories follow the spiral structureof the magnetic fields that thread through the interplanetaryspace. The unique relative locations WIND and Ulysses have permittedM. Reiner, M. Kaiser, J. Fainberg and R. Stone to obtain the first3-D trajectory of a type III radio burst in the heliosphere usingtwo spacecraft triangulation. Several intrinsic properties ofthe interplanetary medium and of the radio source could be derivedfrom these measurements. The measured local plasma density wasfound to be consistent with a density law previously derived withdata from the Radio Astronomy Explorer (RAE). The electron exciterspeed was deduced from the measured frequency drift rate and theintrinsic brightness temperature and beaming characteristics ofthe radio source were also derived from these unique data. Studiesare underway that combine WIND/Ulysses observations of local enhancementsin type III radio emission that occurred at the time the WINDspacecraft was inside a magnetic cloud.

Magnetic Clouds: Magnetic clouds are interplanetary fluxropes from the Sun characterized by strong magnetic fields, asmooth rotation of the magnetic field direction and low protontemperatures. A magnetic cloud was identified in real time byL. Burlaga in the magnetometer data from the WIND spacecraft onthe period Oct. 18, 1995. News of this event was posted on theWorld Wide Web, and a number of geomagnetic events were predicted,including unusual aurora, which were observed.

A plasma depletion layer was observed just in front of magneticclouds by C. Farrugia (UNH) and LEP colleagues, and a theory explainingthe existence of this layer was published by N. Erkaev and coworkers.An MHD model describing observed cloud rotation was constructedby C.

Farrugia, V. Osherovich and L. Burlaga. The work of C. Farrugia,V. Osherovich and L. Burlaga showed that the spheromak modelsof magnetic clouds have serious shortcomings.

L. Burlaga, R. Lepping, K. Ogilvie, A. Szabo, and colleagues,in collaboration with A. Lazarus and J. Steinberg (MIT) and C.Farrugia and L. Janoo (both at UNH), conducted a study of thewell known October 18 - 20, 1995 interplanetary magnetic cloudand stream events, which occurred in interval #1 of the FirstIACG Science Campaign. They concentrated on the in-situ propertiesof the event and have started an in depth study of the cloud'seffects on the Earth's magnetosphere. They were able to modelthe magnetic cloud as a force free flux rope of diameter 0.27AU. Its axis was estimated to be nearly perpendicular to the Earth-Sunline and close to the ecliptic plane, not an uncommon attitudefor these structures when observed at 1 AU in the ecliptic plane.The boundaries of the cloud and an upstream shock, which occurredabout 8 hours earlier than the front boundary of the cloud, wereall studied in detail and shown to be in attitudinal agreementwith the axis of the cloud. An abrupt feature internal to thecloud, appearing shock-like in most but not all respects and havingan unusual surface normal far off the Earth-Sun line, has beenexamined; only preliminary conclusions can be given presentlyconcerning its true nature and origin, which are still under consideration.

R. Lepping, A. Szabo, K. Ogilvie, and R. Fitzenreiter, in collaborationwith A. Lazarus and J. Steinberg (MIT), have examined characteristicsof the Earth's bow shock resulting from its interaction with thelarge interplanetary magnetic cloud of February 8, 1995. The cloudwas first observed at WIND far upstream of the Earth, and thenby IMP-8 about 1 hour later which was located fortuitously atthe bow shock, which became unusually inflated at the time. Thebow shock was estimated to reach at least 32 R_E atits nose, and was observed directly to reach 39 $R_E$on the dusk flank. The study, requiring very careful estimationsof the bow shock surface normal for the shock's numerous IMP-8measurements, revealed that the bow shock tended to expand almost'isotropically' as the cloud passes. The expansion was apparentlydue to many factors including the high Alfvén speed andlow Alfvén Mach number occurring during the cloud passage.

A technique used to study the properties of interplanetary magneticclouds as force-free magnetic field flux ropes was recently extendedby R. Lepping, J. Slavin, M. Hesse, and A. Szabo to study structurallysimilar flux ropes in the magnetotail; these are smaller, however,by a factor of about 600 on average. These magnetotail flux ropes,sometimes know as tail plasmoids, were examined by R. Lepping,D. Fairfield, J. Slavin, and A. Szabo in two independent studiesusing ISTP-GEOTAIL and ISEE-3 tail data. Comparison of the resultsof these studies showed many similarities and a few differencesin the flux rope sizes and their attitudes: from the latest study,ISEE-3, it was found that flux rope axes are spread considerablyin direction, but have a slight tendency to be aligned "cross-tail."An earlier, GEOTAIL, study showed similar results but over-emphasizedthe cross-tail tendency, probably because of the smaller dataset utilized.

The magnetic field structure within a cloud can be quite complex.Several diagnostics have been developed to determine whether ornot these clouds are magnetically connected to the corona. Withina cloud there are sometimes regions within which the electronheat flux is bi-directional, suggesting that both ends of themagnetic field are still topologically connected to the solarcorona. A recent analysis of a magnetic cloud observed by theWIND spacecraft (M. Goldstein, A. Roberts) indicates that whena bi-directional heat flux is present, the Alfvén wavesare also propagating both up and down the flux tube.

Heliospheric Current Sheet. R. Lepping, A. Szabo, and M.Peredo, in collaboration with T. Hoeksema (Stanford), analyzedWIND magnetic field data for the first six months after launchof the spacecraft, in order to better understand the propertiesof the heliospheric current sheet (HCS), the occasionally surroundingplasma sheet, and to look for a temporal connection of the HCSto the solar surface current sheet using a potential field sourcesurface model, for this quiet phase of the solar cycle. A largenumber of carefully selected HCS crossings, 212, were used inthe study which showed a nearly periodic occurrence of this structurein the early portion and a smooth evolution from 2 to 4 sectorstructure after a few months. Also it was determined that whenthe plasma sheet's presence is most apparent, the directionaldiscontinuity in the magnetic field encompassing the thin regionof the current sheet appears to be more abrupt than in other cases.Comparison of the results of the source surface model to the *insitu* WIND magnetic field observations for this rather largedata set enabled the team to better estimate the time delay ofthis structure over 1 AU. There resulted a surprising 'disagreement'or bias of 1 day, based on solar wind convected speed only. Thereis a possibility that the moderately slow average solar wind speednear the sun, due to acceleration over about 20 R_S,from very slow speeds at the source surface, could be responsible.By incorporating this temporal bias the agreement between thetwo positions was very good for the full six months. Numerousother properties of the HCS, and preliminarily for the plasmasheet, were determined. A very intriguing one is the existenceof apparent wave-like structures on the HCS with scale-lengthsof about a few times 10^3 km; other interpretationsfor these new findings are possible and being pursued.

Interstellar Pickup Protons: Neutral particles enter theheliosphere from the interstellar medium and are ionized to produce"pickup protons". These have been identified directlyin the Ulysses data at 5 AU, where the pressure of pickup protonsis negligible. L Burlaga et al. presented indirect evidence thatpickup protons are present at 30 AU, where their pressure greatlyexceeds that of the solar wind and is comparable to the pressureof the magnetic field. This result was extended by L. Burlaga,N. Ness (Bartol) and J. Belcher (MIT) who showed that the pickupproton pressure is greater than that of the magnetic field andsolar wind near 30 AU. They inferred that pickup protons havea major effect on the dynamical processes in the distant heliosphereand must be included in models of the interaction between thesolar wind and the interstellar medium. Y. C. Whang (Catholic),L. Burlaga, and N. Ness (Bartol) developed a spherically symmetricmodel of the interaction between the solar wind and the ISM thatpredicts pressure variations of the pickup protons, magnetic field,and solar wind protons that are consistent with the observations.

Merged Interaction Regions: Merged interaction regions(MIRs) are regions previously identified by L. Burlaga and F.McDonald (UMCP) in which the interplanetary magnetic field isunusually strong as the result of the coalescence of interactionregions and shocks observed within ~10 AU. As reviewed by N. Ness(Bartol) and L. Burlaga, corotating merged interaction regions(CMIRs) were observed near 14 AU during the declining phase ofthe last solar cycle in association with recurrent coronal holes.L. Burlaga, N. Ness and J. Belcher (MIT) obtained the surprisingresult that CMIRs were not observed near 40 AU during the decliningphase of the current solar cycle. It is likely that CMIRs aredestroyed between 14 AU and 40 AU, but the process by which thisoccurs is not known.

Large-Scale Fluctuations of the Heliospheric Magnetic Field:L. Burlaga and N. Ness (Bartol) showed that a multifractal structureof the large-scale magnetic field strength fluctuations continuedto be observed out to $_6$0 AU by Voyager 1 at high latitudesabove the sector zone and at

40 AU by Voyager 2 at low latitudeswithin the sector zone. The spectra of the magnetic field strengthfluctuations observed during 1994 indicate that turbulence persistsout to 40 AU, but shock-like jumps dominate the spectra of thespeed fluctuations, suggesting something analogous to Burgersturbulence (L. Burlaga, N. Ness, and J. Belcher).

Coronal hole boundaries: After examining four years ofdata from ICE, K. Ogilvie and M. Coplan (UMCP) have shown thatthe boundaries of ecliptic coronal holes are very sharp, similarto those of the polar holes. The abundances of oxygen, neon, andiron were found to be closer to photospheric than to slow solarwind values.

Shock Heating. D. Berdichevsky and colleagues J. Geiss(Bern), G. Gloeckler (UMCP), and U. Mall (U. Michigan) used theU. Maryland-Bern solar wind ion composition spectrometer on Ulyssesduring its trip in the ecliptic plane to Jupiter to determinethe excess heating of $^{4}He^{++}$ and O^{6+}relative to H^{+} down- stream of interplanetary shocks(ISs). This work presents the first comprehensive result on thedifferential heating, downstream of ISs, of a plasma constituentspecies other than $^{4}He^{++}$. This result canhave important implications in the input in the equation of stateof the magnetized interplanetary plasma in magnetohydrodynamic(MHD) models, as well as to the location of the heliosphere'stermination-shock.

Radio Wave Observations. R. MacDowall, R. Hess, and G.Thejappa published a synopsis of the URAP radio wave observationsthroughout the Ulysses mission with emphasis on the fast latitudescan interval. The Ulysses trajectory is uniquely suited for identifyingthe differences between levels of wave activity in fast and slowsolar wind. Significant differences are observed for Langmuir,ion-acoustic-like, and whistler waves, which can be used to testcurrent theories of the generation and evolution of these waves.

Waves Near Shocks. URAP has also provided important resultsrelating to waves in the vicinity of interplanetary shocks. D.Lengyel-Frey, G. Thejappa, R. MacDowall, and R. Stone analyzedwave data upstream and downstream of 42 shocks and concluded thatthe Langmuir and ion-acoustic-like wave intensities were sufficientto explain both fundamental and harmonic radio emission by a coalescencemechanism. G. Thejappa, R. MacDowall, and R. Stone discoveredlow frequency electric fields in the vicinity of interplanetaryshocks, particularly at high heliographic latitudes. D. Lengyel-Frey,R. Hess, R. MacDowall, and R. Stone demonstrated that whistlerwave intensities in the solar wind are strongly correlated withmagnetic field amplitude and are routinely observed by Ulysseswhen the predicted signal level exceeds the instrumental background.These waves are likely to play a significant role in the regulationof the solar wind heat flux.

Magnetic Holes. R. MacDowall, N. Lin (U Minn.), and P.Kellogg (U Minn.) reported the discovery that magnetic "holes"-abruptdecreases in the interplanetary magnetic field magnitude- are populatedby a variety of wave modes. In particular, these structures arefrequently the reason for observations of Langmuir waves in theinterplanetary medium. Prior to this discovery, the presence ofLangmuir waves was assumed to be an indication of a solar transient.Following up on the Ulysses discovery, R. MacDowall, R. Fitzenreiter,K Ogilvie, and R. Lepping used Wind spacecraft data to confirmthat electron beams existed in and near the magnetic holes.

*Terrestrial Low-frequency (LF) Radio Bursts.*The Wind/WAVES experiment (M. L. Kaiser, PI) has made detailedobservations of a little-known by quite common component of Earth'snatural radio spectrum. This component, call LF bursts, is reminiscentof type III solar bursts but on a vastly faster time scale. TheyLF bursts are also quite similar to a component of Jupiter's radiospectrum known as Jovian "type III" or QP (quasi-periodic)bursts. The terrestrial LF bursts have now been observed simultaneouslyby WAVES and the radio experiments on Geotail and Polar. The burstsare also associated with a unique signature in ground-based magnetogramsand are strongly correlated with period of high solar wind velocity.With the large data base now available with the ISTP spacecraft,we believe the source and cause of these LF bursts will be determinedin the near future.

Plasma Radiation. M. Reiner, M. Kaiser, M. Desch, J. Fainbergand R. Stone used the unique WIND radio direction finding capabilitiesto study the origin of the terrestrial 2fp radio emission. Byusing an interplanetary shock as a diagnostic, they were ableto locate the radio source and determine that it extended some100 RE in the downstream wing of the electron foreshock region.The WIND direction finding analyses of terrestrial 2fp radio emissionwere combined with similar analyses from Geotail to obtain thefirst 3-D source location via two spacecraft triangulation. Thismethod is being used by M. Reiner, M. Kaiser, Y. Kasaba (RASC,Kyoto), H. Matsumoto (RASC, Kyoto), and I Nagano (Kanazawa) tostudy the dynamical behavior of the foreshock region in responseto changes in orientation of the interplanetary magnetic field.

*Observations of Solar Wind Turbulence***.** Solar winddata, accumulated over three decades, now samples regions from0.3 to more than 40 Astronomical Units (AU). Analyses undertakenby D. A. Roberts and M. Goldstein of magnetic field and plasmadata from the high heliographic latitude pass of the Ulysses spacecraftindicate that the evolution of the plasma fluctuations with latitudeand distance are in accord with predictions and expectations derivedfrom Helios, ISEE, and Voyager data and a variety of numericalexperiments. The fast solar wind at high latitudes evolves moreslowly than does the highly striated and complex flows that originateat low latitudes near the stream belt. The Ulysses data also confirmsthe suggestion from Helios analyses that the spectrum of turbulencein the corona has a relatively flat power-law index and that theKolmogoroff-like spectral shape observed at relatively greaterheliocentric distances and at relatively high wave numbers reflectsthe evolution and development of magnetohydrodynamic (MHD) turbulence.Some aspects of these observations have been modeled numericallyby S. Ghosh, D. A. Roberts, and M. Goldstein. Ulysses data hasalso afforded a unique opportunity to look for systematic periodicitiesin the data and D. A. Roberts and M. Goldstein have found evidencea 34 day period characteristic of the photospheric rotation ratein the high-latitude plasma and magnetic field data.

*MHD Simulations of Heliospheric Phenomena***.** The Laboratorywas successful in obtaining two grants under NASA's Space PhysicsTheory Program (T. Birmingham, Project Scientist). One (PI, M.Goldstein) uses a variety of simulation methods to study heliosphericphenomena including the role of waves in accelerating and heatingcoronal plasma (E. Siregar) and the evolution of turbulence inthe presence of convected structures (A. Roberts, S. Ghosh, M.Goldstein). The emphasis is on trying to model the fluid behaviorof the solar wind, primarily by solving the compressible and incompressibleMHD equations dimensions (A. Roberts, M. Goldstein, S. Ghosh,E. Siregar, and A. Deane),. More detailed studies, however, usehybrid (fluid electrons and kinetic protons), fully kinetic simulationsdescription (A. Figueroa-Viñas), and direct solution ofthe Vlasov-Maxwell equations (A. Klimas) to understand processeswhich occur on time and length scales that cannot be resolvedin the fluid description. These situations have resulted in increasinglymore accurate descriptions of the physical processes which characterizethe solar wind.

Theoretical Studies of Solar Wind Turbulence. A new codeusing a Flux Corrected Transport algorithm is being modified toinclude the spherical expansion of the solar wind. The presentversion of the code has been used to produces high resolutioncompressive solutions of the interaction of fast and slow flowacross a velocity shear layer as the supersonic magnetofluid convectsdown a tube (A. Deane, D. A. Roberts, M. Goldstein). Another areaof emphasis has been to understand how solar wind turbulence dissipates(S. Ghosh, E. Siregar). One approach has been to generalize theMHD equations to include finite Larmor radius corrections (S.Ghosh, E. Siregar, M. Goldstein). An even more detailed descriptioninvolves using kinetic theory, in particular, the evolution ofthe ion cyclotron instability, to derive the dissipation termsused in the MHD equations (E. Siregar, A. Viñas). Thisproject involves detailed comparisons between kinetic theory,hybrid simulations, and spectral solutions of the MHD equations.

Shock Acceleration. A study of the importance of the magneticfield in the control of shock accelerated particles in Co-rotatingInteraction Regions is being carried out by K. Ogilvie and collaboratorswith data from SWICS and LAN instruments. Phase space densitiesfrom these two instruments cover from ~10 eV to 5 MeV. Indicationsare that the magnetic field may be more important than the specificentropy.

Ionosphere-Thermosphere-Mesosphere

Substorm Electrodynamics. J. Gjerloev, a graduate studentfrom Denmark, and R. Hoffman are producing the first realisticempirical models of electron precipitation and resulting ionosphericconductivity enhancements on the nightside during substorms. Ageneric bulge-type aurora was previously deduced from global auroralimages from the Dynamics Explorer 1 satellite by R. Fujii whopreviously worked with Hoffman. Each Dynamics Explorer 2 passat low altitudes was placed into one of six sectors of this genericaurora based on its location through the actual auroral patternobserved simultaneously by the imager. Using data from 39 suchpasses, the average characteristics of the electron precipitationhave been obtained. To the west of the auroral surge and bulgeand within the surge, much of the precipitation in the boundaryplasma sheet region, the most poleward precipitation region, hasthe form of inverted-Vs, with the characteristic energies of afew keV, increasing to above 10 keV into the surge. In the bulgeand east of the bulge the most energetic precipitation lies inthe more equatorward central plasma sheet region with Maxwellian-typespectra. However, some of the most intense precipitation in thesurge shows a rather featureless spectrum. Pederson and Hall conductivitiescalculated from the electron distributions reach many 10s of mhoson the average, with peak values up to several hundred mhos. Theconductivities also display very large gradients. These valuesare many times larger than previous models derived from radarand ground magnetometer data which don't have the resolution ofthe satellite data. The Hall to Pederson conductivity ratios areabout 2 in contrast to the value of 1 in previous models. Thesedata will be combined with typical field-aligned current patternsand ionospheric convection patterns previously derived from thesame data set from the Dynamics Explorer satellites to producea self-consistent ionospheric model of the bulge-type aurora,the most typical type.

Ionosphere-Thermosphere Interactions. F. Herrero, in collaborationwith C. Arduini and G. Laneve (U Rome), presented the first studyof the propagation of the midnight density maximum

(MDM) in theequatorial thermosphere of the Earth between altitudes of about200 and 400 km. The study used the San Marco satellite data obtainedby the San Marco Project scientists at the University of Rome(Arduini and coworkers) with their drag balance instrument . Theresults support the mechanism of upward propagation of tidal energyfor the space-time evolution of the MDM. In addition, strong altitudestructure found in both phase and amplitude, suggest viscous andion-drag interactions that may affect the vertical propagationitself with possible reflections of some of the tidal modes thatdrive the MDM. The MDM, a thermospheric feature that occurs onmost nights, is believed to be a consequence of compressional(adiabatic) heating that may occur in the midnight sector of theglobe driven by the flow field originating in the dayside. Mostof the heating is expected to occur in the lower thermospherebelow 200 km, thus giving rise to temperature and density maximaat higher altitudes. Such a description is that of a tidal phenomenon,driven by solar EUV heating in the dayside and propagating upwardsto ionospheric F-region heights, consistent with the San Marcosatellite data. In collaboration with Clemson University, evidencefor orographic wave heating in the equatorial thermosphere atsolar maximum was found in the Fabry-Perot interferometer (FPI)airglow (OI 630 nm) measurements of Meriwether and Biondi. TheFPI measured the nighttime horizontal wind and the temperatureat F-region heights just south of the geomagnetic equator at Arequipa,Perú. The data revealed thermospheric temperatures overthe Andes mountains that were 100 to 200 K higher than the correspondingtemperatures over the Pacific Ocean. This temperature differencepersisted throughout the night and was most pronounced in localwinter for moderate to high solar fluxes. Correlated with thistemperature difference there was also a sustained difference inthe zonal thermospheric wind of 50 to 70 m/s; the wind movingmost rapidly over the Ocean. The lack of neutral density datamakes it difficult to estimate the pressure gradient to predictthe observed wind gradient. Nonetheless, the temperature gradientobserved is comparable to the largest gradients observed on theAE-E satellite, and of the right sign and sufficiently large toslow down the zonal wind by the observed amount with a modestdensity gradient. Waves generated by tropospheric wind as airflows over the Andes are invoked as a possible explanation ofthe observed heating, a hypothesis not inconsistent with troposphericwind patterns in the region.

Electron Density Fluctuations. There is considerable evidencethat irregularities in the electron density Ne can be generatedin the direction perpendicular to the ambient magnetic field **B**in space plasmas both by natural processes and during controlledactive experiments. Since these transverse Ne irregularities aremaintained for long distances along **B**, they are calledfield-aligned irregularities or FAI. They can easily be detectedby radio waves that are either scattered by them or are guided(ducted) along them. R. Benson presented evidence suggesting thationospheric topside sounders stimulate (or enhance) FAI on a veryshort time scale (<< 1 sec) by the efficient absorptionof sounder energy via the ponderomotive force when the plasma/gyrofrequency ratio is nearly an integer value significantly greaterthan one. Thus, in addition to providing information on globaldistributions of the topside electron density and on natural radioemissions, satellite-borne ionospheric sounders can be consideredto act as mobile ionospheric heating facilities. Investigationsof such topics using data from the International Satellites forIonospheric Studies (ISIS) program in a digital format are nowbecoming possible (see http://nssdc.gsfc.nasa.gov/space/isis.html).

Mesospheric Observations. In August 1994, the MALTED (MesosphericAnd Lower Thermospheric Equatorial Dynamics) Program was conductedfrom the Alcântara rocket site in northeastern Brazil aspart of the International Guará Rocket Campaign to studyequatorial dynamics, irregularities and instabilities in the ionosphere.This site was selected because of its proximity to the geographic(2.3°S) and magnetic (~0.5°S) equators. MALTED was concernedwith planetary wave modulation of the diurnal tidal amplitude,which exhibits considerable amplitude variability at equatorialand subtropical latitudes. The goals were to study this globalmodulation of the tidal motions where tidal influences on thethermal structure are maximum, to study the interaction of thesetidal structures with gravity waves and turbulence at mesopausealtitudes, and to gain a better understanding of dynamic influencesand variability on the equatorial middle atmosphere. Four (twodaytime and two nighttime) identical Nike-Orion payloads designedto investigate small-scale turbulence and irregularities werecoordinated with twenty meteorological falling-sphere rocketsdesigned to measure temperature and wind fields during a ten dayperiod. These in situ measurements were coordinated with observationsof global-scale mesospheric motions that were provided by variousground based radars and the Upper Atmosphere Research Satellite(UARS) through the CADRE (Coupling and Dynamics of Regions Equatorial)campaign. The ground-based observatories included the Jicamarcaradar observatory near Lima, Peru, and medium frequency (MF) radarsin Hawaii, Christmas Island, and Adelaide. Since all four Nike-Orionflights penetrated and overflew the electrojet with apogees near125 km, these flights provided additional information about theelectrodynamics and irregularities in the equatorial ionosphericE-region, and may provide information on wave coupling betweenthe mesosphere and the electrojet. Simultaneous with these flights,the CUPRI 50-MHz radar (Cornell University) provided local soundingof the electrojet region. From a study of electron density fluctuationsmeasured by rocket probes, indications have been found for equatorialmesospheric neutral-atmospheric turbulence between 85-90 km. Furthermore,falling-sphere data coupled with a detailed study of the tidalmovements, as ascertained from the meteorological rocket data,provide the first evidence for equatorial gravity wave breakingand for its importance as a source for this turbulence.

Magnetospheric Physics

Near Magnetotail. J. Slavin has been serving as the GeomagneticEnvironment Modeling Program coordinator for the WIND perigeeintervals. These intervals are unique because, in conjunctionwith Geotail, Interball and the DoD and NOAA geosynchronous satellites,they allow for multi-point observations of the low-latitude nightsidemagnetosphere. In collaboration with R.P. Lepping (WIND/MagneticFields Investigation Principal Investigator), D. Fairfield, A.Szabo, and other ISTP scientists,. Slavin reported the first observationsof substorm associated bursty bulk flows and magnetic field dipolarizationextending across more than ten earth radii in the magnetotailin the dawn-dusk direction. The understanding of such plasma dynamicsduring substorms is a primary objective of the ISTP program.

Distant Magnetotail. J. Slavin , D. Fairfield, and R. Leppinghave conducted the first multi-spacecraft studies of plasmoidejection during substorms utilizing the magnetic field, plasmaand energetic particle investigations on-board the IMP 8 and Geotailspacecraft. As detailed in a paper just submitted to the J. Geophys.Res., they have found several intervals in the ISTP data setswhere the initial plasmoid ejection can be detected first at IMP8 (~35 earth radii down the tail) as a so-called traveling compressionregion, and then about half an hour later a plasmoid was observedby the Geotail spacecraft (~200 earth radii down the tail). Theseobservations confirm that large, i.e. several thousand cubic earthradii, segments of the central magnetotail (i.e., the plasma sheet)become detached during magnetospheric substorms and are ejecteddown the tail to eventually merge with the solar wind. In addition,these observations have also provided new insights into number,location and intensity of reconnection neutral lines in the magnetosphereand their roles in the substorm process.

Magnetic Field Models. N. Tsyganenko, D. Stern, and M.Peredo are working to derive quantitative relationship betweenconditions in the solar wind and the configuration of the Earth'smagnetosphere, based on extensive sets of data from many spacecraftand mathematical models of principal sources of the geospace magneticfield. During the last year, the first version of the new-generationglobal model of the magnetospheric field was developed by N. Tsyganenkoand made available to the space physics community on the WorldWide Web. The essential features of the new model, not presentin all earlier models, are (i) an explicitly defined boundarywith a realistic shape, whose size is controlled by the pressureof the solar wind, (ii) interconnection between the geomagneticand solar wind magnetic fields, and (iii) taking into accountthe contribution from the large-scale Birkeland current systems,and (iv) a continuous parameterization of the model by the parametersof the solar wind and the Dst-index. New sets of spacecraft datawere prepared and added to the existing database for the magnetosphericfield modeling, including the data of Hawkeye, AMPTE/CCE, andCRRES. This significantly improves the spatial coverage and isexpected to result in an increased reliability of future versionsof the model in the near magnetosphere and distant polar regions.

Current Disruptions. M. Hesse and J. Birn (LANL) extendedtheir simulations of magnetospheric dynamics to include a detailedstudy of magnetotail current disruption. This study demonstratedthat current disruption and magnetic reconnection are intimatelylinked and part of the same large scale magnetotail instability.Further investigations showed that flux-rope-like plasmoids canform from bubble-like plasmoids if thermal contact between theplasma contained in the plasmoid and the low-latitude boundarylayer is established by magnetic reconnection. Another study involveda comparison between two very different MHD codes in their applicationto the tail instability problem. The study showed that the resultswere very similar, despite the large difference in methodology.Finally, new investigations involving particle tracing in self-consistentMHD fields show that ion injections in the inner magnetospherecan be explained by particle acceleration caused by a large scalemagnetotail instability.

*Terrestrial Foreshock.*Observations of the radio emission at twice the local plasma frequencyemanating from Earth's electron foreshock area have been madeby the WAVES experiment (M. L. Kaiser, PI) on the Wind spacecraft.Simultaneous direction or arrival measurements by WAVES and theGeotail PWI experiment have allowed us to triangulate the sourcelocation of the $2f_p$ emission for the first time, showingthat the emission comes from the leading edge of the foreshockand can be both upstream and downstream of Earth.

Cusp Model. M. Smith and his collaborator M. Lockwood fromRAL, England have continued development of the pulsating cuspmodel. Recent publications include a major article in Review ofGeophysics.

Current Sheet. M. Hesse and M. Kuznetsova have extendedtheir 2 1/2 dimensional hybrid code to include driving electricfields as are thought to be provided by magnetic reconnectionat the dayside magnetopause. Results of simulations of the drivenresponse of the current sheet demonstrate the formation of newthin current sheets within the larger equilibrium current sheet.The ion response to the driving appears to be best described bya simple density and temperature enhancement, rather than theformation of significant anisotropies. They also found that theapplied electric field does not penetrate into the current sheetdue to finite plasma compressibility. As a result, significantion acceleration was not seen. Further, a boundary layer on scalesless that ion skin depths formed in which Hall electric fieldscause a reduction of the ion and strong enhancements of the electroncurrent density. This result has profound implications for localsubstorm onset. Furthermore, the Hall electric field may serveas a remote sensing signature for magnetospheric observations.

Ion acceleration. M. Hesse and M. Kuznetsova have alsoperformed a fully self-consistent analysis of ion accelerationmechanisms using a hybrid model of magnetic reconnection in magnetotailconfigurations. They have found that ions can be accelerated ina variety of fashions. First, the ensuing reconnection electricfield accelerates ions both earthward and tailward, thus explainingthe observed energetic ion beams around plasmoids. Second, itwas found that bouncing ions trapped between the dipole magneticfield and an earthward propagating dipolarization front can alsoexperience acceleration due to a quasi-Fermi effect. Even thoughparticle boundary conditions were handled very carefully, particlesignatures taken from nonself-consistent models are present buthidden in the distributions taken from the self-consistent model.The reason is that particles originating from various differentregions are intermixed and subjected to fluctuating electric andmagnetic fields. As a next step a newcode was developed to study in detail the role of thermal versusbulk electron inertia in collisionless dissipation as requiredfor magnetic reconnection. Analytic scaling shows that for finiteelectron beta thermal effects should require a slightly largerscale length that bulk inertia effects. The investigation showsthat reconnection driven by electron bulk flow inertia appearsto be highly nonstationary whereas thermal anisotropies tend tolead to more laminar reconnection regions. Finally, Hesse andKuznetsova recently developed a fully three-dimensional hybridcode to generalize our studies.

Low-Dimensional Dynamics. Nonlinear autoregressive movingaverage filters have been shown to be effective predictors ofgeomagnetic activity driven by the solar wind and controlled bythe magnetospheric dynamics. These filters are noteworthy because,in addition to their prediction capabilities, they are deriveddirectly from the solar wind and geomagnetic activity data withno assumptions on the properties of the magnetospheric dynamics;they are unbiased representations of the magnetospheric dynamics.They are also, however, impenetrable to physical interpretation.Recently, A. Klimas and colleagues D. Vassiliadis and D. Baker(LASP) have constructed a transformation of the prediction filtersto low-dimensional nonlinear dynamical models that are amenableto physical interpretation. In effect, they have found a generalmethod for finding, and modeling, suspected causal relationshipsbetween pairs of otherwise independent time-series data sets.A generalization to multivariate analysis is anticipated thatwill enable finding, and modeling, spatio-temporal relationshipsbetween larger numbers of data sets.

Simulation of the Earth's Electron Foreshock. Velocitydispersion-driven bump-on-tail unstable electron plasmas are observedin a variety of spatial locations in the magnetosphere and theheliosphere. They are invariably an indication of plasma energizationsomewhere on the magnetic field line threading the observing spacecraft,and can be used to study the properties of the energization siteand the space between that site and the spacecraft. The best observedand most studied example of this phenomenon is Earth's electronforeshock. Remarkably, the existence of the foreshock is stillwithout explanation. According to present plasma physical understandingthe foreshock should consist of a weak perturbation in the solarwind very close to the bow-shock; it should not exist to tensof earth-radii away from the bow-shock where it is observed. Theprimary difficulty in understanding the foreshock is the couplingbetween very large spatial scales, tens of earth-radii, to verysmall spatial scales, hundreds to thousands of meters, which isthought to be responsible for maintaining the foreshock. A. Klimasand colleagues R. Fitzenreiter and R. MacDowall are studying thiscoupling using a Vlasov plasma-simulation method that is designedfor this purpose. Up-shifted and broad-band down-shifted electronplasma waves have been found in the simulation results in conjunctionwith electron velocity distributions that are in excellent agreementwith those observed on the ISEE and WIND spacecraft. Some evidencefor the persistence of the bump-on-tail unstable electron distributionshas been found in the initial simulation results.

Global Simulations. S. Curtis is the principal investigatorof a new major grant from the Space Physics Theory Program. Byperforming calculations on a time variable, three dimensionalgrid, unprecedented resolution is possible for global MHD simulationsof astrophysical systems. The specific astrophysical plasma systemsimulated is the Earth's magnetosphere which has by far the largestdata base to test theory against data. Future plans call for theincorporation of kinetic elements into the simulation which willallow the resolution to extend beyond the present limits due tothe graininess of the plasma (several ion gyroradii) and willpermit a detailed study of astrophysical boundary layer processesthat have been previously inaccessible to global simulations.The research group is drawn from a local consortium of universitiesand laboratories, in addition to Goddard: University of Maryland(College Park), Johns Hopkins University Applied Physics Lab,The Naval Research Laboratory, and George Mason University.

V. SOLAR AND STELLAR RESEARCH

Solar and Lunar Eclipses. F. Espenak and J. Anderson (EnvironmentCanada) published a 98 page NASA Reference Publication 1383 "TotalSolar Eclipse of 1998 February 26". Detailed predictionsfor this event include besselian elements, geographic coordinatesof the path of totality, physical ephemeris of the umbra, topocentriclimb profile corrections, local circumstances for over 1000 cities,maps of the eclipse path, weather prospects, the lunar limb profileand the sky during totality. Tips and suggestions are also givento the general public on how to safely view and photograph theeclipse. The path of the total solar eclipse begins in the Pacific,continues through northern South America and the Caribbean Sea,and ends at sunset off the Atlantic coast of Africa. A partialeclipse will be seen within the much broader path of the Moon'spenumbral shadow, which includes parts of the United States andeastern Canada, Mexico, Central America and the northern halfof South America. F. Espenak published a paper "EclipsesDuring 1996" in the *Observer's Handbook - 1996* ofthe Royal Astronomical Society of Canada. This annual contributionpresents predictions for the two partial solar and two total lunareclipses occurring during 1996. Tables of local circumstancesfor each solar eclipse are given. Lunar eclipse predictions areaccompanied by crater contact tables. Global maps show the regionsof visibility for each eclipse and diagrams of the Moon's paththrough Earth's shadow are included. Predicted times for the variousstages of each eclipse are given as are the magnitudes at greatesteclipse.

F. Espenak was a keynote speaker at the NATO Advanced ResearchWorkshop "Theoretical and Observational Problems Relatedto Solar Eclipses" held in Sinaia, Romania on 1996 June 1-

5.This meeting was organized to give researchers a chance to discusscurrent progress and problems in eclipse related solar physicsand to lay the groundwork for planning for the total solar eclipseof 1999 Aug. 11. The path of this eclipse passes through centralEurope, making it easily accessible to millions of people. "NASABulletin for the 1999 Total Solar Eclipse" (F. Espenak) willbe published in the NATO ARW proceedings during Fall 1996. A detailedNASA bulletin on the 1999 eclipse (F. Espenak and J. Anderson)is in preparation and will be published in winter 1996.

Prominence spectra. D. Deming and E. S. Chang (Univ. Massachusetts)completed their analysis of the 1 to 5 μminfrared spectrum of a solar prominence. They are currently involvedin an extension of this work to the 10 μmspectral region. Analysis of 10 μmFourier transform spectra taken by P. Foukal at the McMath-Piercesolar telescope reveals a very pronounced broadening of the high-nHydrogen lines. It is believed that this represents Stark broadeningdue to the prominence electron/ion density, which is indicatedto be of order 10^{11} cm-3. Additional infrared observationsof prominences are planned to be made simultaneously with SOHOobservations of UV emission lines.

Solar Chromospheric Heating. M. Goodman developed a seriesof two dimensional, steady state, resistive MHD models with flowto support the proposition that a major source of heating forthe middle chromosphere is resistive dissipation of large scaleelectric currents driven by a convection electric field. The currentsare large scale in that their scale heights range from hundredsof kilometers in the network to thousands of kilometers in theinternetwork. The current is carried by protons, and flows orthogonalto the magnetic field in a weakly ionized, strongly magnetizedhydrogen plasma. The flow velocity is mainly parallel to the magneticfield. The relatively small component of flow velocity orthogonalto the magnetic field generates a convection electric field whichdrives the current. The magnetic field is the sum of a loop shapedfield and a stronger, larger scale potential field. Solutionsindicate that magnetic loops with horizontal spatial extents of1000 - 5000 km may be confined to, and heat, the middle chromosphericnetwork. Other solutions indicate that magnetic loops with horizontalspatial extents of 10,000 - 30,000 km may span and heat the middlechromospheric internetwork over the interior of supergranules,and may be the building blocks of the chromospheric magnetic canopy.

VI. SPACE FLIGHT PROGRAMS

CURRENT MISSIONS

International Solar-Terrestrial Physics (ISTP) Program

Program Overview. The International Solar-Terrestrial Physics(ISTP) Program provides simultaneous coordinated scientific measurementsfrom most of the key areas of geospace using spacecraft instrumentationlocated in polar, geosynchronous, circular, deep magnetotail,L1, and petal orbits, and using high latitude ground stations.Since September of 1992, Key Parameters (approximately 1 min averagesof more detailed data) are provided from these regions and fromthe Sun by many instruments on Goes 6, 7, 8, and 9; LANL 89, 90,91; IMP-8; WIND; POLAR; Geotail; and SOHO spacecraft, and fromradar, riometer, magnetometer, and other ground-based measurements.This combined data base, available on-line over the NASA

ScienceInternet and distributed on CD-ROM, is being used to obtain amore complete understanding of global magnetospheric dynamics.

Many LEP investigators are involved in the ISTP Program as ProjectScientists: M. Acuña (ISTP), K. Ogilvie (WIND), R. Hoffman(POLAR), M. Goldstein (NASA Cluster), M. Hesse (NASA Equator "S"),S. Curtis (Theory),. W. Mish (Data Systems), D. Fairfield (EquatorScience). Instrument P.I.'s include: K. Ogilvie (WIND/SWE, R.Lepping (WIND/MFI), and M. Kaiser (WIND/WAVES). The LEP also hasa large number of Co-I's associated with WIND and POLAR instrumentsand the ISTP Theory Program, and the Information Analysis andDisplay Office has a number of people involved with the data analysis.

Science Planning and Operations. Tools have been developedby the LEP-based ISTP Science Planning and Operations Facility(SPOF) to display the Key Parameters. In addition the SPOF produces"custom" displays of Key Parameters from Geotail, WIND,IMP-8, geosynchronous satellites and ground-base instrumentation.For important scientific periods these plots are available overthe World Wide Web (http://www-spof.gsfc.nasa.gov/).

The SPOF uses the Satellite Situation Software to generate informationused in planning the instruments operations for Wind and POLARspacecraft, and for coordination of science operations with othermissions. These coordination efforts involve Science Campaignssponsored by ISTP and the Inter-Agency Consultative Group forSpace Science (IAGC) initiatives. Coordination also takes placebetween the Science Planning and Operations Facility and the Solar-TerrestrialEnergy Program (STEP) coordination office.

Theory. Global MHD simulations of the magnetosphere, asthe result of a multi- year effort under the auspices of the InternationalSolar Terrestrial Physics (ISTP) Program led by Project Scientistfor Theory, S. Curtis, are now capable of near quantitative picturesof the magnetosphere. As a result, new strides in understandingexplosive processes in the magnetosphere associated with magneticreconnection have become possible. The simulations provide theframework for connecting the widely separated satellite singlepoint measurements and associated remote auroral observations.Given the solar wind input to the magnetosphere, the detailedmorphology of the aurora can be predicted and compared to observationsfrom the ISTP Polar spacecraft.

POLAR

POLAR is a part of the International Solar Terrestrial PhysicsProgram. On February 24, 1996, this spacecraft was placed in an86 degree inclination elliptical orbit with a 9 RE apogee anda 1.8 RE perigee. The spacecraft contains a large array of electricand magnetic fields instruments, charged particle detectors thatresolve ion species, and three types of auroral imagers coveringthe ultraviolet aurora, visible aurora, and auroral X-rays. Theseinstruments utilize state-of-the-art technology in both theirdetector and electronics systems. Unique data are being acquiredon the entry of plasma into the polar magnetosphere from boththe solar wind and the ionosphere, on important plasma physicsmechanisms that transfer energy between fields and charged particles,and of unprecedented images of the aurora with high time and spatialresolution. R. Hoffman is the POLAR Project Scientist, M. Hessethe Deputy Project Scientist, and N. Fox the operations coordinator.The Laboratory has a number of Co-Investigators associated withinstruments on this spacecraft.

Electric Fields. NASA's POLAR satellite was launched inFebruary, 1996. Included in the payload complement is the firstvector DC electric field experiment to be flown in the Earth'smagnetosphere. The instrument is returning unprecedented dataconcerning magnetospheric electric fields including those associatedwith double layers, cusp crossings, plasma sheet boundaries, thepolar cap and auroral zones, the plasmapause and plasmasphere,and the magnetopause. The Principal Investigator for the ElectricField Experiment on Polar is Dr. Forrest Mozer at the Universityof California at Berkeley. At the LEP, the electric field teamconsists of R. Pfaff, Jr., M. Hesse, and J. Clemmons.

Plasmas. The HYDRA instrument, which measures plasma distributionfunctions and was built in the LEP, is working very well; dataare being reduced and the first publications readied for publication.

WIND

Plasma measurements. The SWE instrument (K. Ogilvie, P.I.)continues to operate correctly and data is reduced and availableto date. Papers have been written on the Lunar Wake, RelativeMotion between Hydrogen and Helium ions in the Solar Wind, TheEarth's Foreshock, Observations in the Magnetosheath, InterplanetaryMagnetic Clouds and many magnetospheric topics.

NEAR

The NEAR spacecraft (APL-led) was successfully launched on February17, 1996. The NEAR XGRS (J. Trombka, team leader) was turned onduring the week starting April 7, 1996 and periodic tests werecarried out through November 11,1996 when the entire system willbe shut down until June, 1997. The x-ray and gamma-ray detectorsystems have all been tested and are operating according to specifications.Both background and calibration data have been obtained.

Ulysses

The Ulysses spacecraft has completed its primary mission withthe first in situ exploration of the interplanetary medium abovethe south and north poles of the Sun. The primary mission includeda "fast latitude scan", which took the spacecraft from80° S. heliographic latitude to 80° N. latitude in only10 months, ending in mid-1995. This fast latitude scan providedunprecedented observations of slow and fast solar wind at solarminimum as a function of latitude. Currently, Ulysses has begunits second orbit of the Sun, which will bring it over the polesof the Sun in 2001-2002 at the height of solar maximum when itwill explore an interplanetary medium that is significantly moreperturbed by transients events.

The GSFC contribution to Ulysses includes involvement with twoof its scientific instrument packages, the Unified Radio and PlasmaWave investigation (URAP) and the Solar Wind Ion Composition Spectrometer(SWICS). URAP Co-investigators at GSFC are M. Desch, J. Fainberg,M. Goldstein, M. Kaiser, R. MacDowall (Principal Investigator),M. Reiner, and R. Stone (PI emeritus); K. Ogilvie is a Co-investigatoron the SWICS team.

Recent URAP results pertain to the observations of both remoteradio sources and in situ plasma waves. M. Reiner, J. Fainberg,and R. Stone provided the first remote "snapshot" ofthe Archimedean spiral of the heliospheric magnetic field, publishedin Science. J. Fainberg, V.

Osherovich , R. Stone, and R. MacDowallpresented an analysis of the thermodynamic properties of a particularlywell-defined magnetic cloud observed by Ulysses. R. MacDowall,R. Hess , G. Thejappa (U. Md.), and D. Lengyel-Frey (U. Md.) reportedon a variety of in situ wave phenomena observed by Ulysses, includingthe significant differences observed in various wave modes duringthe fast latitude scan, the characteristics of whistler, Langmuirand other wave modes in the vicinity of interplanetary shocks,and the discovery by Ulysses of intense wave activity in the vicinityof magnetic holes. M. Kaiser, M. Desch, M. Reiner, and otherscontinued to analyze the wealth of Jovian radio data provide byUlysses. These results are described in the relevant sectionsabove.

FAST

NASA's Fast Auroral SnapshoT Explorer (FAST) was launched on August21, 1996 into its planned 350 km x 4175 km orbit with an 83 degreeinclination. The objective of the satellite is to understand thephysical processes that energize charged particles that producethe Earth's aurora, as well as participate in several other plasmaacceleration processes in the high latitude region of the magnetosphere.Instruments on FAST include fast energetic electron and ion spectrometers,vector electric and magnetic field wave instruments, and an energeticion composition experiment. The Principal Investigator for FASTis. C. Carlson (U C Berkeley). R. Pfaff of the LEP is the NASAProject Scientist for the FAST mission.

IMP-8

IMP-8 has now been providing fields and particles data for 23years and continues in its role as participant in the ISTP program.It functions as either a *solar wind monitor*, providinginformation on upstream solar wind energy and specific magneticfield state-function, or almost as often and now with renewedinterest, as a *source of magnetospheric data*, since anothersolar wind monitor WIND is in orbit. IMP-8 has contributed valuabledata to solar, solar wind, and magnetospheric physics for overa complete (22-year) solar cycle. Because of efforts by personnelat Goddard Space Flight Center, including those within the Lab(M. Comberiate, J. King, and R. Lepping), an IMP-8 tracking stationhas been recently erected at McMurdo, Antarctica. As a resultof this effort useful spacecraft telemetry has increased fromabout 69% to 92% per year when the period mid-year 1995 to mid-year1996 is compared to the year 1994, for example, significantlyenhancing the value of the IMP-8 data set, especially when importantmultipoint measurements are essential to a study. J. Slavin andA. Szabo have recently joined the IMP-8 magnetometer team (R.Lepping, PI).

Support of the Sprite '96 Campaign

Members of the Laboratory of Extraterrestrial Physics participatedin the Sprite '96 observation campaign in the summer of 96 atthe Yacca Ridge Field Station in Ft. Collins Colorado. The groupobtained AC magnetic measurements in the ELF-VLF regime of theluminous events observed over thunderstorms, now commonly called"sprites." Laboratory members built a fast samplingVLF burst detection system that triggers on impulsive events,such events defined by their broadband frequency spectra. Thesystem captures the event waveform in an extended time interval.All totaled, the group captured over 70 events with simultaneousradio and visual observations.

FUTURE MISSIONS

Cassini

E. Sittler and team members M. Johnson, A. Ruitberg, F. Hunsaker,T. Vollmer and S. Bakshi are developing for the Cassini PlasmaSpectrometer Investigation (CAPS) the Spectrum Analyzer Module(SAM), 16 kV High Voltage Power Supply, and Flight Software forSAM and the Data Processing Unit (DPU). The primary objectiveof the CAPS investigation is to measure the plasma environmentof Saturn's magnetosphere and surrounding regions. The principalinstrument of CAPS is the Ion Mass Spectrometer (IMS) which usesa Linear Electric Field (LEF) time-of-flight section to determinethe composition of the plasma which is believed to be composedof hydrogen, water, nitrogen and carbon ions with mixtures ofmethane and ammonia ions. The 16 kV High Voltage Power Supplyis to provide the required 30 kV across the LEF time-of-flightsection of the IMS. The primary function of SAM is to accumulatemedium and high resolution time-of-flight spectra for all eightangular sectors of the IMS and process the time-of-flight spectrausing a specially developed high speed spectral analysis algorithmto compute the ion abundances. The flight software in the DPUcontrols SAM and the Time-to-Digital Converter (TDC) and acquirestime-of-flight data, ion abundance data, and housekeeping datafrom SAM and raw singles data and housekeeping data from the TDC.The delivery of the flight unit is currently in progress.

Mars '96

γ-Rays. There are a number ofgamma-ray spectrometers aboard the Mars '96 spacecraft. LEP membershave co-investigator responsibility for four of these spectrometers;this instrumentation development is described in Section VII below.

Magnetic Fields and Plasmas. J. Slavin is a Co-I on thecombined magnetic fields and plasma investigation (MAREMF) whichwill fly on the Russian Mars-96 mission this fall. The co-principalinvestigators are Prof. W. Riedler (Austrian Academy of Sciences)and Dr. M. Verigin (Russian Space Research Institute). U.S. Co-I'swere competitively selected by NASA Headquarters to participatein the various Mars-96 scientific investigations some years agoas part of a scientific exchange which also involved the appointmentof Russian Co-I's to the Mars Observer investigations. Slavinwas also selected by NASA Headquarters to support the Mars GlobalSurveyor mission's magnetic field and electron reflectometer investigation(M. Acuña, P.I) as a Participating Scientists. Both theMars-96 and Mars Global Surveyor Missions will be launched towardMars in November of 1996. In addition to conducting studies ofthe Martian plasma environment and planetary magnetic field, Slavinwill assist the science teams of both missions in the coordinationof their measurements and the exchange of data products.

Mars Global Surveyor

J. Pearl continues his activities as a Co-Investigator on theMars Global Surveyor Thermal Emission Spectrometer (TES) experiment;P. Christensen (Arizona State University) is the TES P.I. Preparationsare under way to provide information to the MGS Project on thermaland aerosol conditions in the Martian atmosphere to assist inthe aerobraking phase of the MGS mission. M. Smith's exploitationof a new pressure-dependent mathematical transformation providesrelatively narrow weighting functions for inversion of upward-lookingspectral data obtained from a planetary surface. Developed witha Martian lander in mind (using the 15 micrometer band of CO_2)the method is applicable to more general situations, such as terrestrialobservations using microwave O_2 lines. This allowsprobing of the planetary diurnal boundary layer in the lower scaleheight at a resolution of about 100m.

Clark

Under the X-ray and γ-ray FacilityDevelopment program (J. Trombka, P.I.; see below) large area roomtemperature detector systems (APD's and CZD's) were developed(R. Starr, P.I., J. Trombka and M. Acuña, LEP Co-I'.s)for the for the advanced-technology Clark Mission to be launchedduring the Spring of 1997; the data obtained will be very importantin development of future planetary x-ray remote sensing systems.

Mars Surveyor '01

In anticipation of the Mars Surveyor '01 (B. Boynton, U. Arizona,P.I.; J. Trombka, L. Evans, and R. Starr, Co-I.'s) remote sensingGRS, plans for a number of investigations have been undertakenunder the . These include a review of the Mars Observer GRS, astudy of simplifying and improving the system and a planfor studying low level (comparable to interplanetary cosmic-rayfluxes) proton induced damage and simultaneous room temperatureannealing. This would attempt to simulate events during the MarsSurveyor '01 cruise phase.

Solar Probe

Plasma Instrument. E. Sittler and team members D. Chornay,F. Hunsaker, J. Keller, K. Ogilvie, A. Roberts, A. Ruitberg andW. Vaughn (LaRC) are developing a plasma instrument which mayeventually be used for the Solar Probe Mission. The plasma instrumentprovides 3-D measurements of the plasma within the Sun's coronaand near solar wind where the spacecraft comes within 4 solarradii of the Sun. The 3-D measurement capability of the plasmainstrument will allow the measurement of ions within an environmentwhere MHD waves can provide large directional swings of the flowwithin the spacecraft frame of reference. It will also allow themeasurement of the strahl electrons which are expected to be movingradially away from the Sun. Previous instrument concepts had theplasma instrument looking to the side within the protective shadowof the spacecraft heat shield and could not look at the Sun. Theplasma instrument uses toroidal top hat analyzers with commoncollimator for the ion and electron measurements. A steering lensis used to provide measurements out of the orbit plane of thespacecraft and the ion spectrometer has time-of-flight sectionfor a mass separation capability. The novel feature of the plasmainstrument is the electrostatic mirror system with miniature heatshield which allows the plasma instrument to look at the Sun.This will allow one to measure high speed flows emanating radiallyfrom the Sun, flows deflected into the anti-solar direction andthe strahl component of the electrons.

In-Situ Measurement Requirements. D. A. Roberts servedas moderator with J. Gosling (LANL) for a subgroup concentratingon the required instrumentation for *in situ* measurementsby a Solar Probe during the workshop on the *Scientific Basisfor Robotic Exploration Close to the Sun* held in Marlboro,MA during Feb. 1996. They summarized the group's findings in thisarea for the proceedings to provide a basis for other planningefforts. A number of LEP members also made individual contributionsto the proceedings.

IMAGE

The Imager for Magnetopause-to-Aurora Global Exploration (IMAGE)is the first of NASA's new MIDEX missions. Its objective is totake the first pictures of Earth's magnetosphere using UV, neutralatom, and radio sounding techniques. It is scheduled for launchin January 2000. M. Smith is the Co-I responsible for the LENAinstrument and is also the Mission Scientist. The PI is Dr. JamesA. Burch from Southwest Research Institute.

SSTP

The TRW Small Satellite Technology Program (SSTP) satellite, tobe launched in the winter of 1996, will carry a new infrared spectralimager (LEISA) designed in the LEP (see Section VII).

EO-1

New Millennium Program Earth Orbiter 1 (EO-1) mission to be launchedin the spring of 1999 will also carry a version of the LEISA infraredspectral imager (see Section VII).

MIDEX Mission Planning

Major strides have been made in developing new multiprobe conceptsfor magnetospheric and ionospheric missions in the NASA MIDEX($70M) class. The effort has been the result of large teams ledby S. Curtis which include scientists from the University of Minnesota,UCLA, Berkeley, University of Colorado Boulder, South West ResearchInstitute, Johns Hopkins University Applied Physics Laboratory,Rice University, and Cornell. An industrial partner Orbital SciencesCorporation/ Fairchild provided the spacecraft engineering breakthroughs.Specifically, two near microsat class missions have been developedwhich fully incorporate commercial-off-the self technology, workstation-based shared commercial ground stations, fully integratedteams, and reduced program management. The first of these spacecraftclusters is composed of 4 spacecraft each with a wet mass of 140kg. With on-board interspacecraft ranging and propulsion capableof 1 km/sec, they fly in a tetrahedral formation with typicalspacecraft separations ranging from 10-60,000 km. throughout themagnetosphere from near earth to 12,000,000 km, the antisolarLagrange point, from equatorial to polar latitudes. This mission,Grand Tour Cluster lite, would for the first to uniquely separatespace and time over scale lengths of interest to magnetosphericplasmas. It would allow a quantitative study of morphology, kinematics,and dynamics of an astrophysical plasma system where measurementsare not limited to radiating plasmas alone. The second mission,Auroral Lites, is also composed of four microsatellites (wet mass110kg each) flying in a tetrahedral formation in 3000 X 6000 kmpolar orbit with separations from 1 to 100km. The focus here ison the plasma energization processes associated with the earth'smagnetosphere's most powerful radiating signature, the aurorallights. Finally, we note that using the Grand Tour Cluster litespacecraft as a point of departure, it has been shown that a Mercurymultiple flyby mission is possible in the MIDEX cost class. Itwould complete the surface map of Mercury, and the initial explorationof the Hermian magnetic field and magnetosphere, as well as penetratecloser to the sun in the inner heliosphere than any probe to date.The mission would be highly complementary to the advanced MercuryOrbiter mission being considered by the European Space Agency.

VII. SPACE FLIGHT INSTRUMENTATION DEVELOPMENT

Infrared Spectral Imaging. D. E. Jennings, D. C. Reuterand G. H. McCabe (in collaboration with the Engineering Directorate)are developing infrared spectral imagers based on the LEISA (LinearEtalon Imaging Spectral Array) concept. LEISA represents a completelynew concept in spectrometer design made possible by large-formatdetectors and advances in thin-film technology. Originally developedfor the Pluto Fast-Flyby Mission (PFF) under the Advanced TechnologyInsertion Program, LEISA uses a state-of-the art filter (a linearvariable etalon, LVE) in conjunction with a detector array toobtain spectral images. The major innovation of LEISA is its focalplane which is formed by placing a LVE in very close proximityto a two-dimensional detector array. The LVE is a wedged dielectricfilm etalon whose transmission wavelength varies along one dimension.In operation, a two-dimensional spatial image is formed on thearray, with varying spectral information in one of the dimensions.The image is formed by an external optic. Each spatial point isscanned in wavelength across the array, thereby creating a two-dimensionalspectral map. Scanning may be accomplished by a number of methodssuch as by the orbital motion of the spacecraft, by rotating thespacecraft, as was planned for PFF, or by a steerable mirror.The actual spatial resolution is determined by the spatial resolutionof the imaging optic, the image scan speed, and the readout rateof the array. The spectrometer has no moving parts, a minimumof optical elements and only one electronically activated element,the array. Compared to conventional grating, prism, or Fouriertransform spectrometers and mechanically or electrically tunablefilter systems, it represents a great reduction in optical andmechanical complexity.

The first space-borne application of LEISA will be as one of themajor scientific instruments on the TRW Small Satellite TechnologyProgram (SSTP) satellite, Lewis, scheduled to be launched in thewinter of 1996. For this earth-viewing application the imagerwill operate in the 1 to 2.5 μm spectralregion with a constant resolving power ($\lambda/\Delta\lambda$)of about 250 at a spatial resolution of 300 meters. Under daylightconditions the spectral images obtained will provide maps of spectrallydependent surface and atmospheric reflectances and atmospherictransmittances. These may be analyzed to yield: 1) surface informationincluding soil and vegetation types, extent of vegetation, snowand ice fields, zones of fire damage and pollution etc. and 2)atmospheric information including areal cloud fractions, cloudheights, cloud particle sizes, cloud particle phases, aerosolproperties, large fire smoke extents, volcanic dust and aerosolproduction and so on.

Another version of LEISA (LEISA/Atmospheric Corrector or LAC)will fly on the New Millennium Program Earth Orbiter 1 (EO-1)mission to be launched in the spring of 1999. In this case thecamera will provide 250 meter spatial resolution, 0.85 to 1.6mm spectral images at a constant spectral resolution of ~30 cm^{-1}.The primary purpose of this atmospheric data is to correct thehigh spatial resolution, low spectral resolution Landsat-typemultispectral images (from another instrument on-board) for thespatially and temporally variable effects of the atmosphere. Plannedformation flying encounters with the operational Landsat satellitewill allow the operational Landsat data to be corrected for atmosphericeffects as well. The unique hyperspectral images will also providescientific data in their own right, including water vapor estimates,cloud and aerosol parameters, and surface properties. EO-1 isthe first of the earth observing New Millennium missions.

Tunable Diode Laser. An LEP spectroscopy group (D. C. Reuter,J. M. Sirota, J. J. Hillman and D. E. Jennings) places a strongemphasis on improving instrumentation and, among other accomplishments,has developed a unique tunable diode laser (TDL) system for obtainingspectra to ~30 μm employing advanced(Si:Sb) BIB detectors, high performance lead-salt lasers and along-path White-type sample cell. A very long-path, coolable White-typecell is currently in fabrication which will allow pathlengthsin excess of 500 m at temperatures as low as 120 K. They are alsoplanning to enhance the long-wavelength capability of the KittPeak National Observatory McMath FTS spectrometer by employinga series of long-wavelength beamsplitters, and are developingmethods for external cavity stabilization of long-wavelength TDLs.

Radio Sounder for Space Plasmas. A state-of-the-art radiosounder design known as a Radio Plasma Imager (RPI) will be oneof the instruments flown on the IMAGE (Imager for Magnetopause-to-AuroraGlobal Exploration) satellite scheduled to fly in January, 2000as the first Medium-class Explorer (MIDEX). R. Benson is a memberof the RPI team and has helped to develop the concept of magnetosphericradio sounding based on his experience with ionospheric topsidesounding. The RPI (Instrument PI: B. Reinisch, U. Mass., Lowell)is one of a complement of remote sensing instruments on IMAGE(PI: J. L. Burch/Southwest Research Institute). Together theyshould provide a major advance in remote observations of magnetosphericstructures and dynamics (see http://bolero.gsfc.nasa.gov/~image/IMAGE.html).

Electric Fields. A group led by R. Pfaff designs and buildselectric field double probes for flights on sounding rockets inthe earth's ionosphere. In the past year, these instruments wereflown on a sounding rocket payload launched from Poker Flat, Alaskato study the atmospheric response to the aurora. The Goddard experimentincluded electronics to measure both the DC and AC vector electricfield components. On-board processing electronics, developed atGoddard, were included in the instrument to carry out on-boardFFT processing that extended the measured frequency regime to8 Mhz

Plasma Detector. J. Keller, F. Hunsaker, and D. Chornaydeveloped a new kind of charged particle analyzer using ellipticallyshaped electrostatic mirrors to image space plasma distributionfunctions. The technique borrows concepts from light optics toachieve 2 degree angular resolution with a wide field-of-viewand high thoughput. The techniques developed for this work arebeing extended to build an electrostatic periscope for use ona solar probe mission. This will allow measurement of the solarwind in the direction of the Sun with out exposing the interiorof the spacecraft to direct solar radiation.

Neutral Atom Imaging Instrumentation. The LEP is collaboratingwith Lockheed-Martin Palo Alto, the University of Maryland, theUniversity of Denver, the University of New Hampshire, and theUniverisity of Bern on the development of the Low Energy NeutralAtom (LENA) imager for the IMAGE mission. M. Smith is leadingthe effort with support from F. Herrero and science and engineeringstaff from throughout the LEP. The LENA instrument uses a uniqueneutral-to-ion conversion surface developed by the team to enablethe instrument to function at very low neutral atom energies (feweV to 300 eV). The Engineering Unit subsystems are being producedat present and testing of critical systems is underway.

M. Hesse, working with colleagues from APL and LANL, developeda model that is capable of predicting neutral atom fluxes causedby charge exchange between exospheric hydrogen and plasma sheetprotons. The proton model is based on three-dimensional MHD simulations.Results show that neutral atom imaging should be feasible forenergy ranges upward from some 10 keV, or lower, if a cold plasmasheet component is present. The investigation was extended toinclude realistic instrument parameters.

*X- and γ-Ray spectrometers.*J. Trombka is the P.I. for the X-ray and γ-rayDevelopment Facility under NASA's Planetary Instrument Designand Development Program. He and his team (P. Clark, L. Evans,S. Floyd, R. Starr) have continued to design and produce state-of-the-artinstrumentation for a variety of spacecraft (see above). Theirdevelopment efforts (for Mars '96) include helping in the design,developing verification calibrations of the flight detectors,developing calibration procedures for the cruise phaseof the mission, and developing analytical methods for theinterpretation of the cruise and orbital gamma-ray spectra. Thisyear's effort concentrated on the Ge detector system knownas the Precision Gamma-Ray Spectrometer (PGS) and on the CsI detectorin the Penetrator Gamma-Ray Spectrometer (PeGRS). Comparison calibrationswere carried out on three Ge detectors and two of the detectorswere chosen for the flight units. Our group participatedin the final assembly of the PGS instrument and the verificationtesting and calibration of the flight system. The flight systemmet the design specifications. Our major effort with respect tothe PeGRS, has been to calculate the background and induced activitiesproduced by the Radio Thermal Generators (RTG) and the Radio HeatingUnits (RHU) aboard the penetrator. These calculations will beneeded in order to interpret the data obtained when the penetratoris in the Martian surface. Detailed calibrations of an engineeringunit of the PeGRS will be carried out in the US in the late spring,predicated on a successful launch of Mars '96.

VIII. OUTREACH ACTIVITIES

Education Initiative. R. Lepping, J. Clemmons, and F. Ottensstarted an Education Committee with the purpose of outreachingto the public and assisting nearby schools to better understandthe role of space scientists and our Lab's work in particular.The committee is presently setting up a home page which will includethe work of the Lab in terms that are comprehensible to the public,a tutorial on magnetospheric physics, an interactive exerciseused to learn about the NEAR mission from J. Trombka's team, andsimilar teaching tools. The LEP also contributes to or maintainsWWW pages for many of the projects it is involved in, includingISTP and other missions; some of these are mentioned below.

Elementary Education. P. Romani in May of this year collaboratedwith teachers and their students at Glenarden Woods ElementarySchool in Glenarden, Maryland and at Wildwood Elementary Schoolin Amherst, Massachusetts to duplicate Eratosthenes's measurementof the circumference of the Earth. Eratosthenes was a Greek wholived and experimented in Egypt in the Ptolemaic era. His determinationof the Earth's circumference was within 15% of the modern dayvalue. The experiment was a success and the details were presentedat the 1996 Division of Planetary Sciences meeting.

Visiting Teacher. As part of the NASA/Prince George's CountyTeacher Intern Program, D. Taylor from Martin Luther King MiddleSchool, Laurel MD, visited the Laboratory for six weeks; he participatedin research aimed at understanding positional changes of the Earth'sbow shock using IMP-8 magnetic field data. He worked with A. Szaboand his mentor, R. Lepping.

Eclipse Home Page. F. Espenak developed a World Wide Webhome page focusing on solar and lunar eclipses which went on-linein July 1996. This web site presents predictions for all solarand lunar eclipses during the 1000 year period 1501 through 2500.More detailed maps and figures focus on eclipses occurring from1996 through 2010. A special series of maps show the paths ofall total and annular solar eclipses through North America from1851 through 2100. In response to NASA's public outreach program,instructions are provided to the general public for safely observingsolar eclipses. There are also detailed explanations on how toobserve and photograph both solar and lunar eclipses. The PlanetarySystems Branch home page is under continuous development and growth.The URL for the eclipse home page is:

http://planets.gsfc.nasa.gov/eclipse/eclipse.html.

Planetary Systems Branch Home Page. F. Espenak and D. Stephens(Unicom Communications) developed a World Wide Web home page forNASA/Goddard's Planetary Systems Branch which went on-line inJuly 1996. This web site describes a range of activities and linesof research which branch members are currently engaged in. Researchactivities covered include infrared spectroscopy, molecular spectraand structure, comets, detection and characterization of extra-solarplanets, and the Sun at infrared wavelengths. Components of researchactivities cover topics such as infrared interferometer spectrometers,analysis of planetary infrared spectra, laboratory spectroscopy,new technology spectrometers and detectors, ground-based and aircraftobservations, terrestrial stratospheric trace species, and CompositeInfrared Spectrometer (CIRS) for the Cassini Mission. In addition,the NASA Reference Publication 1349, "Twelve Year PlanetaryEphemeris: 1995 - 2006" (F. Espenak) is also available electronicallythrough the Planetary Systems Branch home page. The URL for thehome page is:

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IX. PUBLICATIONS

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