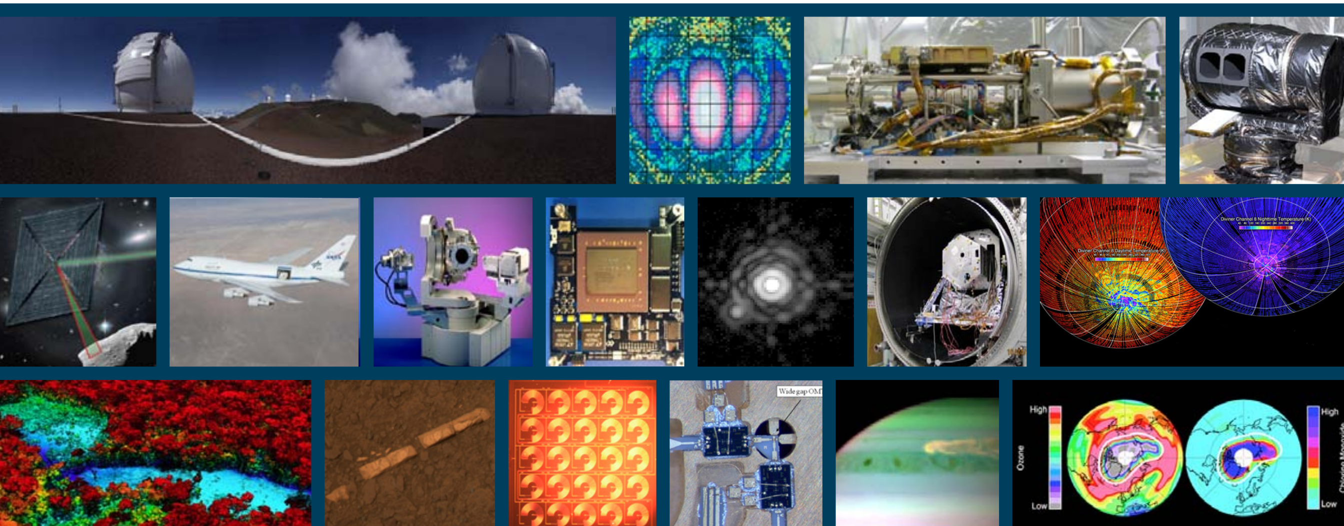
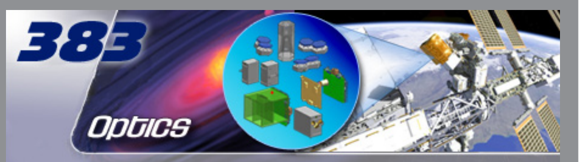
National Aeronautics and Space Administration

Jet Propulsion Laboratory

Instruments and Science Data Systems Division

2011 Annual Report





Annual Report – FY 2011

Instruments and Science Data Systems Division

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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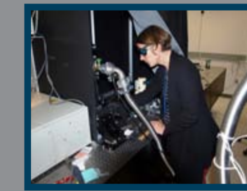

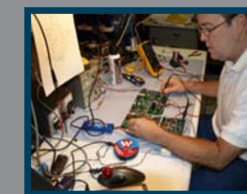

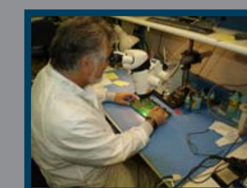

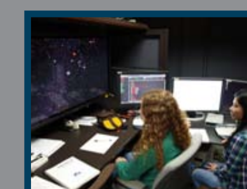

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Contents

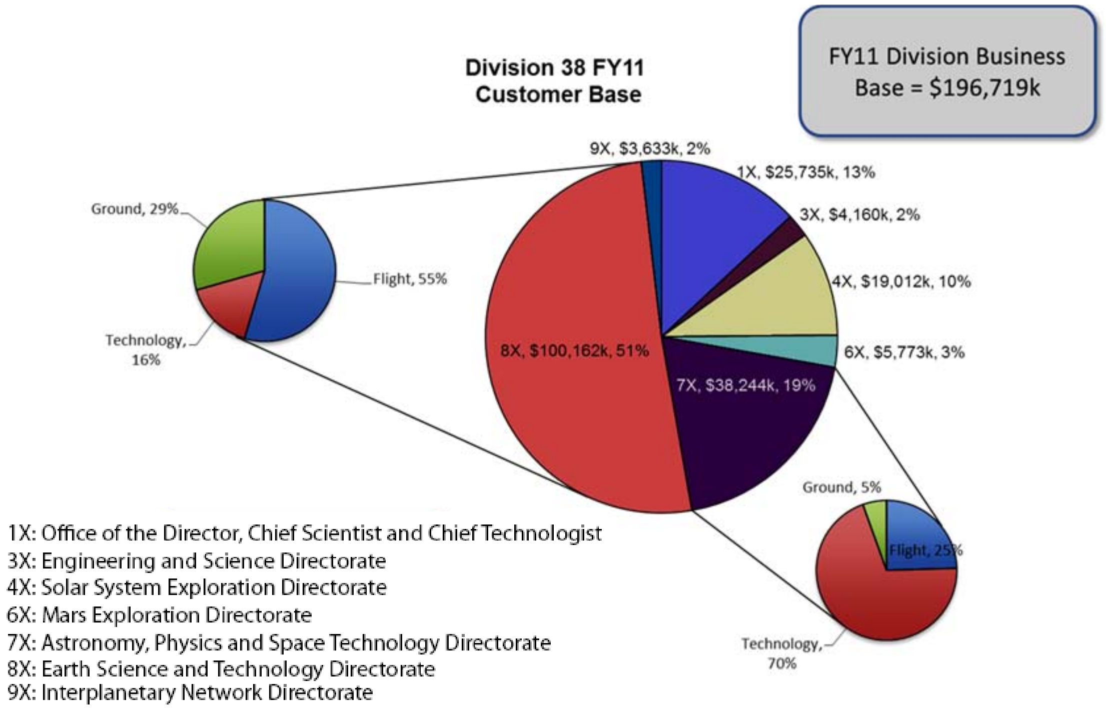
INSTRUMENTS & SCIENCE DATA SYSTEMS DIVISION

Year in Review

ANNUAL REPORT FY 2011

Year in Review

FY 2011 brought unusual challenges for the Instruments and Science Data Systems Division. Budget uncertainties made planning for the year difficult and somewhat unpredictable. However, in the end, the Division finished the year with a modest business growth (4%) driven by numerous smaller projects representing more diverse technologies and implementation approaches than have been seen in the recent years. This success was evidence of the entrepreneurial nature of this Division and its multi-talented people. The Division's two largest customers remained the same as years' previous; the Earth Science and Technology Directorate (8X) and the Astronomy, Physics and Space Technology Directorate (7X). In the end, there was some growth in instruments for Earth Science resulting from the continued development of the Orbiting Carbon Observatory-2 (OCO-2), and new starts with Jason-3 and a series of hyperspectral imagers for the National Ecological Observatory Network (NEON). Work for 7X experienced a modest decrease as the Space Interferometry Mission (SIM) was closed out and the Mid-Infrared Instrument (MIRI) for the James Webb Space Telescope (JWST) was delivered. There was also a significant drop in work for the Solar System Exploration Directorate driven by delivery of the Microwave Radiometer (MWR) instrument for the recently launched Juno mission to Jupiter. Other significant deliveries include the Carnegie Airborne Observatory (CAO) Visible/Short Wave Infrared Imaging Spectrometer and the NPOESS Pre-Project (NPP) Sounder Peate data system, each for the Earth Science and Technology Directorate. A breakout of Division's customer base is shown in the figure below.



The Division supported the implementation of numerous flight instruments and data systems. We continued to operate over 20 instruments, and led or supported too-numerous-to-count proposals for new work and formulation activities. It was through this latter proposal and formulation activity that the resilience of the Division was evident. Over $20M in new, unforecasted business was developed over the course of the year enabling the Division to maintain its core capabilities while minimally impacting institutional retention resources.

Awards and Recognition

This year we once again had a number of people recognized for their achievements, as individuals and in teams both in the JPL and NASA awards categories. Ken Cooper received the Lew Allen Award for Excellence, an award recognizing early career researchers for excellence. Jordanna Blacksberg was awarded the Ed Stone Award for Outstanding Research Publication. The Division also had several people on the team that were awarded the NASA Software of the Year Award.

The Ed Stone Award for Outstanding Research Publication

The Edward Stone Award for Outstanding Research Publication recognizes and encourages publication of significant research results in science and in technology by JPL employees throughout their professional careers. Generally, two awards are presented each year.

L-R: JPL Director Charles Elachi; former JPL Director Ed Stone; Jordana Blacksberg, JPL Chief Scientist Dan McCleese; JPL Deputy Director Eugene Tattini.

Dr. Jordana Blacksberg was one the recipients of this award for developing a new method for capturing high-temporal-resolution laser Raman spectroscopy that has revealed clear mineral signatures in Mars analog clays, sulfates and phosphates despite large unwanted fluorescence background signals, opening a path to new planetary instrumentation

See: J. Blacksberg, G. Rossman and A. Gleckler, "Time Resolved Raman Spectroscopy for In Situ Planetary Mineralogy", *Applied Optics, 49* (26), pp. 4951-4962, 10 September, 2010.

The Lew Allen Award for Excellence

The Lew Allen Award for Excellence recognizes and encourages significant individual accomplishments or leadership in scientific research or technological innovation by JPL employees during the early years of their professional careers.

Dr. Ken Cooper received this award for the development and demonstration of the first THz imaging radar system. Dr. Cooper has pioneered the development of this technology through a series of innovations such as a new transceiver concept that makes use of normally dumped beam power to refocus energy on the target and provide two pixels with a single transceiver (new patent). The THz radar concept shows promise as a new instrument for planetary sounding using a novel absorption backscatter approach.

NASA HONOR AWARDS

As expected, the division was represented and recognized for a diverse array of achievements; Of special note this year, the highly competed and coveted NASA Software of the Year Award went to JPL with the contributions of our 388 colleagues.

NASA Software of the Year Award (SOYA)

The Autonomous Exploration for Gathering Increased Science (AEGIS) system enables automated data collection by planetary rovers. This system was development jointly by Division 38 and Division 31. AEGIS software was uploaded to the Mars Exploration Rover (MER) mission's *Opportunity* rover in December 2009 and continues to successfully demonstrate automated onboard targeting based on scientist-specified objectives.

Team members - Front row, from left: Robert C. Anderson, Benjamin Bornstein (388), Dan Gaines, Michael Burl (388). Back row, from left: Tom Soderstrom, head of JPL's Office of the IT, Chief Technology Officer; JPL Director Charles Elachi; Tara Estlin; Rebecca Castano (388), Michele Judd; David Thompson (388); Chris Jaggers of the Innovative Technology Asset Management Office. (Not shown Charles de Granville)

Exceptional Achievement Medal

Kenneth Klaasen
Nikzad (Benny) Toomarian

Exceptional Engineering Achievement Medal

Xin An
Bijan Nemati

Exceptional Service Medal

Stythe (Tom) Elliott
Robert Green
James Lamb
Robert Staehle
Ronald Steinkraus

Exceptional Technology Achievement Medal

Pantazis (Zakos) Mouroulis

Group Achievement Awards

AEGIS Development
Cassini Mission Sequence Subsystem
Cassini Solstice Uplink Transition Leadership
Early Detection Research Network Informatics
Earth Science Outreach and Communications
Emergency Response
EPOXI Science
GFSC AIRS Product Generation System
High Contrast/Resolution Exoplanet Imaging
LMMP Infrastructure Group
Mapping Reflected-energy Spectrometer
MIRO Flight Operations

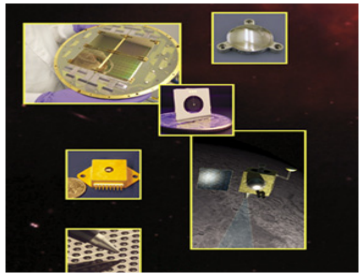
Group Achievement Awards (con't)

Mobile Application Development
MRO Flight and Relay Operations
MRO MCS Science
Phaeton Mast Dynamics Central Assembly
Planck Data Analysis and Operations Support
Robust Operations (RO)
SIM Spectral Calibration Development Unit
SIM Science Office
SIM-Lite Astrometric Beam Combiner (ABC)
SIM-Lite Cryo Heat Pipe Test
SIM-Lite Precision Positioning Mechanisms
SIM-Lite Real Time Control
Software Quality Improvement
Space Images iPhone Application
Spitzer Battery Heater Operations & Analysis
Spitzer Integrated Ground Anomaly
Spitzer Warm Mission Operations
ST-7 Precision Control Flight Validation
Stardust NExT Science
Terahertz Radar Development
Thermally Powered Unmanned Underwater Vehicle
University Relations Recruiting
Vehicle Cabin Atmosphere Monitor (VCAM)
Visitor Center Redesign
WISE Project Mission Assurance

JPL Honorees Awarded by Other NASA Centers

Constellation SE&I Preliminary Design Review
Genesis and Rapid Intensification Processes (GRIP)
ISLO-ISRU 2010 Field Test
LCROSS/LRO Measurements
NASA Gulf of Mexico Oil Spill
Near Earth Objects Observation Program
SMD American Recovery and Reinvestment Act
The LRO Mission Operations
The Lunar Reconnaissance Orbiter (LRO) Exploration
The Sample Analysis at Mars

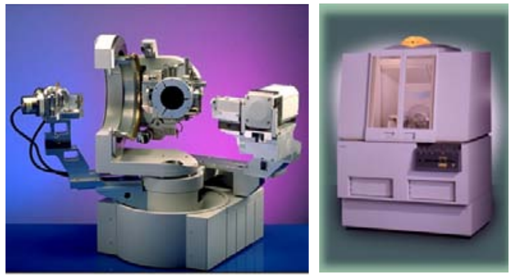
Microdevices Laboratory (MDL)



MDL is a unique institutional facility built in early 1990s with the mission to create a multi-agency, critical mass program developing innovative, high-risk/high-payoff microelectronics concepts and devices for NASA and DoD space missions that are not available from industry nor likely to be developed elsewhere. In addition to inventing and developing new technologies, MDL staff also develop and deliver flight-qualified devices and components that enable new missions and instruments.

During FY 2011, JPL has continued to invest in advancing MDL capabilities in material characterization. Two of the noteworthy investments are the addition of an X-ray Diffraction (XRD) system and an Electrochemical Capacitance Voltage (ECV) profiler.

The XRD system is a fundamental analysis tool that is necessary for any program that involves deposition or growth of materials when the quality or nature of the materials is important for the application. This tool can be used to characterize crystalline materials grown using epitaxial methods (e.g., molecular beam epitaxy, or MBE), as well as amorphous materials. In the first case, information about the crystal structure and orientation is obtained; in the latter case, the film texture, density, stress, and roughness are probed. This system will be located outside the MDL clean room and does not require new utilities to be provided.



X-ray Diffraction (XRD) system

Epi-layer doping is an important material characteristic that has to be measured and controlled during the fabrication of epitaxial compound semiconductor devices. The electrochemical capacitance vs. voltage profiler (ECV) has become the principal method of measuring carrier densities for compound semiconductor device structures. It is the only method that can profile a multi-layer structure and this has led to its universal acceptance for compound semiconductors. The newly installed ECV profiler allows the measurement of carrier type and concentration vs. sample depth (doping profiles) with 1 nm depth resolution, applicable for III-V and II-VI semiconductors, III-Nitrides, Si, and SiC films.

ECV Profiler

INSTRUMENTS & SCIENCE DATA SYSTEMS DIVISION

Advanced Concepts and New Business

ANNUAL REPORT FY 2011

Some Winning Concepts and Candidates for Future Wins

The Division supported numerous proposals with instruments and science data systems as part of JPL-originated, and non-JPL mission concepts. Imaging spectrometers, thermal imagers, cameras, microwave radiometers, heavy-throughput and inexpensive science data systems, and novel detectors were at the heart of most of the proposals supported. Some other proposals featured adaptive optics, high-capacity onboard processing electronics, sample acquisition support, *in-situ* measurements, and other specialties. Proposals in which our work was included went primarily to NASA and other Government agencies, while some went to commercial entities where JPL-unique technology offers solutions to complex problems.

To date, the Division has been involved with conceiving, constructing and operating instruments in nearly every part of the electromagnetic spectrum: gamma ray, x-ray, ultraviolet, visible, near-, short-wave-, mid-wave and far-infrared, submillimeter, and microwave. (Our sister Communications, Tracking and Radar Division (33) provides instruments and data systems in the radio frequency part of the spectrum, including a variety of radars, scatterometers, and GPS receivers.) Division-originated science data systems have supported science investigations across the electromagnetic spectrum.

Instrument and science data system work proposed successfully in FY 2010 and FY 2011 went into full-swing development and application as result of being part of four winning proposals in NASA's first Venture solicitation, and part of two winning proposals in the joint ESA-NASA Mars Trace Gas Orbiter (TGO) call for proposals. Other work began in support of improved petroleum and gas production, along with unique instrumentation for non-NASA Government agencies.

Division expertise from Earth and planetary science instrumentation was infused in novel ways to the astrophysics discipline in the FINESSE Explorer proposal selected by NASA to proceed into Step 2. Mark Swain of JPL's Science Division is PI for the Fast INfrared Exoplanet Spectroscopy Survey Explorer.

The NASA-DLR Stratospheric Observatory for Infrared Astronomy (SOFIA) is housed in a modified Boeing 747 to fly above 99% of the water vapor in Earth's atmosphere. The Division designs, builds and operates instruments for several sponsors that fly aboard Twin Otter, WB-57, ER-2, DC-3, DHC-8, UAV and other host aircraft. Photo: NASA

Division instruments and science data systems were part of several Discovery and Explorer mission proposals from JPL and non-JPL institutions. Legacy instruments are part of Bruce Banerdt's (JPL Science Division 32) Geophysical Monitoring Station (GEMS) concept selected by NASA to proceed to Step 2. Division instruments are also part of SOFIA airborne astrophysics proposals for second-generation observations from the US-German 747 that flies above 99% of the atmosphere's water vapor. Division instruments were also part of two New Frontiers mission proposals.

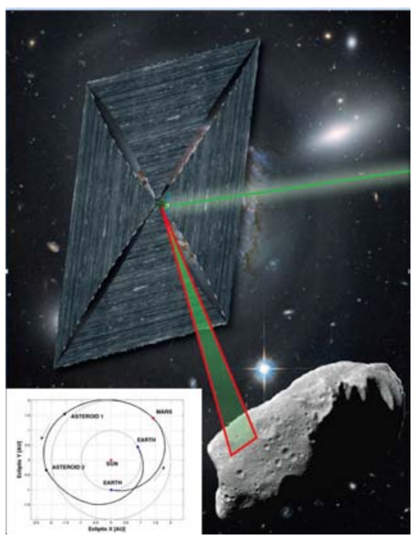
The Keck Institute for Space Studies (KISS) program "Next Generation UV/Optical Instrument Technologies" was selected through a competitive process with co-leaders in the Division, and at Caltech and Columbia University. The study was kicked off with its first workshop in August that included leading authorities in astrophysics, heliophysics, planetary science, ultraviolet/optical sciences, detectors, optics design, and nanotechnology. The workshop included multi-discipline short courses to unite the understanding of science, technology and fabrication across the participants. The intended goal of the study is to form a technology development portfolio that can be proposed to the Keck Foundation as well as NASA and other agencies.

The first JPL payload was launched aboard a CubeSat at the start of FY 2012, based on a proposal submitted in late FY 2010 and implemented on an accelerated schedule during FY 2011. The Division now actively supplies hardware and software for technology demonstration payloads aboard three University-based CubeSats, with the other two in different stages of preparation by partners University of Michigan, and California Polytechnic University-San Luis Obispo. Additional CubeSat investigations are under discussion and being proposed with a variety of partners. Definition of the first Interplanetary CubeSats has begun, led from the Division, as one of 30 NASA Innovative Advanced Concepts (NIAC) selected for funding in August. JPL is actively seeking internal and external science partners for high-maneuverability CubeSat missions beyond Earth that could start from ~2017 into the 2020's.

Technology development within the Division, as well as with small business, academia and other partners, continues to support science investigations enabled by new instrument and science data system concepts. Primary foci today are on developments that will shrink the size and cost of spaceborne instrumentation, shorten implementation schedules for airborne instrumentation, dramatically increase the throughput of science data systems, and combine measurements from disparate sensors into understandable low-latency information for a variety of science and applications purposes.

Some instruments and software systems can now be developed and delivered on a time scale of roughly a year or less, though longer periods are clearly required for new and complex situations. In part because of accelerated schedules, some of our work is fitting within unprecedented cost constraints, while containing risk.

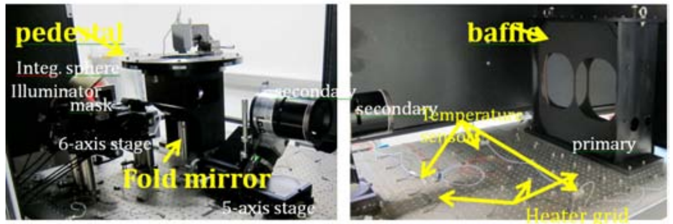
Concepts are now in development with JPL and external investigators for a variety of upcoming opportunities in Earth and planetary science, astrophysics, heliophysics and space physics, and several applications ranging from national interest and disease prevention to emergency response. Collaborations are anticipated with US and non-US partners in academia, industry, and governments. The Division is always open to new collaborations where our strengths can be combined with those of other investigators to mutually create new value for customers. The following are some examples of current concepts in development with multi-functional teams:



Among the farthest-out concepts pursued by the Division is that of Interplanetary CubeSats. This recipient of one of 30 NASA Innovative Advanced Concepts (NIAC) awards was selected from over 700 proposals, joining 3 others from JPL as winners. In the 2020s, and maybe a little before, spacecraft ~10 kg can carry imaging spectrometers and other instruments weighing <2 kg to a variety of destinations, using a solar sail to maneuver without propellant. In this artist's concept, an imaging spectrometer based on the Division's airborne Portable Remote Imaging Spectrometer (PRISM) scans to build up a mineral map of one of several near-Earth asteroids to be visited on a a single mission departing as a secondary payload at low cost from an unrelated launch. A tiny laser terminal is commanded from JPL's Table Mountain lasercomm ground station, and transmits science results back to the 5-meter telescope at Palomar Mountain. The concept is being developed with co-investigators from three JPL divisions, CalPoly San Luis Obispo, The Planetary Society, and small business Stellar Exploration. Art: Ryan Sellars/CalPoly-SLO.

Inset: Notional multi-asteroid trajectory propelled by a solar sail delivering a ΔV of 5 – 20 m/sec per day.

Weak Gravitational Lensing in the Laboratory - Missions Under Study: Wide-Field Infrared Survey Telescope (WFIRST)



Photograph of Precision Projector System. Control parameters for the laboratory emulation experiments include (1) 6-axis rotation & translation and specification of spot masks at the object plane, (2) (e.g. PSF control with illumination wavelength & f/# and ellipticity at either pupil or object plane) in the optical path and (3) rotation of the CCD or IR detector (0 – 360 deg.) at the image plane.

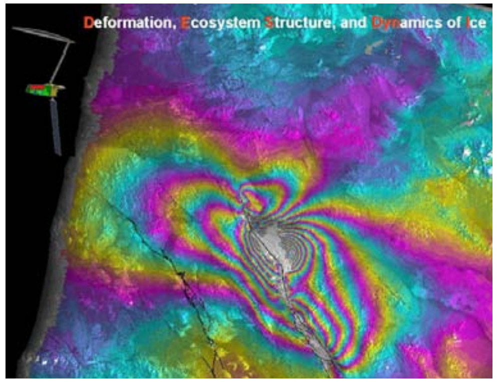
In a joint effort with JPL's Science Division (32), we have developed a Precision Projector system with a globally unique capability to project, measure and quantify galaxy shapes over the full field of CCD and IR detectors relevant for measuring weak gravitational lensing, the distortion of the shapes of background galaxies by foreground dark matter. The planned first-of-a-kind laboratory experiments significantly shift the development paradigm for space-based weak lensing observations by providing an experimental methodology to identify effects and mitigation strategies arising from real detectors. The experiments will mimic planned observing conditions (e.g., f-number, undersampling, dither patterns, image recombination algorithms). These measurements are essential to demonstrate the viability of missions such as NASA's Wide Field Infra-Red Survey Telescope (WFIRST) and ESA's Euclid concepts and to quantify the impact of primary drivers of mission cost and science performance of a reference mission design. Our expertise in weak lensing science gives us the necessary tools to measure galaxy shapes using the Precision Projector. This system capability and the collaboration between weak lensing scientists and detector physics experts is a unique strength of our effort, increasing the overall competitiveness of our ability to pursue involvement in all aspects of these missions.

Observational cosmology using weak lensing has been demonstrated to be a powerful probe of both dark matter and dark energy, provided that systematic effects are understood and mitigated. However, weak lensing promises to be a very difficult measurement to perform in space because of the necessity to measure very fine shape distortion measurement accuracies of < 1 part in 10^3. Various factors affect these measurements. The problem is further exacerbated by the fact that existing reference designs require strongly undersampled images of galaxies and reference stars used to make calibration measurements of the PSF-distortion of the telescope itself. Previous assessments of measurement sensitivities have only been performed under idealized conditions with either simulated images or simplified input signals to real detectors. In prior work, we have also shown that detectors will only meet the demanding requirements of planned space missions with both precise characterization and significant post-processing mitigation strategies.

Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) Science Data System

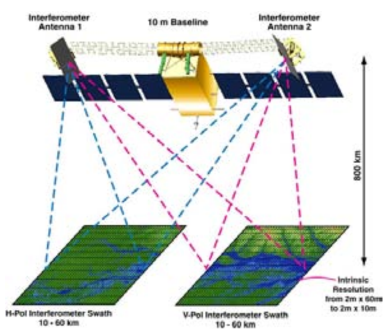
The Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) Mission led by the Communications Tracking and Radar Division (33) is one of four first-tier Earth Observing Missions recommended by the National Research Council (NRC) Earth Science Decadal Survey published in 2007. The original DESDynI mission included two complementary sensors placed on two independent platforms, an L-band Interferometric Synthetic Aperture Radar (InSAR) with multiple polarization capability and a multiple beam infrared lidar, to provide observations surface deformation, terrestrial biomass structure and ice dynamics. This mission, which went through a multi-year formulation phase and a successful mission concept review (MCR) in January 2011, has been directed to re-scope to meet increasingly stringent NASA budget constraint. DESDynI is currently being reformulated to be a single sensor mission comprised of only an L-band InSAR. The goals are to complete partnership studies in early spring of 2012, settle on a partnership decision and mission concept in late spring/early summer, and convene a MCR in late summer in time for a FY 2012 start.

The DESDynI Science Data System (SDS) led by Division 38 is to be based on the SDS being developed for the Soil Moisture Active/Passive (SMAP) Earth Science Decadal Survey mission, but with much higher throughput. Currently, cost reduction alternatives are under study. Additional studies and concept development in the SDS area will hinge on the ultimate mission concept decision and partnership arrangement made in early 2012.



Interferometric map of 1999 Hector Mine earthquake derived with European Space Agency ERS-2 satellite data (courtesy G. Peltzer of UCLA). The magnitude 7.1 Hector Mine earthquake occurred 1999 October 16, near Barstow, CA. One full color cycle in the map represents 10 cm of range displacement between pre- and post-quake measurements. A Division-provided DESDynI science data system is expected to facilitate routine mapping of surface breaks and surface displacement fields produced by earthquakes over broad areas using similar and improved imaging and data processing techniques.

Surface Water Ocean Topography (SWOT) Science Data System



The Surface Water Ocean Topography (SWOT) mission is one of five second-tier Earth Observing Missions recommended by the National Research Council (NRC) Earth Science Decadal Survey published, in 2007. SWOT is a collaborative mission involving NASA and the French space agency, Centre National d'Études Spatiales (CNES), with the goal of bringing together the hydrology and oceanography communities toward a better understanding of the world's oceans and its terrestrial surface waters. SWOT uses a Ka-band Radar Interferometer (KaRIN) instrument with two Ka-band Synthetic Aperture Radar (SAR) antennae placed at opposite ends of a 10-meter boom.

The SWOT Science Data System (SDS) is expected to ingest 7.1 Tb/day of radar data acquired by the KaRIN instrument, process the data into 12 product types, and generate on average 14.7 TB of data products daily for use and archive. The SWOT SDS will be based on the Division's evolving Object Oriented Data Technology (OODT) based Process Control System (PCS) Product Line, with significant cost savings derived from the sharing of common infrastructure with and the adaptation of common components from preceding JPL missions including Orbiting Carbon Observatory, National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) Sounder PEATE, and Soil Moisture Active Passive.

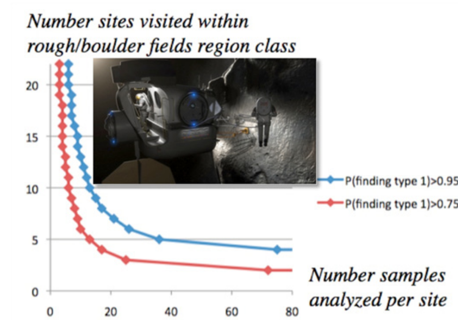
In the coming year, SWOT will finalize its Conceptual Design, Operations Concept, and cost estimate in preparation for a MCR (Mission Concept Review) in March 2012, followed by the Key Decision Point (KDP)-A, and anticipated Phase-A start in June/July 2012.

Hypespectral Infrared Imager (HyspIRI)

The HyspIRI Mission is one of five second tier, Earth Observing Missions recommended by the NRC Earth Science Decadal Survey for launch in the next decade. The HyspIRI mission is currently in pre-project study phase, preparing for its Mission Concept Review in 2014. The HyspIRI mission has two instruments on board, a Visible ShortWave Infra-Red (VSWIR) Imaging Spectrometer and a multi spectral Thermal InfraRed (TIR) Scanner. Combined, these instruments are expected to provide data critical to meeting the science goals of the Decadal Survey and improve our understanding of climate and climate change. The VSWIR instrument is expected to leverage from prior developments such as the Moon Mineralogy Mapper (M^3) and Airborne Visible and Infrared Imaging Spectrometer (AVIRIS). The TIR scanner has matured significantly in the last year and has strong heritage with the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The HyspIRI Science Data System (SDS) will process global datasets at 60 meters equivalent spatial resolution to 5 petabits (5×10^{15}) of data over the three year mission. HyspIRI is expected to utilize the advanced SDS Architectures to reduce implementation costs and risks.

Designing a Human Mission at an Asteroid

Modeling expertise within the Division was called upon to answer the unusual question, can the mission's architecture be designed to maximize discovery potential while maximizing efficiency? A software model was developed to compute the optimal numbers of sites to visit and samples per site to investigate with the objective of finding a sample of dissimilar composition from the bulk of the asteroid, given precursor estimates of the asteroid's composition and the expression of a desired level of confidence. Doing so can maximize the potential for scientific discovery with the most efficient use of resources and minimize risk to astronaut safety as represented by traverse about the asteroid and time spent in EVA.



Instruments Concept Team

An early stop in the development of many instrument concepts to meet emerging customer needs is the Instrument Concepts Team (ICT). The ICT is a multi-Division JPL asset used by external and internal customers to rapidly innovate, develop, evaluate, and estimate the cost of space instrumentation concepts. The team draws from over 100 senior experts in all relevant disciplines across most JPL Divisions. 2011 saw yet another year of increase in both the Division's capabilities for instrument formulation, and an increase in our customers' utilization of those capabilities. During 2011, the team assisted with Version 5.0 of the NASA Instrument Cost Model (NICM), which adds recent instruments from JPL and other Centers to the model plus a module for Joint Confidence Level estimation.

During calendar year 2011, the ICT supported Team-X in over 14 mission studies and led over five instrument/payload studies across four JPL program directorates (Solar System Exploration, Mars Exploration, Astronomy and Physics, Earth Science and Technology).

Using the ICT, viable instrument concepts can be developed in a matter of days interactively with a customer, focusing a hand-picked set of experienced practitioners from each relevant discipline on virtually any new instrument need. System engineering, optics, electronics, detectors, mechanical systems, opto-mechanics, thermal control, software, science data systems, integration & test, calibration, safety, mission assurance, and management are all represented by engineers who have performed analogous work before on real instruments. Design trades can be guided by cost, technology risk and other factors relevant to the problem at hand.

Those interested in working with the Division to develop new opportunities can contact any member of Division management to discuss possibilities and available resources.

INSTRUMENTS & SCIENCE DATA SYSTEMS DIVISION

Instrument Systems Development

ANNUAL REPORT FY 2011

Instrument and science data system work proposed successfully in FY 2010 and FY 2011 went into full-swing development and application as result of being part of four winning proposals in NASA's first Venture solicitation, and part of two winning proposals in the joint ESA-NASA Mars Trace Gas Orbiter call for proposals. Other work began in support of improved petroleum and gas production, along with unique instrumentation for non-NASA Government agencies.

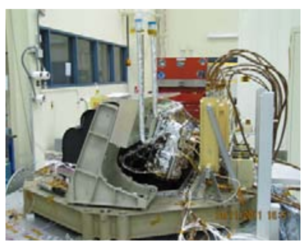
Earth Science

Orbiting Carbon Observatory – 2 (OCO-2) Spectrometer

Work on OCO-2 during FY 2011 initially concentrated on building up the flight and flight spare electronics and optical subsystems. Initial testing showed some unexpected performance issues with both optics and electronics. Optical mounts were strengthened and retested to demonstrate acceptable performance. Electronic issues stemmed from the replacement of obsolete or unobtainable parts used in OCO-1 with modern parts. Differences in sensitivity to transients and radiation sensitivity compounded the difficulties encountered by the engineering team. The flight electronics were completed, the flight optics were aligned, all major contract activities were brought to a close. As the fiscal year ended, most technical difficulties have been overcome and the instrument was transitioning to instrument level Integration and Test. The instrument team is on schedule for an end of April 2012 instrument completion.

Orbiting Carbon Observatory - 2 (OCO-2) Science Data Operations System (SDOS)

The SDOS put in place a data system specifically to support the needs of thermal/vacuum testing. This system was used first to support board-level testing and flight electronics testing with Level 0 & 1 data processing. It has now evolved into one fully capable of meeting the Project's instrument integration and test plans and will rapidly process instrument packets to Level 1 in order to characterize the instrument performance and calibration.



The OCO-2 instrument configured for ground testing

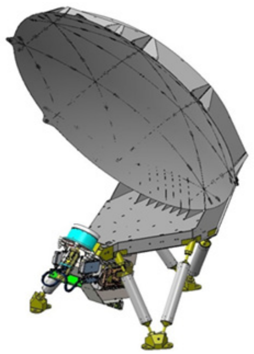
The development for orbital operations began by resurrecting and updating OCO-1 software, making updates to meet new OCO-2 requirements and incorporating important lessons learned from both OCO-1 and the Atmospheric CO_2 Observations from Space (ACOS) experience. In addition, after performing trades studies, an upgraded version of the Object Oriented Data Technology(OODT)-processing infrastructure (PCS) was chosen to automate the product generation and delivery.

In FY 2012, SDOS will be collaborating with the OCO-2 Algorithm Team to develop software components through Level 2 and the processing pipeline. SDOS will deliver a data system to support orbital operations and begin the process of verification and validation of that system prior to launch.

Orbiting Carbon Observatory – 3 (OCO-3)

OCO-3 is in pre-phase A. The OCO-2 instrument design is being modified to be able to fly on the Japanese Experiment Module (JEM) aboard the International Space Station (ISS). Initial efforts have been coordinated with Johnson Space Center (JSC) and have resulted in an instrument design that is well suited to the Space Station, while preserving nearly all the instrument hardware design used in OCO-2. The new design has different science goals than OCO-2, trading polar-orbiting views for time-varying views of the most of the populated regions of the world. Initial efforts have been focused on studying compatibility with the ISS. Studies have included location vs. field of view, pointing requirements, polarization stability, and electronic and data compatibility. No serious issues have been found, allowing next year's efforts to focus in more detail on polarization and pointing control issues.

Jason-3 Advanced Microwave Radiometer (AMR-2)

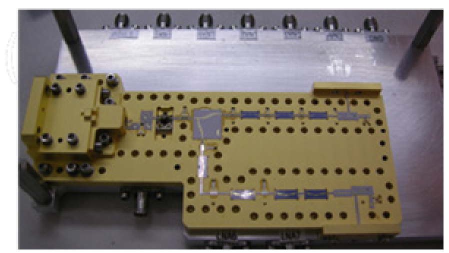


AMR Instrument

Continuing the multi-decadal ocean topography measurements of Jason-2, the Jason-3 project entered Phase C in October 2011, with a target launch date of April 8, 2014. Signaling a transition to operational ocean altimetry, NOAA and EUMETSAT are now the lead agencies with NASA/JPL, with CNES providing implementation support. Among Jason 3's key roles are to provide insight into global climate phenomena such as El Niño and La Niña, to monitor the pattern of global sea level rise, and to improve models used for hurricane forecasting and predicting individual storm severity.

The Division is developing the Advanced Microwave Radiometer-2 (AMR-2) for Jason-3, which measures the altimeter signal path delay due to tropospheric water vapor, a key element in meeting the Jason 3 science requirements. Jason-3 AMR will maximize the design inheritance from the successful Ocean Surface Tomography Mission (OSTM) AMR instrument while seeking to reduce both development and performance risk. The Jason 3 AMR effort incorporates experience from both OSTM AMR and Juno MWR to position Division 38 as a leader in ultra-stable radiometer design.

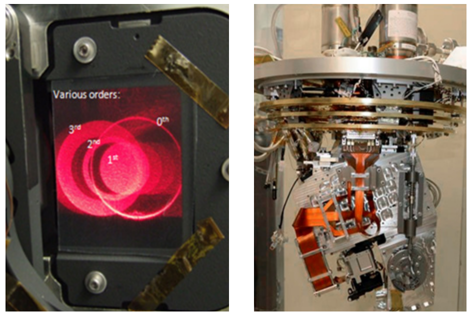
Prototype Receiver Unit



18 – 24 GHz Carrier

Next Generation Imaging Spectrometers (NGIS)

Carnegie Airborne Observatory (CAO) PI: Greg Asner (Carnegie Institution of Washington)
National Ecological Observatory Network (NEON) PI: Tom Kampe
Airborne Visible/InfraRed Imaging Spectrometer (AVIRIS) PI: Rob Green (JPL)



Left: Next Generation Imaging Spectrometer during alignment showing illumination through the middle of the air slit. Right: NGIS during integration and test.

This year marked the delivery of the initial two NGIS-next generation (ng) instruments to external customers and the start of three additional builds. These deliveries represent a return on JPL technology investment in the design, manufacturing and alignment of high uniformity, high-SNR optical systems, made over the past 30 years. Specific achievements include fabrication of optical gratings and ultra-uniform air slits using electron-beam lithography, development of focal plane warm alignment techniques and ultra-stable mechanical and thermal systems.

The first imaging spectrometer, Airborne Imaging Spectrometer (AIS), was conceived and developed at JPL and flew in 1982. For the past two decades, JPL has invested in key designs and technologies to enable high fidelity imaging spectrometers for Earth as well as planetary science. The results of these investments are captured in the new NGIS and support the ecological science goals of CAO.

NGIS builds on the capabilities of the AVIRIS airborne platform, an imaging spectrometer owned by NASA and operated from JPL, and extends its breakthrough chemical mapping capability to longer duration missions and the needs of more scientists. Imaging spectrometers work by delivering calibrated images of upwelling spectral radiance for each instrument channel. The spectral images are taken simultaneously and contiguously span the operational wavelength band of the instrument. For both the older AVIRIS design and the newer NGIS design, the operational wavelengths extend from the near-IR through the visible (480 nm to 2500 nm). Careful analysis of the resulting molecular absorption and particle scattering signatures collected allows identification, measurement and monitoring of the constituents of a planet's surface and atmosphere. Applications on Earth are very broad and include studies of ecology, geology, snow and ice hydrology, environmental hazards and monitoring of commercial mining and agricultural activities among myriad others.

NGIS in Integration and Test

In the coming year, three more spectrometers will be developed: AVIRISng (next generation) for NASA, and two additional spectrometers for the National Ecological Observatory Network (NEON Inc.) of Boulder, Colorado. The two NEON units will be delivered in FY 2013 and FY 2014.

Hyperspectral Thermal Emission Spectrometer (HyTES)

PI: Simon Hook (JPL)

HyTES in the lab

HyTES is a hyperspectral thermal infrared imaging instrument, designed and developed at JPL for airborne operations under the Instrument Incubator Program (IIP). The design is built upon a JPL-developed Quantum Well Infrared Photodetector (QWIP) focal plane array (FPA).

The imaging instrument has 512 pixels across track and 256 spectral channels between 7.5 and 12 μm in the thermal infrared. The detector array was developed and fabricated at JPL's Microdevices Laboratory (MDL). The complete instrument was integrated in October 2011 and laboratory testing is underway. First flight is scheduled on a Twin Otter aircraft in mid-2012. HyTES data will provide a completely new measurement capability for Earth scientists working with thermal data. The high spectral resolution is intended to provide precursor science data and guidance for thermal band placement for the upcoming HysPIRI satellite mission.

Advanced Electronics for Multi-angle Spectro-Polarimetric Imager (MSPI)

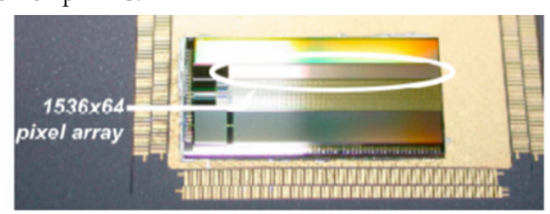
PI: David Diner (JPL)

The Division continues contributing to the very successful MSPI instrument. The heart of this high performance polarimetric imaging system is a custom CMOS Focal Plane Array designed in 2008. This 1536×64 imager, has on-chip analog-to-digital conversion (ADC) and has demonstrated a noise floor of 9 e- at 11 Mpix/sec with a full well of 70,000 e-. The electronics board for this camera includes complex FPGA code developed for the instrument.

A ground-based version of this camera has been operated by JPL's collaborators at the University of Arizona, while an airborne version has been flown on NASA's ER-2 high altitude aircraft in the summers of 2010 and 2011.

During 2011 key contributions were made to the methodology for data extraction and analysis, and improvements in electrical and optical calibration. The development of an optical probe for stabilization of the photo-elastic modulators was the basis of the polarimeter, including optical design, theory, algorithms and FPGA code. Open-loop measurement was demonstrated and closed-loop control, which will further enhance the precision of the instrument, is under development. The design of an infrared readout integrated circuit (ROIC) to extend the range of the MSPI instrument into the short wave infrared was initiated.

A paper was published in *Applied Optics*, with Division co-authorship, describing the methodology and results. A New Technology Report (NTR) was filed, for which Caltech has elected to pursue a patent, on unique features of the MSPI on-chip ADC.



The MSPI focal plane array.

Electronics for Geostationary Costal and Air Pollution Events (GEO-CAPE)/ PanFTS

PI: Stan Sander (JPL)

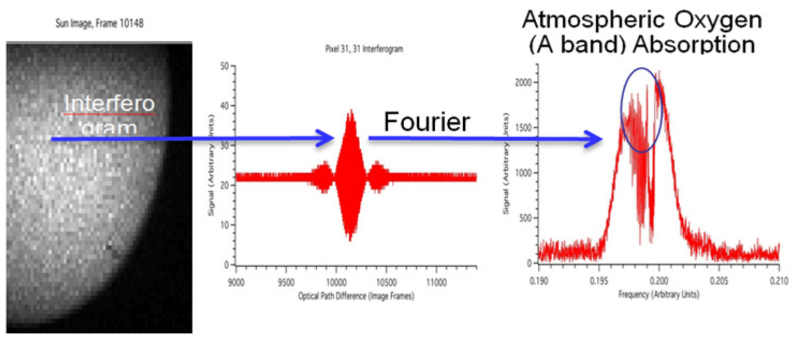
JPL is developing an imaging Panchromatic Fourier Transform Spectrometer (PanFTS) for the GEO-CAPE mission. The Division has supported this effort by developing two high speed imagers/Readout Integrated Circuits (ROIC), under the names PanFTS and GeoCAPE, using two different architectures. Both are designed to operate at a 16 kHz frame rate.

The PanFTS imager includes a ROIC that reads out a 4×4 subarray of a hybridized 61×61 photodiode array. It is based on the sigma-delta architecture implemented by the Division. Two designs were implemented: a conservative baseline design, and an alternative design promising higher performance. The ROIC was designed and fabricated in 2010 at Avago Technologies and tested in 2011.

Both the electronics board and timing for the imager were successful. The baseline design has a noise floor near 250 e- while the alternate design demonstrated a noise floor as low as 35 e-, both with a full well of 10^6 e- and a frame rate of 16 kHz. FPGA code for the decimation filtering needed by the sigma-delta architecture has also been developed. Silicon photodiode arrays have been hybridized to the ROICs, and they have been operated in a spectrometer on Mt. Wilson.

The GeoCAPE imager takes advantage of the 60µm pixel pitch to implement a novel in-pixel ADC in each pixel of its 128×128 array. This imager was designed in 2010 and fabricated at Taiwan Semiconductor Manufacturing and tested in 2011. Substantial effort was required to develop the electronics board and FPGA code for this imager, which requires complex timing. The speed fell just short of the design goal, achieving a frame rate of 12 kHz. This presented a challenge in the data acquisition, with a rate of 200 Mpix/sec. This imager demonstrated a noise floor below 700 e-, and is believed capable of as low as 100 e-, with a 10^6 e- full well, while consuming less than 1 W of power.

The imager was operated in the Fourier Transform Ultraviolet Spectrometer (FTUVS) on Table Mountain in May, 2011. Using the integrated photodiodes, which were implemented to facilitate testing prior to hybridization with a photodiode array, high spatial and spectral resolution absorption spectra were measured while imaging the Sun.



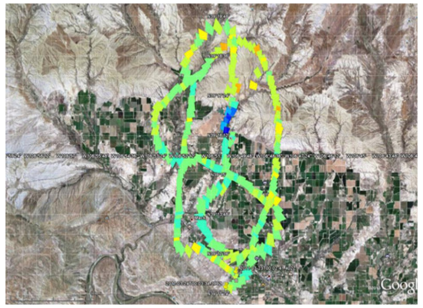
Atmospheric oxygen measurement results from the FTUVS with the GEO-CAPE ROIC.

Instrument Systems Development

Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) Science Data System

PI: Charles Miller (JPL)

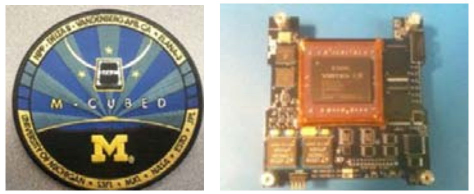
In 2011, the Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) Data System team and its Airborne Cloud Computing Environment (ACCE; see description in multi-mission section) partners created a Level 0/Level 1 processing system for the multi-instrument CARVE payload. The team demonstrated these capabilities by generating Level 1 data products from the CARVE engineering flights in the spring. The team also completed development on its data storage system, data distribution system, and Level 3 processing system. In 2012, the team looks forward to working with the CARVE Science Team to integrate their Level 2 product generation capabilities into the data system. Addition of that capability will complete the Data System.



CARVE brightness temperatures measured during a payload checkout flight in Colorado

CubeSat Onboard Processing Validation Experiment (COVE)

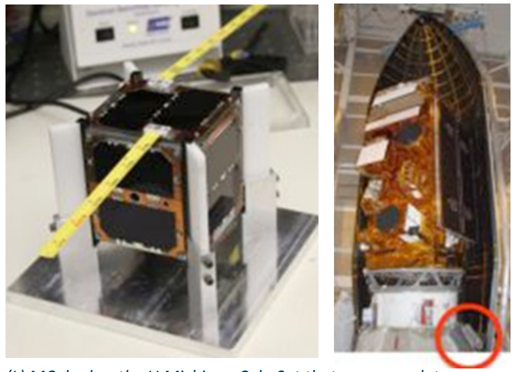
PI: Paula Pingree (JPL)



(L) Mission patch, M-Cubed patch designed at U. Michigan.
(R) COVE SIRF — the Flight Model (FM) CubeSat Payload designed, built and delivered by JPL.

This technology validation task was funded by NASA's Earth Science Technology Office (ESTO) to complete development and testing of a spacecraft conforming to typical CubeSat specifications (1U = 10 cm x 10 cm x 10 cm), integrate a JPL on-board image-processing payload, and to launch the satellite to begin mission operations in low Earth orbit. This was a 18 months start-to-launch effort, with a budget of $1.8M, including six months of operations support.

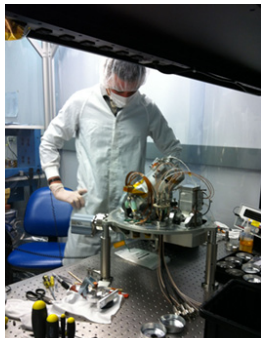
The host satellite is the Michigan Multipurpose Minisatellite (M-Cubed), a CubeSat that is intended to take medium-resolution images of the Earth. COVE is a JPL-designed electronics payload that contains the Xilinx Virtex-5QV Single event Immune Reconfigurable FPGA (SIRF) with an image-processing algorithm developed for the Multi-angle SpectroPolarimetric Imager (MSPI) instrument, also under development at JPL (PI: D. Diner/32). The COVE board interfaces to the M-Cubed spacecraft processor to receive image data from the camera that is then processed by the algorithm. The image, on-board processing results, and housekeeping telemetry are to be downlinked for validation of the Virtex-5 FPGA and image-processing algorithm. M-Cubed/COVE was launched as a secondary payload of the NPP mission from Vandenberg Air Force Base on October 28, 2011.



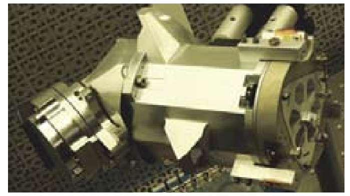
(L) MCubed — the U.Michigan CubeSat that accommodates our COVE payload
(R) NPP Fairing — red circle indicates our P-Pod integrated on the NPP secondary stage

Portable Remote Imaging Spectrometer (PRISM)

PI: Pantazis Mouroulis (JPL), Lead Scientist: Heidi Dierssen (Univ. of Connecticut)



PRISM Assembly

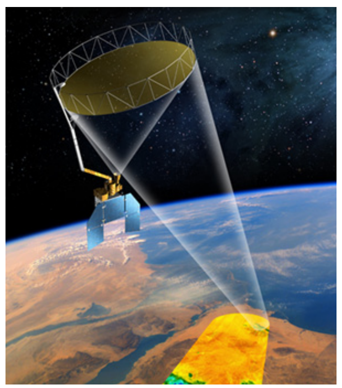


PRISM spectrometer and telescope subassembly

The Portable Remote Imaging Spectrometer (PRISM) completed its second year of development. PRISM is an airborne instrument specially designed for the challenges of coastal ocean research, intended to become a NASA facility instrument. It is due for completion and calibration/test flights in 2012. PRISM comprises an imaging spectrometer covering the 350-1050 nm range and a separate two-channel short-wavelength infrared (SWIR) radiometer at 1240 nm and 1610 nm to aid with atmospheric correction. PRISM will be the first high-throughput and high-uniformity Dyson imaging spectrometer to operate in the visible/near IR spectral range. It incorporates unique JPL technologies including a broadband, concave, low-polarization grating, and a lithographically formed slit on low-scatter substrate. At the end of the second year, the instrument entered the final integration and testing phase. Optomechanical subassemblies have been completed and are being integrated with electronics and thermal control.

Full instrument assembly is expected by December, first calibration flight by February, and a science investigation over optically shallow and optically deep waters in the Monterey Bay, California, area in July.

Soil Moisture Active Passive (SMAP) Science Data System (SDS)



SMAP Spacecraft & Instrument Design

The SMAP Project is close to the end of Phase B, with a baseline launch in October 2014. The project completed a successful Project Preliminary Design Review (October 2011), and the Mission System Preliminary Design Review was held in mid-November 2011. The SDS is designed to support a three year science mission, processing 135 GB raw data per day, automatically producing 350 products daily, with 750 TB end-of-mission storage. The system is sized to accommodate simultaneous reprocessing. The science data products will be hosted at the Alaska Satellite Facility, and the National Snow and Ice Data Center for community distribution.

The SDS architecture leverages Apache Object-Oriented Data Technology (OODT) components, and a processor interface framework. The OODT architecture framework has been used for other Earth missions, and includes workflow, file and resource manager. The processor interface framework includes run-time configuration interface, HDF5 product input/output, ISO 19115 metadata series, uniform framework for handling variable bit-flags in data products, message handling to track run and error conditions. To demonstrate inter-operability of the data system framework and processor interface framework, a radar prototype processor was successfully integrated with the file management and processing management capabilities. This model and design pattern will be employed to integrate the additional 23 processors with the processing and file management.

In a joint activity with the project science office, simulated SMAP products have been generated and made available to Early Adopters. Simulated products are in HDF5 format and conform to SMAP product

design. The simulated products enable users to generate software that would be used after launch, and provide feedback on product format and design.

Planetary Science

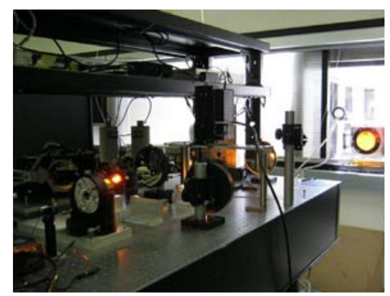
ExoMars Trace Gas Orbiter (TGO) Mars Atmostpheric Spectrometer (MATMOS)

PI: Paul Wennberg (Caltech)

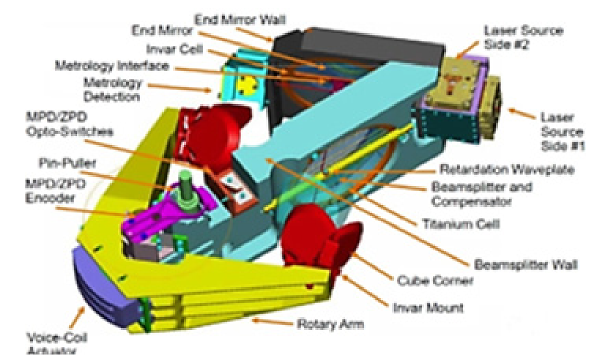
Developed jointly between JPL and the Canadian Space Agency (CSA), MATMOS is a Solar Occultation Fourier Transform InfraRed spectrometer (SFTIR) with a co-aligned solar imager that will detect, profile, and map with parts per trillion (ppt) sensitivity all trace gases of interest to the ExoMars Joint Instrument Definition Team (JIDT). SFTIR was identified by the JIDT as the technique that provides the best means of surveying atmospheric composition with high sensitivity. The science team combines key members of the international SFTIR community and planetary and terrestrial scientists with the expertise to complete the MATMOS investigation.

The Division is providing the Systems Engineering, as well as delivering the Fore and Aft Optical Assemblies, Instrument Electronics, Flight and Ground Software and the MATMOS Performance and Algorithm Testbed (MPAT). Since being selected one year ago to fly aboard the ESA's Orbiter the team has been engaged in negotiating interfaces with ESA and CSA, and creating a preliminary design.

MATMOS Preliminary Design Review is currently scheduled in March 2012 with the Critical Design Review a year later.



The MPAT, which consists of an FTS Modulator contributed by the CSA and breadboard electronics and optics went operational ahead of schedule and is currently being used to characterize the FTS and to evaluate the flight algorithms and MATMOS' 24 bit analog to digital electronics architecture.



The modulator assembly is the heart of the instrument. It consists of a Michelson interferometer containing a metrology subsystem to measure the optical path difference (OPD) in real time, and electronics to control the assembly.

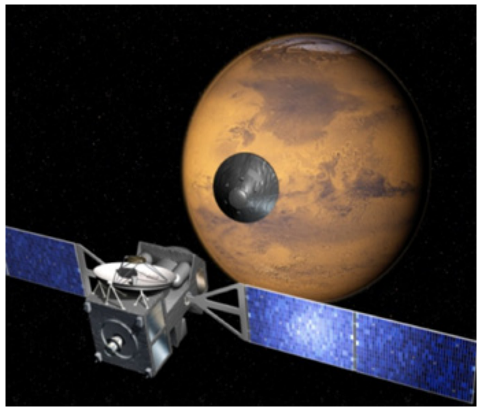
ExoMars Trace Gas Orbiter (TGO) Climate Sounder (EMCS)

PI: Tim Schofield (JPL)

EMCS will be a near copy of the Mars Climate Sounder instrument, shown in this figure.

The ExoMars Climate Sounder (EMCS) is an atmospheric limb sounding radiometer designed to map temperature, pressure, water vapor, water ice, CO_2 ice, and dust in the martian atmosphere. EMCS is slated to fly as part of the science payload on the Mars 2016 Trace Gas Orbiter mission. The measurements will cover all Mars local times, adding a new dimension to data previously obtained from sun-synchronous missions. This instrument is a largely build-to-print copy of the Mars Climate Sounder instrument, which has completed five years of science collection aboard the Mars Reconnaissance Orbiter. The EMCS team successfully completed its PDR in November. EMCS will be built at JPL, with mechanisms and optical filter assemblies manufactured under outside subcontracts.

ExoMars Trace Gas Orbiter (TGO) Science Operations Center (SOC)



During this past year, we continued to support development of the ExoMars Trace Gas Orbiter (TGO) Science Operations Center (SOC) in collaboration with the European Space Agency (ESA), the Mars Program Office, System & Software Division (31) and the TGO science community. The SOC will be located at JPL and will serve as the operational hub for all integrated TGO science planning activities, downlink instrument data processing, data management, science product distribution, and science data archive assurance. The SOC will provide the operational interface between all five TGO instrument operations facilities, project relay operations facilities, and the ESA Mission Operations Center (MOC) located at the European Space Operations Center (ESOC) in Darmstadt, Germany.

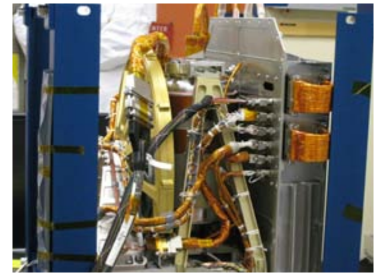
Achievements this year include successful participation in the ESA-led ExoMars TGO Preliminary Design Review, the NASA-led TGO Software Requirements Review, and numerous technical interchange meetings with ESOC partners, instrument teams and institutional service providers. Support for these reviews and technical meetings resulted in a well-regarded set of formal SOC requirements, a highly detailed SOC operations concept, and a set of SOC documentation detailing SOC processes, designs, and implementation plans that prepares for us well for the critical ESA-NASA Ground System Requirements Review scheduled for early 2012.

Mars Science Laboratory (MSL)

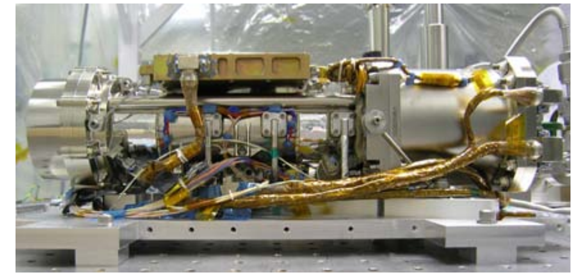
Mars Science Laboratory with its rover *Curiosity*, launched on November 26, 2011, carries the JPL Tunable Laser Spectromter (TLS) built for NASA/JPL PI Dr. Chris Webster; and the Chemistry & Mineralogy (CheMin) X-ray diffraction/X-ray fluorescence instrument built for NASA/Ames PI Dr. David Blake. TLS is

a 2 channel laser absorption spectrometer (Channel 1 is CO_2 isotopologues and H_2O, and Channel 2 is CH_4 and $^{13}CH_4$), which is part of the GSFC Sample Analysis at Mars (SAM) instrument suite on MSL. CheMin will be able to definitively determine specific mineral composition, improving upon MER's present reliance on measuring only elemental abundances that can infer any of several minerals that could have different formation histories.

MSL Cameras

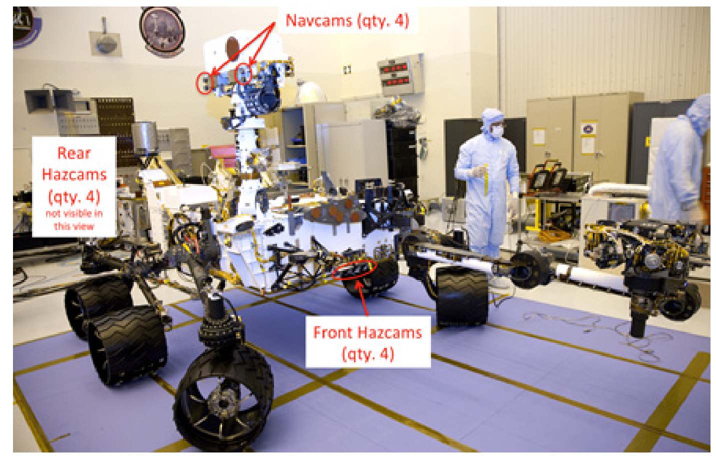


Chemistry and Mineralogy (CheMin) X-Ray Diffraction/X Ray Fluorescence Instrument



MSL's Tunable Laser Spectrometer (TLS)

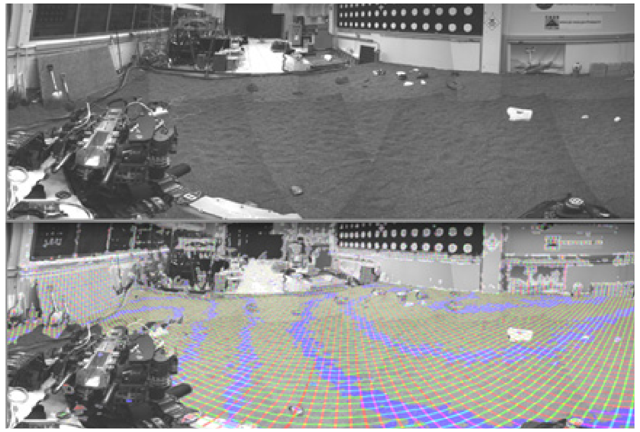
JPL built all 12 Flight Engineering Cameras aboard *Curiosity*, plus 14 engineering models and spares, delivering them on time and within the budget of $5 M for the total package. The cameras are based on the Mars Exploration Rover (MER) *Opportunity* cameras which have operated flawlessly for over seven years, as compared to a "design life" of 90 days on the surface of Mars.



The MSL's Engineering Cameras were tested aboard the Curiosity rover in JPL's cleanroom integration facility.

Water in Mars' past: color view of the "Homestake" mineral vein called taken by Mars Exploration Rover Opportunity's panoramic camera (PanCam), designed, built and tested at JPL. Opportunity examined this vein in November 2011 and found it to be rich in calcium and sulfur, possibly the calcium-sulfate mineral gypsum. The vein is about the width of a human thumb (0.4 to 0.8 inch, or 1 to 2 cm), 16 to 20 inches (40 to 50 cm) long, and protrudes slightly higher than the bedrock on either side of it.

MSL Operations Product Generation Subsystem (OPGS)



The Division/OPGS team has been busy implementing MSL processing capabilities this year. The top image is a mosaic of the Mars sandbox taken during a Surface Normal Thread Test (SNTT), using the testbed rover. The bottom image overlays that with an XYZ grid computed from the stereo images. This mosaic demonstrates in a microcosm much of OPGS capability. The images were acquired onboard and "downlinked" to the team, where they were automatically processed by the OPGS pipeline and then mosaicked. The resulting products (images, XYZ, mesh, slope, reachability, etc.) were sent to the rover and science planners, where they were used to command the next day's activities for the rover. All this was accomplished in a flight-like manner. While development is not quite complete, this successful end-to-end test demonstrated the readiness of OPGS to support surface operations in 2012.

Astrophysics

Gemini Planet Imager (GPI)

The JPL GPI Cal Instrument being integrated with the GPI AO instrument

JPL is providing the precision calibration wavefront sensor (CAL) for the Gemini Planet Imager (GPI). The GPI is a high-contrast imaging spectrometer behind an advanced adaptive optics (AO) system and coronagraph. It is designed to directly detect and characterize young exoplanets from the ground. The CAL sensor will accurately measure wavefront errors that would otherwise swamp the planet image in the final science focal plane. It consists of two independent sensors: the low-order sensor (LOWFS) and the high-order sensor (HOWFS). The LOWFS consists of an infrared Shack-Hartman wavefront sensor that coarse samples the input pupil for aberrations like tip, tilt and focus. As such, it defines and maintains the system boresite. The HOWFS is a white light interferometer and quantifies the level of light scattered into the science path.

The CAL system was delivered for integration at UC Santa Cruz in November 2010. Incredibly, when delivered, the white light fringe location was measured to be within less than one micron of where it was last measured here at JPL. Given that the shipment involved a 350 mile drive from Pasadena to Santa Cruz, this is a testament to the mechanical stability of the CAL box.

Instrument Systems Development

In early October, the CAL sub-system was integrated with the rest of the GPI instrument. Installation went smoothly over two days: the first day was mechanical and electrical integration, the second day was software integration and optical alignment. Integration and test of the full GPI instrument will continue at UC Santa Cruz before heading to the Gemini South 8-meter telecope in Chile in the early fall of 2012. First light is now expected by end of 2012.

JWST/MIRI Ground Support Equipment and Instrument Flight Software

MIRI flight Software and the Ground Support Equipment software were delivered to our European partners in United Kingdom last January 2011. In February 2011 the Flight Focal Plane System was delivered as well. The performance testing and thermal vacuum testing were performed with the integrated instrument in Europe. All tests were successful and had no formal problem reports on the software. An official and formal delivery to Goddard Space Flight Center when Europe delivers the instrument to GSFC for payload integration is pending.

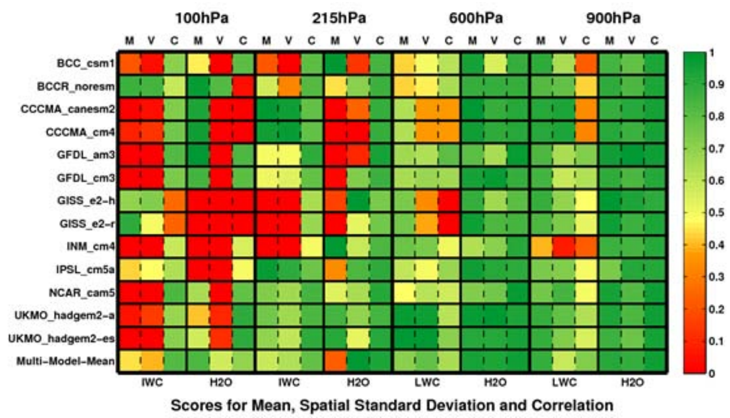
Multi-mission & Multi-discipline

Airborne Cloud Computing Environment

The Airborne Cloud Computing Environment (ACCE) is a reusable cloud capability for sub-orbital instruments providing process control and data management services at low-cost, and low-risk, with a predictable, scalable cost model. To lower cost and increase scalability, ACCE has leveraged the science data system product line currently applied to spaceborne missions to provide support for algorithm development and testing as well as standard algorithms that can be plugged in. Through the sharing and commoditization of computing resources, ACCE provides a cost effective hosting environment on a pay-as-you-go basis. Additional benefits of ACCE include risk reduction and increased usability. While no longer needing to be concerned with computing issues, airborne instrument teams are free to concentrate on instrument innovation and science experiments. When an airborne instrument is ready for a spaceborne mission, the data processing environment is a direct plug-in to the mission Science Data System. Distribution and archive of airborne data are more systematic and uniform for future data analysis activities. Integration of ACCE with the Lab's Global Change and Energy (GC&E) efforts will allow the sharing of data from different sources (e.g. regional study of California water cycle). Through the unified portal access, the instrument teams have increased mobility, being able to access data and information from wherever they are located. ACCE is currently the backbone for the Venture 1 Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) Science Data System and provides data archive and distribution capabilities for the JPL Near-IR Laser Hygrometer (JLH)/Unmanned Aerial System Laser Hygrometer (ULH) instrument team.

Evaluation of Climate Models using A-train Satellite Observations

Climate change is one of the hottest topics in Earth science research. Our work contributes to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). Due to the complexity of the climate system, it is a great challenge to reliably predict climate change. Now model centers all over the world are working together toward the goal of correctly predicting future climate. To determine how reliable the prediction may be, it is crucial to evaluate the performance of climate models in simulating the current climate. We use the A-Train satellite observations including CloudSat, Aura-MLS, and Aqua-AIRS data to assess the performance of all the climate models that are participating in IPCC/AR5. We focus on the hydro-cycle because these satellite observations provide water contents in three states (vapor, liquid, and ice) and so far, the cloud feedback is among the largest uncertain factors in climate prediction. On one hand, clouds block the solar radiation and thus cool down the Earth, but on the other hand, clouds also trap the long wave radiation of the Earth and thus warm up Earth's surface by the greenhouse effect. The net result gives the sensitivity of climate change in response to anthropogenic effects, for example the release of CO_2. A-Train satellites provide nearly collocated measurements of atmospheric parameters at different altitudes above the ground. We analyze the data using various statistical metrics and developed a grading system to quantify the model performance. We specifically evaluated the model performance at different altitudes so as to provide modelers insights on how models perform in simulating boundary layers and deep convections. The evaluation results are useful for determining the model's reliability for predicting the future climate. Our future work will establish the connection between the model performances in simulating hydro-cycle and their climate sensitivities.



INSTRUMENTS & SCIENCE DATA SYSTEMS DIVISION

Operational Missions

ANNUAL REPORT FY 2011

Earth Science

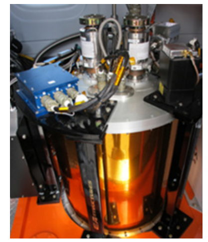
Next Generation Imaging Spectrometers (NGIS)

PI: Greg Asner (CAO), and Tom Kampe (NEON)

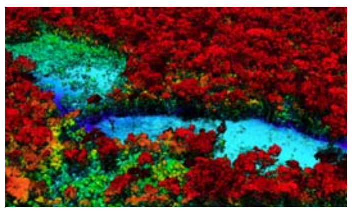
These high fidelity airborne instruments were delivered to the Carnegie Airborne Observatory (CAO) based in Washington, D.C. and the National Ecological Observatory Network (NEON Inc.) of Boulder, Colorado.

Both CAO and NEON use their instruments to advance ecological studies, centered on forest physical structure and chemical composition. The spectrometer can detect dozens of signals such as photosynthetic pigment concentrations, water content of leaves, defense compounds like phenols, structural compounds such as lignin and cellulose, as well as phosphorous and other micronutrients. These signals can build signatures to distinguish individual plant species as well as other measures of forest condition. The result is a system that can map the chemical and spectral attributes of a forest that (as in the CAO of tropical areas) may have more than 200 species of trees in 100 acres.

The Carnegie crew, flying the first JPL NGIS instrument.



The first Next Generation Imaging Spectrometer, delivered to Carnegie in May 2011.

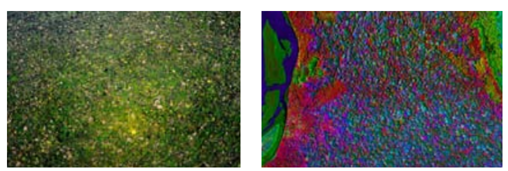


This image shows a small deforested patch with individual trees, colored by height. The densest biomass is red, while deforested areas — with low biomass — are shades of blue. Spectral data (shading) provided by the JPL Next Generation Imaging Spectrometer. Image courtesy of the Carnegie Airborne Observatory

"The whole idea is to measure each of the things that plant ecologists measure on the ground to evaluate biodiversity," says Dr. Greg Asner, the Principal Investigator of the Carnegie Airborne Observatory. "When leaves interact with sunlight, the compounds bend, stretch, and vibrate at different patterns and rates. This is the gateway to understanding the chemistry of the system." CAO has paired the NGIS with other instruments to enable breakthrough three-dimensional mapping of forest physical structure and chemical composition, tree by tree.

This past year the CAO was used to conduct a biological a survey of a never-before-explored tract of remote and inaccessible Peruvian cloud forest. The aircraft that carries the NGIS allows mapping of large areas, sometimes more than 120,000 acres a day. The scientists hope to determine not only what species may lie below and how the ecosystem is responding to last years drought, the worst ever recorded in the Amazon—but also help the Peruvian government map biodiversity, develop a better mechanism for monitoring deforestation and degradation and alleviate uncertainty about carbon emissions from deforestation and different forms of forest management.

Delivery of the initial imaging spectrometer for NEON, made in December 2011, forms the core of a similar mapping system to be used in NEON's study area of the continental US, Alaska and Puerto Rico. Two further deliveries of NGIS instruments from JPL, to be made in spring and fall 2013 will complete the NEON system of aircraft instrument platforms.

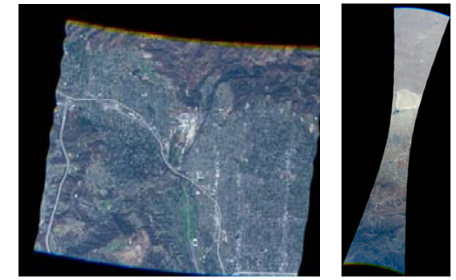


Two views of tropical forest canopy in Madre de Dios, Peru from the CAO. The right kaleidoscopic image, taken in the Manu Biosphere Reserve, reveals biodiversity signals that are missed with the naked eye. Spectral data (shading) provided by the JPL Next Generation Imaging Spectrometer. [Photos and images courtesy of the Carnegie Airborne Observatory.]

Multi-angle SpectroPolarimetric Imager (MSPI) Data Processing

PI: David Diner (JPL)

AirMSPI flew another successful engineering flight on August 31, 2011. The purpose of this flight was to test the on-board processing in-situ and to test fixes and improvements to the data acquisition system.



(L) AirMSPI Intensity RGB (R=660nm, G=555nm, B=470nm) Nadir view of JPL
(R) AirMSPI variable velocity slew RGB image over Palmdale airport

The on-board processing system utilizes an embedded PowerPC CPU core in the camera FPGA to perform the first steps of calibration and science retrievals. This flight tested the on-board retrieval of the Stokes parameters U and Q of linear polarization from the MSPI polarization channels, as well as the retrieval of the intensity components I0 and I45 for those channels. Both raw instrument data and retrieved data were collected, so the on-board retrievals could be verified against the ground data processing system (PGE). The goal of the on-board processing system is to demonstrate the feasibility of reducing the amount of raw instrument data to meaningful science quantities in order to reduce the data output rate of the instrument.

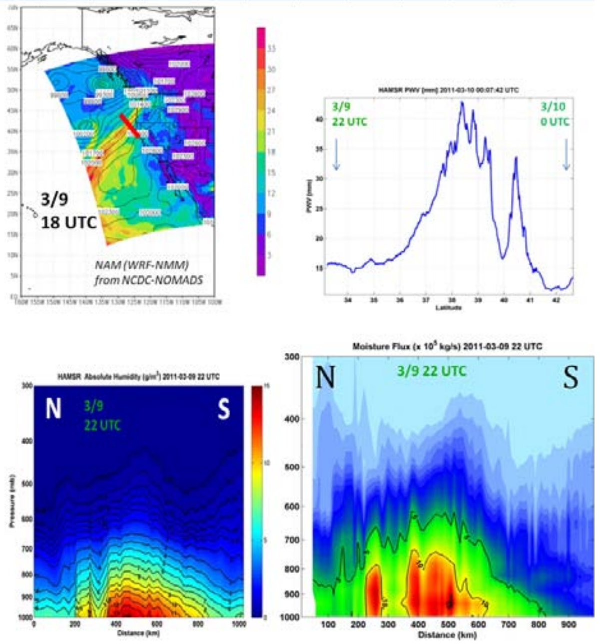
The data acquisition system also experienced some improvements: 1) a new variable velocity gimbal slew mode to compensate for aircraft motion; 2) a windshield wiper slew sequence to scan back and forth, in addition to the standard step and stare mode; 3) fixed cable binding issue that was preventing the gimbal from reaching the extreme aft angles; 4) implemented an on-board validator consisting of multicolor LEDs illuminated through various angled polarizers; and 5) the implementation of the ER-2's Reveal data downlink system, which uses the Iridium satellites to downlink instrument logs for monitoring the instrument during flight from the ground.

High Altitude MMIC Sounding Radiometer (HAMSR)

PI: Bjorn Lambrigtsen (JPL)

In 2011, the High Altitude MMIC Sounding Radiometer (HAMSR) - a state-of-the-art microwave sounder built and operated from JPL – flew on the Global Hawk (GH) UAV in the NOAA-sponsored Winter Storms and Pacific Atmospheric Rivers (WISPAR) field campaign and also flew on the GH during the first flights of the NASA Ventures Hurricane and Severe Storm Sentinel (HS3) mission. The primary objective of the WISPAR campaign was to study atmospheric river events and winter storm cyclogenesis using a newly developed NOAA dropsonde system and HAMSR and to evaluate the GH platform for providing observations with better coverage over a longer duration. The focus of the HS3 flights was to inter-compare three atmospheric profiling systems that will fly during the 2012-2014 HS3 science flights to study tropical cyclones, but on different aircraft. During the 2011 HS3 flights, the NOAA dropsonde system, HAMSR and an infrared sounder (S-HIS) co-flew on the GH over a wide range of atmospheric conditions during two flights, providing a rich dataset with which to inter-compare these systems.

During WISPAR, HAMSR provided unprecedented measurements of the horizontal structure across an atmospheric river event at 1.9 km spatial scales. Atmospheric rivers are thin filaments of enhanced water vapor that develop in the warm sector ahead of polar fronts and occur in a region of high near-surface winds, termed a low level jet. Previous studies have shown that atmospheric rivers (AR) are responsible for up to 90% of the poleward moisture flux and can cause extreme, long-duration precipitation events and associated flooding when the ARs interact with the coastal topography found on the west coast of the United States. Observations that reveal the structure of these ARs over the ocean will help improve models to enable better coastal precipitation and flood forecasting.



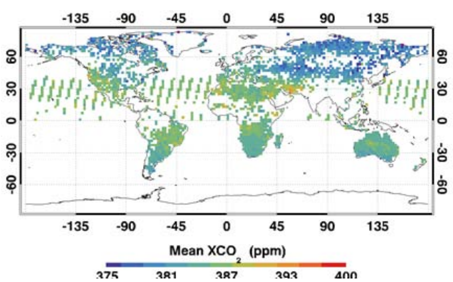
The figure shows the anatomy of atmospheric river as observed by HAMSR during one of the two transects across this AR on 3/9/2011. The top left plot shows a synoptic overview from a model on 3/9/2011 at 18 UTC, just prior to the Global Hawk's first transect of the AR. The top right plot shows the HAMSR precipitable water vapor across the river starting at 22 UTC on 3/9. The transect location is indicated by the red line on the top left plot. The bottom left figure shows a cross-section of the water vapor content across the river, showing the narrow 200 km core of the river which is concentrated in the lower troposphere. The bottom right figure shows a cross-section the derived moisture flux, illustrating the intense core of enhanced moisture directed toward the U.S. west coast.

Atmospheric CO_2 Observations from Space (ACOS)

The Japanese Greenhouse gases Observing SATellite (GOSAT) continues to make worldwide observations which are ingested and processed here as the ACOS task.

The Japan Aerospace Exploration Agency (JAXA) and the ACOS Science Data Operations System (SDOS) completed several updates to the instrument calibration and processing software. One full reprocessing campaign (24 months of GOSAT observations) was completed.

Enhancements to the Full-Physics retrieval algorithm concentrated on improved accuracy by targeting key components of the process. As a result, the bias in CO_2 abundance results (relative to ground measurements) was reduced from 7.7 ppm to about zero. The bias in surface pressure results was reduced from 10 hPa to about zero. These improvements were made without compromising the average computing time per observation of about 18 minutes.



ACOS CO_2 abundance results for July 2009

Collaborators at Colorado State University provided software to act as a cloud screener. This successfully eliminated the processing of soundings whose retrievals would have failed due to clouds. In addition, processing of ocean observations was enabled and found to yield results equivalent to those over land.

Close collaboration with the JAXA partners continued via regular telecons and an on-site calibration activity in the Nevada desert.

NPOESS Preparation Project (NPP) Sounder Project Evaluation and Test Element (PEATE) Science Data System

NPP was successfully launched from Vandenberg Air Force Base on October 28, 2011.

The National Polor-obriting Operational Environment Satellite System (NPOESS) Preparatory Project (NPP) is first in a NASA program of next generation environmental and weather forecasting satellites for NOAA and DOD. NPP was successfully launched aboard a Delta II rocket at Vandenberg Air Force Base. While NASA's primary role is to manage the fabrication and launch of the spacecraft, its secondary mission is to evaluate the continuity and quality of NPP data products and to determine whether these products can be used for climate studies. The NPP Sounder PEATE's specific role is to assist the NPP Sounder Science Team in determining whether NPP temperature and water vapor products, generated from the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) instruments, are "climate quality." JPL's experience developing and managing AIRS is crucial in analyzing these new data products. The Sounder PEATE is currently developing a data computing facility that will be used by the Sounder PEATE team and the Sounder Science Team to evaluate the climate quality of NPP data products. Prior to launch, the Sounder PEATE supported the Science Team in evaluation of proxy and simulated products. Since launch, the PEATE supported the Science Team during early calibration activities and in subsequent analyses of NPP standard products.

Several software products are being developed: the PEATE Simultaneous Nadir Observation (SNO) products will be routinely produced for all Nadir intersections of NPP with MetOp-A and Aqua spacecraft, enabling the Science Team to evaluate similarities and dissimilarities between each satellite's observed spectra and retrieval products. Additional tools to generate simulated radiances and temperature/water vapor profiles will enable the Science Team to compare observed vs forecasted products .

The Sounder PEATE is well positioned to receive and study NPP data products as they become available after launch. NPP data will become available in stages, with the microwave products becoming available approximately one-month after launch. CrIS data products will become available between 2-3 months after launch, as the instrument requires a lengthy outgassing and cryogenic cooling process. The NPP Sounder PEATE team will continue to work with the NPP Sounder Science Team to tailor existing products as well as create new analysis products as needed for at least two-to-four years after launch.

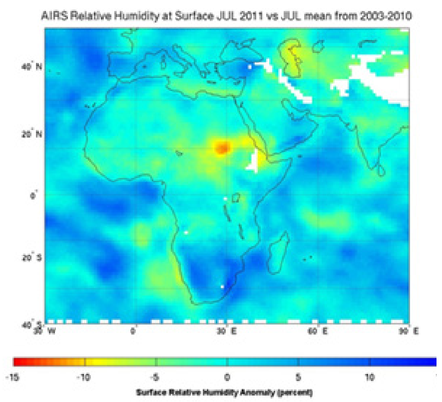
Atmospheric Infrared Sounder (AIRS) on AQUA

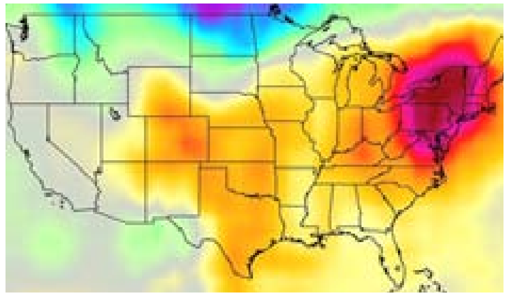
PI: Bjorn Lambrigtsen (JPL)

The AIRS Project continues to develop new research products while maintaining production of standard data products. Now, after more than nine years in orbit, AIRS continues to provide daily global coverage of temperature and water vapor profiles of the Earth's atmosphere. Many trace gases are also "retrieved" from AIRS data. AIRS products have helped improve global weather forecasting models significantly, increasing the accuracy of long-range forecasts by more than six hours. AIRS data products have also been instrumental in improving the accuracy and timing of tracking hurricanes and typhoons as they approach land. Last year, the AIRS Project added routine mapping of mid-tropospheric CO_2 to its global products collection. This year, the CO_2 product will also cover stratospheric and lower tropospheric quantities, giving us a fuller picture of CO_2 distribution in the atmosphere. AIRS also continues to be useful in issuing air transportation warning about volcanic eruptions and other severe dust events.

AIRS Science Data software Version 6 is currently scheduled for release in early 2012, and a complete reprocessing of all Level 2 and 3 products will be produced. Version 6, which is in its final testing, will yield superior products than previous version including higher retrieval yields nearer the surface and in the proximity of clouds. Additionally, new Level 3 products, including the first release of research products in 100 atmospheric layers will be available for the first time.

The AIRS Project, in conjunction with the Goddard Earth Science (GES) Data and Information Services Center (DISC), continues to distribute AIRS data products from the ling-term data archives. Additionally, near-real-time data products including temperature, water vapor, carbon monoxide, and ozone, are now also available at the GES DISC. These products, which supplement the long-term archival record of AIRS data, are mainly used for weather forecasting and issuing weather alerts. The AIRS Project celebrated nine years in orbit on May 4, 2011. The instrument continues to operate flawlessly.





(L) Surface relative humidity anomaly for July 1-18, 2011 relative to the average July surface relative humidity over the previous eight years of AIRS measurements clearly shows regions severely affected by drought (red and yellow-toned regions). Northeast Africa continues to feel the effects of the worst drought to strike the region in decades. The drought is tied to strong La Nina conditions that prevailed in late 2010 and early 2011. The driest conditions, shown in red, are found in northeast Africa. White areas represent data voids caused by the effects of maintain and highland topography penetrating the 850 hPa pressure level, that was used as a quality assurance threshold.

(R) AIRS data was used to track surface skin temperature anomalies during the July 2011 heatwave. This image depicts surface skin temperature anomalies relative to the average July surface skin temperatures over the previous eight years of AIRS measurements. Over the Northeast and northern Midwest, temperatures are 20 F warmer than normal. These high temperatures, along with high humidity, made the central and eastern US one of the areas with the highest heat indexes on the planet in late July 2011.

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on Terra

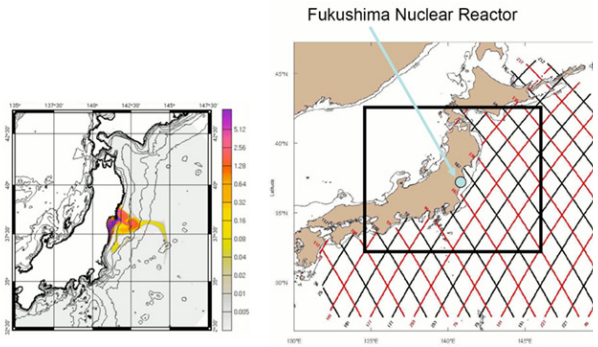
Science Team Leader: Michael Abrams (JPL)

ASTER continues to operate and acquire useful science products after nearly a dozen years on orbit. An improved version of the very popular ASTER Global Digital Elevation Model was just completed and released to the public in October. The ASTER urgent acquisition scheduling capability was used extensively in the aftermath of the deadly earthquake and tsunami in Japan. The combination of high-resolution visible and multi-band thermal imaging was very useful in observing both tsunami debris and possible elevated temperatures near the damaged nuclear facilities. ASTER data were sent directly to disaster response agencies and were used for response planning and damage assessment.

This before-and-after image pair reveals changes to the landscape that are likely due to the effects of the tsunami. The new image is on the left. The image on the right was acquired in August 2008. Areas covered by vegetation are shown in red, while cities and unvegetated areas are shown in shades of blue-gray.

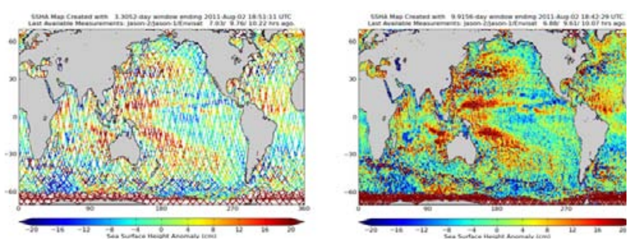
Jason-1 and Ocean Surface Topography Science Team (OSTM/Jason-2)

The OSTM and its associated scientists and investigators have continued to add significantly to research studies directly attributed to the TOPEX/Poseidon, Jason-1 and OSTM/Jason-2 missions. In December 2011, Jason-1 will complete ten years of successful science operations, doubling its five-year mission lifetime. Jason-1 was recently approved for a fourth two-year mission extension, through 2013. In June 2011, OSTM/Jason-2 successfully completed its three-year prime mission and began its first two-year extended mission.



Jason-1 and OSTM/Jason-2 altimeter data were used in ocean models to predict dispersion of radioactive particles from Fukushima

Jason-1 continues to work in tandem with OSTM/Jason-2 to provide optimal sampling of mesoscale ocean features like currents, fronts and eddies. These observations are critical to NASA's science objectives pertaining to the analysis of variances in global ocean circulation on inter-annual, decadal, and longer timescales, and determining how climate variations induce changes in the global ocean circulation. The value of this integrated observation system is illustrated in the following charts which demonstrates how Jason-1 and OSTM/Jason-2 can work with a third altimeter (the European Space Agency's ENVISAT mission) to provide near-real-time estimates of sea surface height anomaly conditions to operational agencies.



Newly Developed Near-Real-Time Sea Surface Height Anomaly Data Product (3-day on left, 10-day on right)

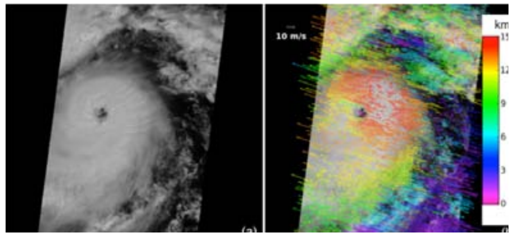
The tandem mission data of the Jason satellites were also instrumental in tracking the

2010 change from El Niño to La Niña, and the resulting drop in global sea-level. Jason data was also used to confirm tsunami prediction models and in predicting possible dispersion of radioactive particles from Fukushima reactor leaks.

Multi-angle Imaging SpectroRadiometer (MISR) on Terra

PI: David Diner (JPL)

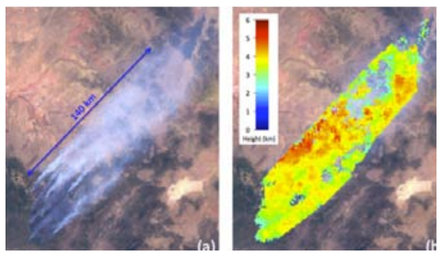
The MISR instrument and Terra spacecraft completed 11 years of successful operations this last year. During that time over 550TB of publicly available data products were generated.



Hurricane Jova observed by MISR. Visible image showing clear eye (a) and 1.1 km spatial resolution vertically resolved cross-track winds

MISR, as part of the Terra instrument set, was directed to continue extended mission operations for at least the next two years as a result of the NASA 2011 Senior Review of Earth Science Operating Missions. MISR, as well as Terra, was given an outstanding science summary rating with highlighted comments such as “The uniqueness of the MISR instrument provides numerous applications not provided by other datasets (3D morphologies, aerosol/ice shape, vegetation structure etc.).”

A new, high spatial resolution cross-track wind retrieval algorithm was developed in the past year. These height-resolved, cross-track winds provide information at the same 1.1 km resolution as the current MISR cloud-top height product. Such winds are useful for revealing details of cloud-scale dynamics. In the image below, cross-track winds are shown for Hurricane Jova, which made landfall in western Mexico in early October, 2011. Colors show motion at different altitudes, with cool colors representing low-level winds moving counter-clockwise into the storm, and warm colors representing winds at the top of the hurricane. The cross-track winds in the upper right quadrant of the storm show divergence (opposing wind directions), indicating regions of strong vertical motion that are helping maintain the intensity of the storm.



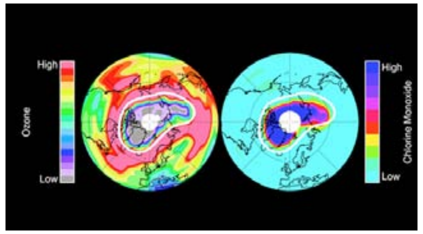
Wallow Fire in Arizona observed by MISR. True color image of the smoke plumes extending over 140 km from their source (a), and retrievals of plume heights ranging from 3 to 6 km

The MISR INteractive eXplorer (MINX) software tool was developed at JPL and enhanced over the last year. This software, which makes working with MISR data easier for individual users, is publicly available and has been downloaded by users from around the world. MINX also provides the capability for detailed height and wind analysis on aerosol plumes.

Microwave Limb Sounder (MLS) on Aura

PI: Nathaniel Livesey (JPL)

2011 has been a challenging and exceptional year for the Microwave Limb Sounder (MLS) instrument. Challenges began late 2010 when MLS suffered a major anomaly when the spacecraft command and data handling system began sending corrupted science data. After about a month, the anomaly eventually resolved itself as it has done in the past. Then, after nearly 7 years on orbit, difficulties with the GHz Mirror Electronics module required switching over to the ‘B’ side. The instrument was successfully returned to operations after 25 days of downtime and observations have been nominal ever since. Exceptional accomplishments also occurred during this period with the quick deployment of L1 SW changes that improved resiliency against data loss. The MLS team achieved another accomplishment in August when they returned the THz module to operations after a hiatus of 20 months. The instrument performed remarkably well during its one month of operation, where a daily average of 89% of OH data was recorded. To extend the limited remaining life in the THz, the MLS team returned it to stand-by mode and plans to turn it on again next August to continue the OH record.

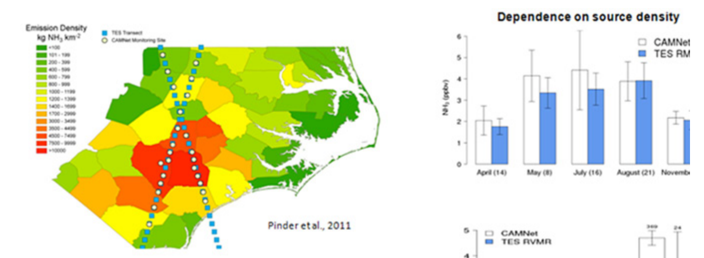


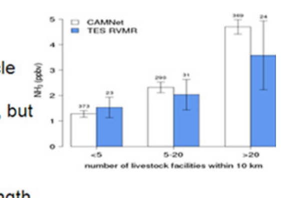
Left: Ozone in Earth's stratosphere at an altitude of approximately 12 miles (20 kilometers) in mid-March 2011, near the peak of the 2011 Arctic ozone loss. Red colors represent high levels of ozone, while purple and grey colors (over the north polar region) represent very small ozone amounts. Right: chlorine monoxide – the primary agent of chemical ozone destruction in the cold polar lower stratosphere – for the same day and altitude. Light blue and green colors represent small amounts of chlorine monoxide, while dark blue and black colors represent very large chlorine monoxide amounts. The white line marks the area within which the chemical ozone destruction took place.

In October, the MLS team and other collaborating scientists published a paper in *Nature* on the unexpectedly large ozone hole that developed over the Arctic in mid-March 2011. This peak period was marked by a long duration of low temperatures in the stratosphere, which triggered chemical reactions that destroy ozone in this layer of the atmosphere. JPL’s news release presented two plots that illustrate the loss of ozone and the presence of chlorine monoxide, which is the primary cause of ozone loss.

Tropospheric Emission Spectrometer (TES) on Aura

PI: John Worden (JPL)





Ammonia (NH_3) plays a major role in the nitrogen cycle and has important ecosystem and human health impacts. NH_3 is regulated and monitored by the EPA, but its sources, sinks, and transport are not well understood. These results from Pinder et al. (2011), shows that TES captures the seasonal and spatial variability of NH3 and its dependence on source strength.

The TES instrument has exceeded seven years in orbit, providing a consistent source of science data products that generate insight into the troposphere’s chemistry. With very high spectral resolution, TES can distinguish concentrations of gases at different altitudes, a key factor in understanding their behavior and impact.

TES science contributions this year include measurements of ammonia, an important aerosol precursor and contributor to the nitrogen cycle, used to characterize emissions from livestock facilities in North Carolina and the California central valley. Other highlights include measurements of ozone and carbon monoxide correlations, used to diagnose global chemistry and transport models and how these models partition their emissions and transport fields; and analysis of water vapor isotopes, used to characterize tropical rainfall evaporation efficiency in global models; this previously unmeasured process is critical for understanding the tropical moisture budget and updating atmospheric general circulation models (AGCM).

Planetary Science

Juno Microwave Radiometer (MWR)

PI: Michael Janssen (JPL)

Juno Launch from KSC, Aug. 5, 2011.

The Juno Microwave Radiometer (MWR) will use passive microwave radiometry at six wavelengths from 1.3 to 50 cm to probe the deep into the Jovian atmosphere to determine the global water abundance. Scientific results from the MWR experiment will help distinguish between various models of Jupiter's origin and the formation of the solar system. The MWR experiment PI is Michael Janssen in JPL's Sciences Division.

In FY 2011, the final details of installation of the MWR instrument onto the Juno spacecraft were successfully completed. The integrated spacecraft flight system then underwent a suite of functional and environmental tests in preparation for launch. On August 5, 2011, Juno successfully launched from Cape Canaveral, Florida beginning a 5-year journey to Jupiter.

Three weeks after launch, the MWR instrument was powered on for the first time, and instrument behavior was found to be normal. During this commissioning phase, the instrument remained powered for 8 days while the spacecraft was spinning at 1 RPM; this allowed for the opportunity to measure our galactic plane's microwave signatures, features of which are particularly prominent in the longer-wavelength channels.

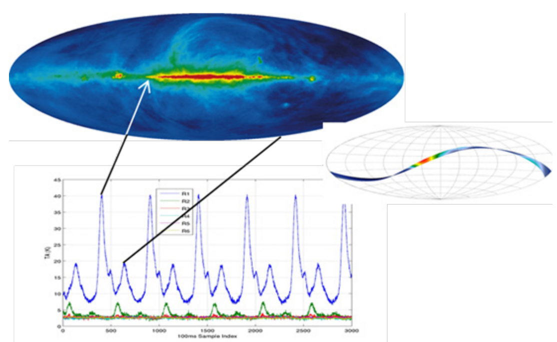
Juno is expected to arrive at Jupiter on July 4, 2016. After some adjustments to the orbit trajectory, later that year should come the prime science data-taking phase of the mission during which the MWR data will be collected and used to determine the global Jovian water abundance.

Juno Science Analysis Subsystem and Science Data System

The Division provided design and operation for the Science Analysis Subsystem (SAS), which is a sub-system of the Juno ground data systems. SAS's primary function is to distribute science and instrument engineering data products (level 1 products) for all Juno instruments to the applicable US and European science teams. In addition, the Division provides science data processing software system (level 2+) for the JPL Microwave Radiometer instrument.

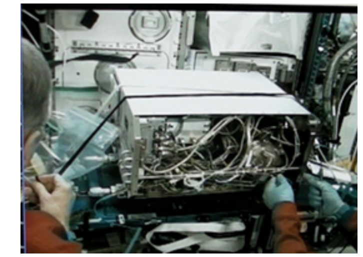
This galactic map at 400 MHz was generated during MWR's first in-flight checkout.

First light galactic plane measurements from MWR instrument taken during 6 successive spacecraft rotations, Aug. 2011. Galactic plane crossings are evident in measurements from each of the MWR radiometers. The plane crossings are especially easy to see in the lowest frequency 600 MHz R1 channel: the large (~40K) peaks occur when the radiometer is looking towards the center of the galaxy while the smaller (~20K) peaks occur half a spacecraft rotation later when looking towards the periphery of the galaxy.



Vehicle Cabin Atmosphere Monitor (VCAM) Analyzing International Space Station (ISS) Air

PI: Ara Chutjian (JPL)



VCAM opened and being worked on by Satoshi Furkawa. For information and images, visit VCAM on the internet at http://aemc.jpl.nasa.gov/instruments/vcam.cfm

VCAM successfully completed its 12-month primary mission on-board the ISS at the end of April 2011. Its mission has been extended to at least January 1, 2012.

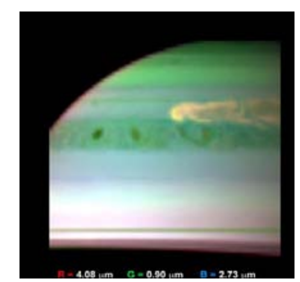
VCAM is a technology demonstration gas chromatograph/ion-trap mass spectrometer designed to monitor the air quality of a crewed vehicle. The JPL protoflight VCAM unit was packaged into a small International Space Station (ISS) EXPRESS Rack enclosure. VCAM detects, identifies and quantifies trace amounts of potentially toxic, organic species. Internal software performs calibration, identification, and quantification functions and generates telemetry. VCAM is equipped with an in-orbit replaceable unit (ORU), that contains the carrier and calibration gas consumed by the instrument. Astronauts have successfully changed out the ORU twice, most recently last May.

In its trace gas (TG) mode, VCAM autonomously identifies and quantifies 35 designated chemical species that can be present in the ISS atmosphere at concentrations of 10 to 104 parts per billion. In its major constituents analysis (MCA) mode, VCAM detects the presence of the species N_2, O_2, Ar, and CO_2, and quantifies their concentrations. As such, VCAM functions as two mass spectrometers in one.

VCAM has a 100-Watt light bulb within the Mass Spectrometer (MS) vacuum chamber that serves to heat up the chamber during a measurement and clean the mass spectrometer during cleaning cycles. In early July 2010, the light bulb malfunctioned and was turned off. The team successfully recalibrated the instrument for use without the light bulb. VCAM has had on board a spare 50-watt light bulb that is wired to the vacuum-chamber flange, but not to the drive electronics. In order to power this spare bulb, the team designed, built, and delivered a jumper cable that re-routes the power from the 100-watt bulb to the 50-watt bulb. On September 9, 2011 the astronaut opened VCAM and added the jumper cable. This operation successfully restored full capabilities.

Cassini

FY 2011 was another year of exciting new discoveries for *Cassini*, showcasing the Division Imaging Science Camera (ISS) and Visual and Infrared Mapping Spectrometer (VIMS) instruments as the spacecraft began operations in the Cassini Solstice Mission. This mission extension, which began in FY 20111 extends spacecraft operations through September 2017, and is named for the Saturnian summer solstice occurring in May 2017. *Cassini* instruments were busy year round capturing data from: numerous Saturn observations, six targeted Titan flybys, two Enceladus flybys and numerous icy



False color image shows clouds of large ammonia ice particles dredged up by the powerful storm in Saturn's northern hemisphere

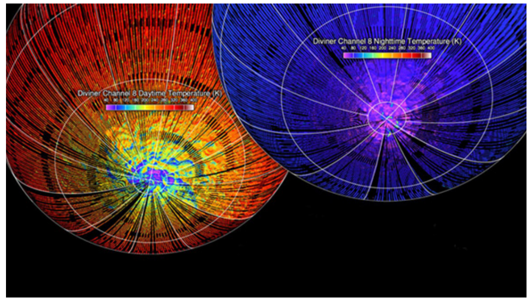
Largest and most intense storm observed on Saturn. This northern hemisphere storm covers 500 times the area of the biggest southern hemisphere storm observed.

satellite flybys. More than 16,800 ISS images and 14,700 cubes were generated and distributed to science teams around the world this year.

Diviner on Lunar Reconnaissance Orbiter (LRO)

PI: David Paige (UCLA)

The JPL Diviner Science Operations Center (JPL SOC) supports the commanding and instrument health monitoring of the Diviner Lunar Radiometer Experiment (DLRE) instrument, and the receipt, processing and distribution of the DLRE data. The JPL SOC is the main interface between the DLRE science team and the LRO spacecraft team located at Goddard Space Flight Center (GSFC). Multi-mission tools are used to support operations, monitor the health and safety of the instrument, data processing pipeline and data distribution.



Daytime and nighttime temperatures

This past year the SOC supported instrument operations during the LRO Science Mission, which ran from September 16th 2010 through September 15th, 2011. During this time period the instrument collected science data continuously without any commanding errors or instrument anomalies with a greater than 98% data return. In addition to continuous nominal operations, the JPL uplink engineers supported monthly calibration activities and several special activities, such as a total lunar eclipse, and multiple observations of off-nadir targets. The JPL downlink team supported four Planetary Data System (PDS) archive deliveries ahead of schedule in addition to daily operations. The PDS deliveries included Diviner prelaunch calibration reports and data, and instrument specific SPICE kernels along with the nominal EDRs and Level 1B products.

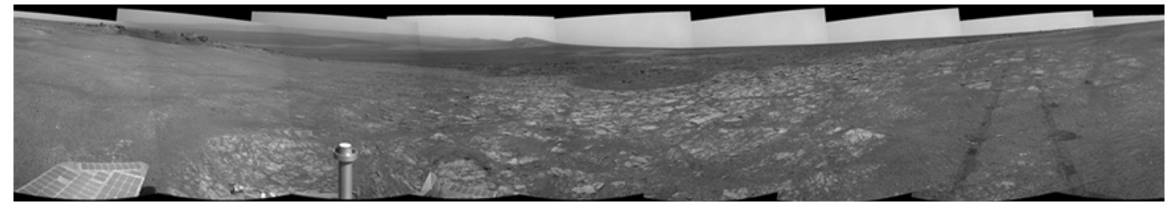
The JPL SOC receives DLRE data from Goddard and automatically sends it to monitoring, processing and distribution tools. The JPL SOC runs in a 24/7 lights dim automated environment producing EDRs, level 1A and level 1B products that are distributed to UCLA and Oxford. The JPL downlink team ensures all data has been received and distributed, manually processes files not supported by the automated pipeline and re-processes the Diviner dataset on a quarterly basis to ensure that a uniform dataset is delivered to PDS. During this past year the JPL downlink team interacted with the science team to improve the geometry and calibration algorithms that are used in the generation of the level 1B products. They also worked to improve the flexibility of the workflow manager software based on operations experience. Diviner planning tools are being developed to support increased Diviner off-nadir target observations in the LRO Science Mission.

Mars Exploration Rovers (MER)

FY 2011 has been both a somber and triumphant year for MER twin rovers. *Spirit* succumbed to the harsh Martian winter and was last heard from on March 22, 2010. Despite multiple recovery attempts to communicate with *Spirit*, no responses were received from her. The MER project ended all recovery efforts on May 25, 2011. *Opportunity*, on the other hand, after traveling more than 21.5 kilometers in a span of three Earth years, has arrived at Endeavour Crater.

Operational Missions

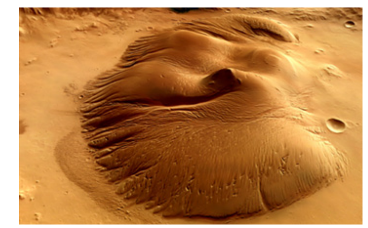
Opportunity, during her journey to Endeavour Crater, encountered an impact crater named Santa Maria. Santa Maria has a diameter of about 110 meters and a depth that varies from 11 meters to 17 meters a science team member solicited assistance from the MER/Multimission Image Processing Laboratory (MIPL) team in conducting a structural geology investigation at Santa Maria Crater. The request involved image processing to extract elevation information on the crater wall rock layers in order to determine their orientation. The MIPL team performs stereo analysis on data received from the rovers on a daily basis in order to make terrain models for use by rover planners and other members of the operations team. Constraints on MIPL's product generation imposed by the compressed tactical operations timeline require some tradeoffs between processing speed versus product quality. This task posted a challenge since the standard terrain data for the crater wall was too low in content and quality to perform good geologic analysis. MIPL personnel were able to re-tune parameters to their software and achieve significantly better results, at the expense of computation time, to successfully complete the task within the acceptable timeframe.



Panoramic view of Endeavour Crater acquired 2011 August 9.

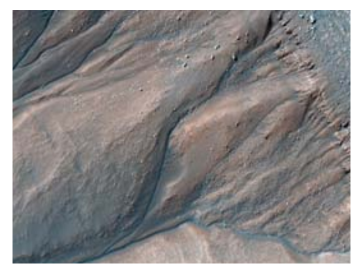
Mars Express (MEX)

The Division continued its operational support, processing and distribution of imaging data from the ESA Mars Express's (MEX) High Resolution Stereo Camera (HRSC) to the 8 U.S. Co-Investigators. MEX is in its 3rd extended mission. In addition to its primary science goal, the spacecraft serves as a communication relay for a number of NASA-lead landed missions including MER, Phoenix and MSL



False color image of the Nicholson Crater. Image Credit: ESA/DLR/FU Berlin (G. Neukum)

Mars Reconnaissance Orbiter (MRO)

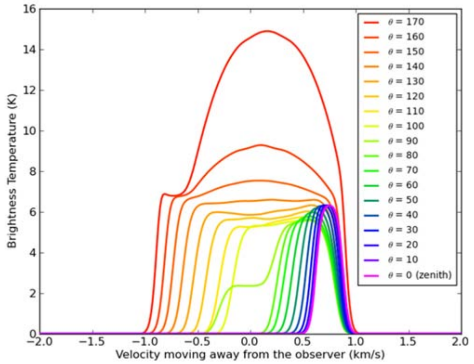


Bedrock layers exposed in the upper slope of an impact crater inside Kaiser Crater

The MRO Raw Science Data Server (RSDS) delivers science data products to nine (9) instrument and experiment teams. In FY 2009 RSDS distributed 109K products totaling 5.9 Tbytes of data bringing the mission total to almost 470K products containing 19 Tbytes. During the year MRO continued to return volumes of data of significant science value. In July 2010 HiRISE took this high resolution image of large sand dunes near the North Pole of Mars. The picture was taken in the summer, with only small patches of ice remaining at the surface: this showed up as bright, somewhat blue, spots on slopes that provide some shading from the sun.

Microwave Instrument on Rosetta Orbiter (MIRO)

MIRO is a microwave detector with two receivers, at 0.5 and 1.6 mm, capable of both continuum and spectroscopic observations. It was built at JPL and is one of 3 US instruments on ESA's Rosetta spacecraft, launched in 2004, with a goal to rendezvous with Comet 67P/Churyumov-Gerasimenko in mid-2014, which it is planned to orbit for over 1 year. On 8 June 2011, Rosetta went into "hibernation mode", in which all subsystems (including the data link to Earth) were switched off in order to conserve power; only heaters that will maintain the instruments at their minimal safe temperatures are still on. This is necessary because Rosetta relies on solar power only, and for the next three years it will be about 5 A.U. from the Sun, too far for the solar panels to supply enough energy for normal operations. It is scheduled to "wake up" from hibernation in early 2014.



During hibernation, the Rosetta project staff will be fully occupied developing plans for Comet operations. As part of this effort, the Division has developed a model of the comet nucleus and coma used to that predict the observations that MIRO will make there. The sample figure shows the changing shape of the H_2O spectral line that is one of MIRO's primary targets, as the view angle ranges from directly away from the nucleus (theta=0) to almost directly at the nucleus (theta=170), while the comet is at a distance of 2.5 A.U. from the Sun and the spacecraft is 100 km from the nucleus.

During FY 2011, the MIRO team also spent considerable time analyzing the observations made during the flyby of the asteroid (21) Lutetia in July 2010. A paper reporting these results has been submitted to Planetary and Space Science, which has been accepted on the condition of moderate revisions.

Lunar Mapping & Modeling Project (LMMP)

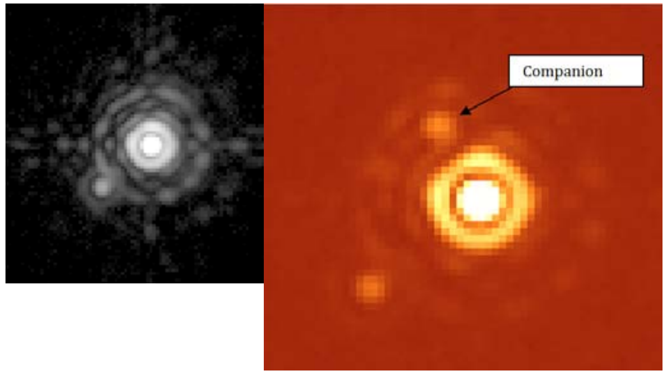
JPL continued to make significant contributions to the LMMP project in FY 2011. This year, Division 38 has made significant contributions to the LMMP information system's underlying infrastructure, including interoperable information systems, data management systems and tools, a single portal as well as mobile applications for access to the lunar map and model products. These products include maps and models generated from the Lunar Reconnaissance Orbiter, Lunar Crater Observation and Sensing Satellite, as well as other historical lunar missions). The Division We played a key role in leading and providing systems engineering and integration support to the project and made a successful delivery of public release of the infrastructure, portal along with iPhone, iPad, Android mobile applications to our customers.

LMMP Portal

Astrophysics

Palomar Adaptive Optics

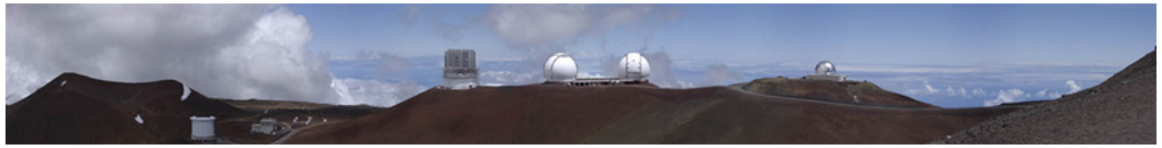
PALM3000 is an upgrade to the Palomar Adaptive Optics (PALAO) system which features a new 3388-actuator deformable mirror (DM) and GPU-based real-time software control at rates up to 2000Hz. It is a joint project between JPL and Caltech. This unique facility instrument has the densest actuator count on-sky of any existing or planned AO instrument. There are currently three science instruments working with the new system which take advantage of the exceptional wavefront correction either for high-contrast infrared imaging and spectroscopy or for visible spectroscopy.



(L) On-sky, 82% Ks Strehl
(R) Binary at 0.3" separation; Star reported to host an exoplanet; Paper in progress

The initial mode of PALM3000 was commissioned on-sky in March-August 2011 and was offered for shared-risk science beginning in the 2011b semester. The system has provided on-sky correction as high as 82% Strehl in K-band (156 nm residual wavefront error). There will be continued work this year on optimizing the system and adding sensing modes to improve sky coverage.

Keck Interferometer



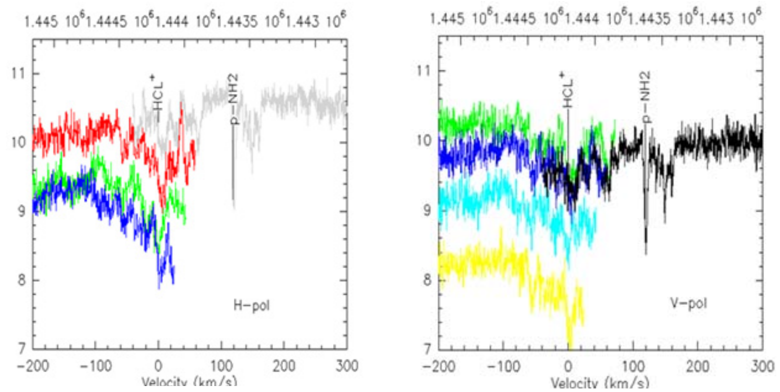
The Keck Interferometer (KI) combines the two 10m Keck telescopes on Mauna Kea, Hawaii, as a long-baseline infrared interferometer. It is a NASA-funded joint development among JPL, the W. M. Keck Observatory, and the NASA Exoplanet Science Institute (NExScI) at Caltech. It offers a number of observing modes available to the Keck community (Caltech, UC, NASA, UH, & NOAO) through the standard proposal process. These modes include standard visibility measurements at H (1.6 um), K (2.2 um), and L (3.8 um) bands; an R = 1700 self-phase-referenced visibility mode at K band; and an N band (10 um) nuller for measuring exozodiacal emission around nearby stars. The N band interferometric nuller and the L band visibility mode are unique capabilities of KI.

During the two observing semesters between August 2010 and July 2011, a total of 12 nights were awarded. The science topics included debris disks around nearby stars, circumstellar disks around young stars, and the centers of active galactic nuclei. Ten referencing papers were published in 2010 and the first half of 2011 based on KI observations. The most recent paper documents the results of one of the science programs of the exozodiacal dust key project carried out over 32 nights in 2008 and 2009. Of 25 nearby main-sequence stars in the sample, 22 were non-detections with an average one-sigma uncertainty of 160 zodis. These are the tightest limits achieved to date for this class of stars.

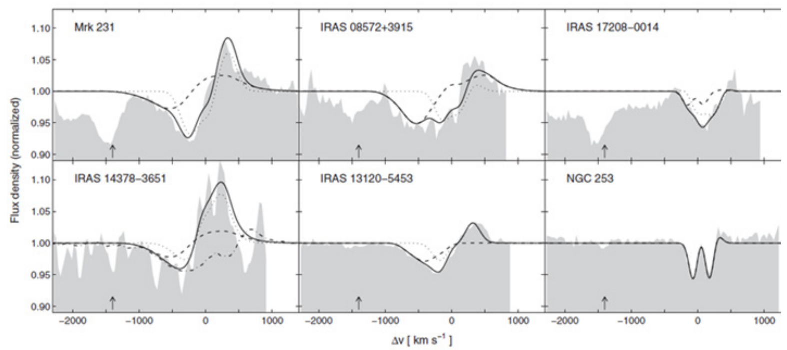
With NSF funding, Keck Observatory is leading a program to add additional capability to KI for phase referencing and astrometry. The self-phase-referenced mode for high spectral resolution listed above was developed under this program. The next modes, off-axis phase referencing and astrometry, are under development and being offered for shared risk observing in 2012.

Herschel Space Observatory

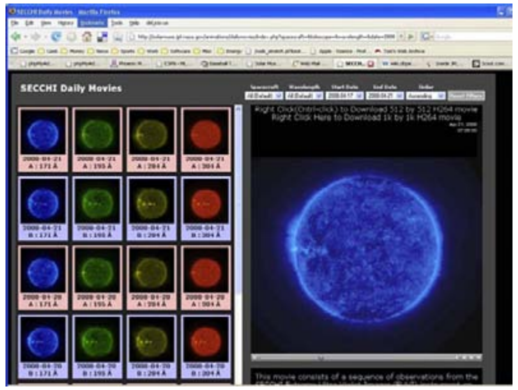
The Herschel Space Observatory (an ESA mission with NASA participation) performed routine science observations for all of FY 2011. There were surprisingly few observational difficulties with the largest one being single event upsets of various control computers. These rapidly diminished as solar activity increased suggesting extra solar origin of the problematic particles. The control computers on Herschel were surprisingly insensitive to the solar particle flux. The detectors produced at JPL for Heterodyne Instrument for the Fas-Infrared (HIFI) and Spectral and Photometric Imaging Receiver (SPIRE) continued to perform as designed. The last few regions of HIFI where the local oscillator produced spurious harmonics were successfully adjusted to be spectrally pure. Key science highlights included detection of water vapor in Saturn's rings by HIFI, detection of a new molecule, HCl+, in the diffuse interstellar medium and detection of water vapor from the outer reaches of a planetary debris disk. The last case infers that the outer part of a forming solar system is a large reservoir of water in ice, more than sufficient to explain the Earth's water. Another key measurement was determination of the D/H ratio of a previously unmeasured family of comets. It proved very close to the terrestrial abundance reopening the hypothesis that a comet(s) delivered water to the Earth. The Photodector Array Camera and Spectrometer (PACS) instrument discovered a feedback mechanism that regulates the star formation rate in merging starburst galaxies by ejecting large quantities (>1000 solar masses per year) of gas in a bipolar outflow from the galactic nucleus. This process is believed to result in elliptical galaxies with low star formation rates.



Spectrum of HCl+ absorption at 1444 GHz (from de Luca et al. submitted)



Spectrum of high velocity bipolar outflows in OH from ultra luminous infrared galaxies from Strum et al., 2011, ApJL 733, L16. This is believed to result in a quenching of the star formation rate.



Custom web page for heliophysics Image Products

Sun Earth Connection Coronal and Heliophysics Investigation (SECCHI)

Images and visualizations of solar activity from past Yohkoh, SOHO, and TRACE have captured the imagination of both the public and the scientific community. Images and videos from NASA current missions like STEREO and Solar Dynamics Observatory (SDO) are even more spectacular. STEREO provided the first three-dimensional (3D) images of our Sun. STEREO and SDO enabled us to see the structures of some of the largest features in the solar system. Using stereoscopic High Definition Video (HDTV) images, the human race has seen for the first time coronal activity (in EUV) and coronal mass ejections (CMEs) in 3D. SDO images the entire disc at the same resolution as TRACE; but at a much faster cadence, providing nearly continuous observations of the Sun and a scientific data rate well in excess of 100 Megabits per second. STEREO and SDO monitor the development and evolution of active regions on both the near side and far side of the Sun. They have enabled us to see "All of the Sun All of the Time" and build instantaneous global maps of the Sun for the first time These 3D and instantaneous global observations at high spatial and high temporal resolution will enable us to develop a new understanding of the physics that drives our local star and thus reveal to us a "New Views of the Heliosphere" and the 3D Dynamic Sun.

This year SECCHI focused on: 1) Creating "Daily Data Deliveries" to the Solar Museum Alliance (MUSE) web page. The deliveries were accessible to all MUSE partners and to 200 other members of the solar community; 2) Providing automated captions of all image and video products; 3) Providing "Daily Heliophysics Movies" (DHM) for all weekdays, using the heliophysics images on the server; 4) Providing the ability to create custom web pages, for all heliophysics image products on the SolarMUSE server, based on a keyword searchable MySQL FITS headers database.

Multi-Mission & Multi-Discipline Science Data Systems – Operations and Data Archive

AMMOS Instrument Operations System (IOS) /Multi-mission Image Processing Laboratory (MIPL)

The MGSS-IOS sponsored MIPL supports many flight or deep space operational missions, including some under development. Missions include: Cassini, LRO/Diviner, MER, MRO, Mars Express, SPITZER, Rosetta/MIRO, and Museum Alliance, all in operations; and JUNO and MSL under development.

The MIPL continues to successfully provide software and infrastructure in support of instrument data processing, production, and distribution of operational missions. In FY 2011, MIPL's stereo image processing and 3D mesh generation capabilities in support of tactical rover operations were adapted for use on MSL. The automated distributed data processing system was fine tuned to handle more data throughput. With its rich history of supporting Mars landers and rovers from *Viking* to *Pathfinder* and on through MSL, the MIPL continues to play an integral role for in-situ missions.

Preliminary work was done to set the framework for a 2-year modernization effort beginning next year that will migrate MIPL data and applications into web services. This effort will remove the existing burdens of file formats and expose existing software capabilities by providing a common framework for distribution, sharing, and analysis in support of science discovery. Prototype web client, iPhone, and iPad clients were developed to demonstrate upcoming capabilities and showcase to customers and sponsors the benefits of this direction.

The MIPL infrastructure continued to evolve, with replenishment and additions of higher performance and more energy efficient computing hardware, and updated third party software. Preparation began in FY 2011 for a FY 2012 transition of the current software configuration management tools to a set of more robust and integrated tools. Integration and test (I&T) further developed the testing strategy for Hyperspectral Image Interactive Holistic Analysis Tools (Hii-HAT) and for MSL, and completed testing for several software deliveries.

Planetary Data System (PDS) Engineering Node

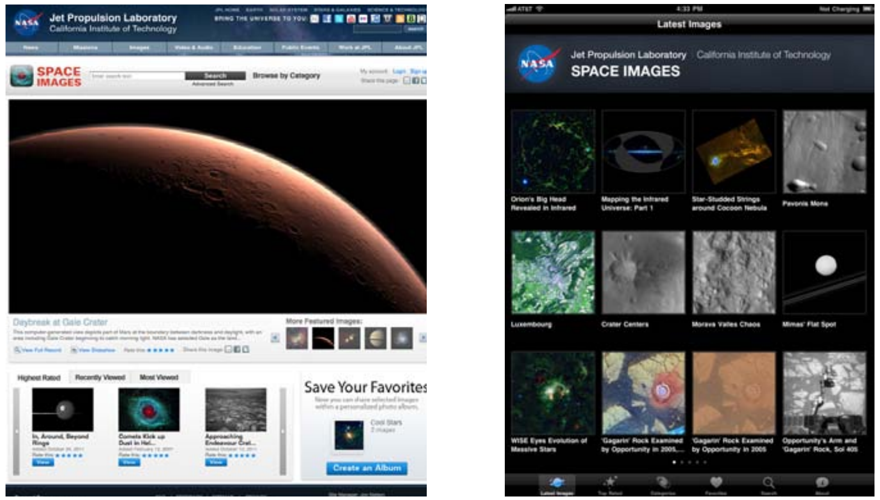
The Engineering Node (EN) continued to make significant contributions to the overall PDS data collection and archiving efforts for FY 2011. The EN completed a number of operational data and software deliveries. The EN has been instrumental in leading the upgrade of the PDS data system and standards to the next generation called "PDS4". PDS4 moves the data system into the era of Service Oriented Architectures integrating both the PDS and international partners into an era of sharing distributed data and software services. This year's focus has been on Build II of that system, scheduled for release in October 2011. The effort included the development of new information architecture along with a corresponding upgrade to the data standards that will be used by the MAVEN and LADEE missions. This build will include a release of the new system and data preparation tool suite. A solid transition plan has been established to ensure existing mission pipelines will not be impacted and the new system will support both current and new data standards (PDS3 and PDS4 respectively). A successful Build II system design review was held resulting in unanimous approval by an external review board. In addition, the EN was also instrumental in driving the International Planetary Data Alliance (IPDA) by successfully leading and completing multiple projects enabling adoption and international use of PDS standards and tools.

Planetary Data System (PDS) Imaging Node

Archive deliveries from operational missions to the Imaging Node in FY 2011 exceeded 138 TB. Quarterly deliveries continue for LRO, Chandrayyan-1, MER, Odyssey, MRO, Messenger, and Cassini. Next up is MSL–the process of archive design, product peer review and end-to-end testing is underway for launch and first delivery of products in early 2013.

The Photojournal and Planetary Image Atlas remain the Node's primary access and retrieval systems, with over 340 TB of data downloaded this year (nearly triple FY 2010, and six times FY 2009). Capabilities of the Photojournal, which provides highly processed, high-resolution images, and the Atlas, which provides access to the entire planetary image archive, continue to be expanded. The major focus for the Atlas this year was the ingestion of data products from the 7 active missions. In FY 2010, in addition to its traditional web interface for search and access, the Photojournal was modified to also serve as the backend database and data provider for the JPL iPhone "Space Images" app. This year, this backend support was also provided to an updated version of the iPhone app, as well as apps for iPad and Android, and a new "Space Images" website at JPL. All of these capabilities are powered by Photojournal.

Imaging Node personnel are actively engaged in the PDS-wide effort to upgrade the data system and standards to the next generation, or "PDS4". Our focus this year has been on Build II, scheduled for internal release in October and public release in early 2012. Data model activities, the main focus for this year, included the definition of imaging-specific keyword classes (Imaging Instrument Parameters, Telemetry, Cartography and Instrument Compression), and the development of Node-specific tools for migration of product labels from PDS3 to PDS4 (keyword finder, label generation, volume metrics). Node personnel also supported numerous data system design reviews and prototyping efforts.



PDS Portal

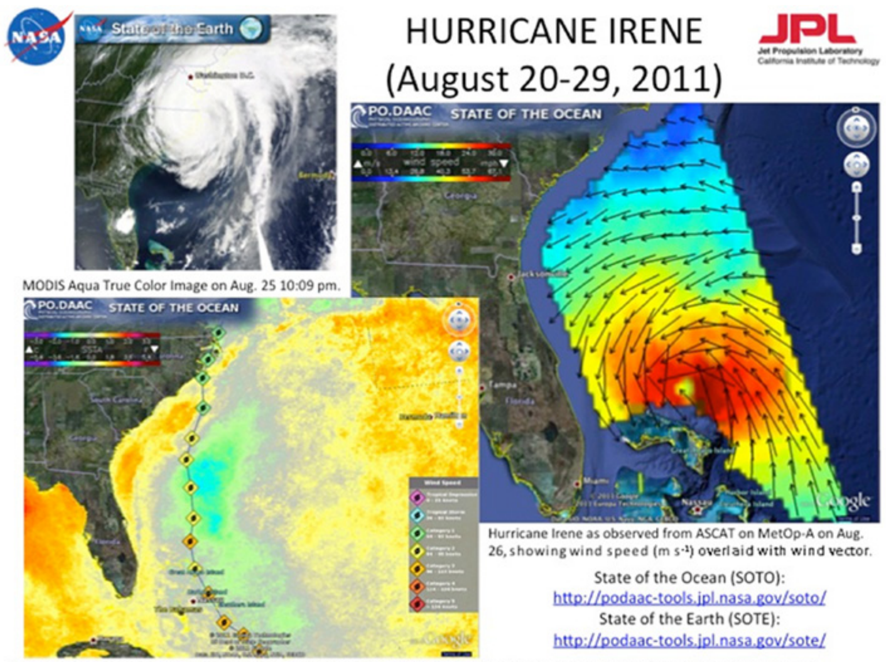
Physical Oceanography Distributed Active Archive Center (PO.DAAC)

PO.DAAC is NASA's data center for satellite physical oceanography. The project is chartered to archive NASA datasets for the benefit of future generations, provide data access services for a broad user community, and support scientific users in the understanding and utility of the data.

The highlights for FY 2011 include a new web portal http://podaac.jpl.nasa.gov that significantly improves how users discover datasets at PO.DAAC. The improved search engine that drives the portal was made possible by the introduction of a new data management and archive system (DMAS). DMAS was a multi-year development and deployment effort that maintains a comprehensive and complete catalog of the PO.DAAC data holdings. Several new data access tools were also rolled out: State of the Oceans provides visualization of near-real time ocean data; Dataminer and POET2.0 provide search and extraction of swath and gridded datasets. See http://podaac.jpl.nasa.gov/dataaccess for a complete list of PO.DAAC data access tools.

In support of Science, PO.DAAC released several important datasets, including a new merged altimeter dataset for sea-level rise studies, wind-climate data records, high-resolution coastal ocean datasets and Aquarius Level-2 data in support of cal/val activities. In support of the IPCC 5th Assessment Report, PO.DAAC collaborated with its partners to create sea surface temperature, ocean winds and ocean height climate data records that can be used to easily evaluate Global Climate Model outputs.

During FY 2011, PO.DAAC saw a 60% increase in volume of data distributed (to 180TB) and an increase of 10% in data users (to 25K). Web portal traffic increased by 5% to 48K unique visitors.



Sea surface temperature anomaly on Sept. 1, showing a ~2°C cooling to the left of Hurricane Irene's track several days after passage.

INSTRUMENTS & SCIENCE DATA SYSTEMS DIVISION

Technology

ANNUAL REPORT FY 2011

The Division actively develops instrument system technology for JPL's three main science themes of Astrophysics and Space Science, Earth Science, and Planetary Science, as well as related technology for other organizations. Our main instrument technology areas are:

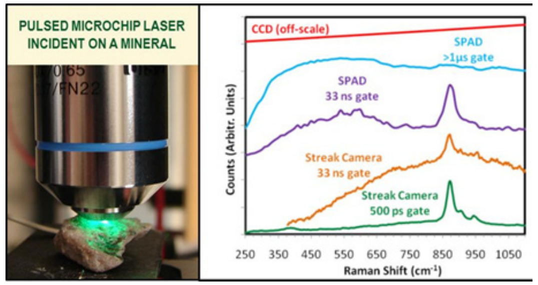
- Imaging and Spectrometer System Technology
- Semiconductor Devices
- Science Data Algorithm and System Technology
- Superconducting Device and Instrument Technology
- Heterodyne Instrument Technology
- Advanced Optical System Technology
- *In Situ* Instrument Technology

Imaging and Spectrometer System Technology

Next Generation Time Resolved Raman Spectrometers for Planetary Mineralogy

POC: Jordana Blacksberg

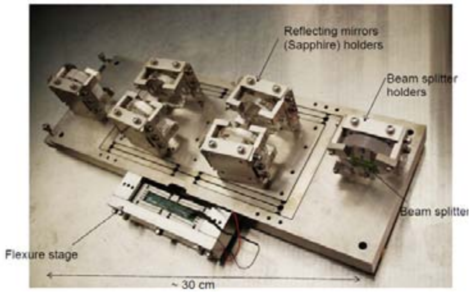
The Division is developing Raman instruments with a new time-resolved CMOS detector, a Single Photon Avalanche Diode (SPAD) array, which exploits the unique time scales of Raman scattering and fluorescence. This development, which allows separating the Raman and fluorescence responses, is particularly important since it offers a significant reduction in size, weight, power, and overall complexity, while providing enhanced science return. This unique technique also offers the possibility of simultaneously collecting microscopic laser induced breakdown spectra (LIBS), which provide complementary elemental information.



Raman spectra from the highly fluorescent mineral willemite illustrate the power of time-resolved Raman spectroscopy under the most extreme fluorescence conditions (green curve). Fluorescence obscures the spectrum without time resolution (red curve). The new solid state detector shows great promise with performance comparable to the more complex streak camera (purple curve).

Fourier Transform X-ray Reflectance (FTXR) Spectral Imager

POC: Jaroslava Wilcox



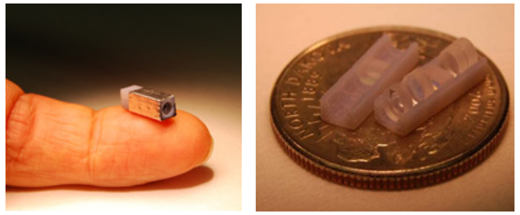
The FTXR interferometer

The Division, in collaboration with the University of Uppsala, has developed, and is testing, a novel miniature soft-x-ray spectral imager, in which an X-ray source, modulated by an interferometer, is reflected off the sample, forming an interferogram that is captured by a CCD detector. The instrument, which uses a unique beam-splitting mirror that meets the stringent vacuum ultraviolet (VUV) surface flatness requirements, adapts techniques from infrared Fourier Transform (FT) spectroscopy to the X-ray spectral region, with correspondingly increased spectral and spatial resolution.

Single Objective Miniature Stereo Camera

POC: Harish Manohara

In collaboration with the Skull Base Institute, the Division is developing a miniature stereo endoscope for neurological surgery and *in situ* planetary investigations. Images are formed with a single objective and two complementary multi bandpass filters (CMBFs). The objective, filters, and imager of 640x480 resolution, are integrated within a 4-mm diameter plastic housing. Figures show a fully assembled camera and opened housing with lens and CMBF train. When fully developed, this camera is expected to be <10 mm long and ~4-mm diameter, and to produce stereo images of (1080x1080) resolution.



The prototype 15-mm long assembled stereo endoscope (left). Endoscope lens arrangement (right). Each half of the endoscope housing contains one part of the CMBF assembly.

Semiconductor Devices

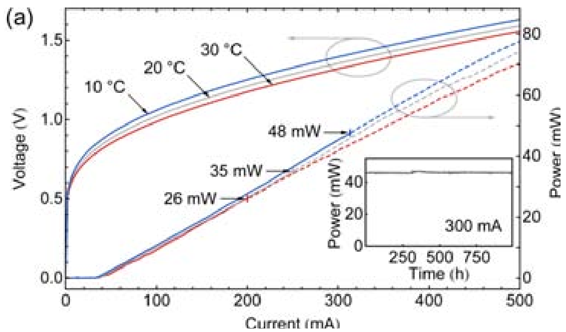
MegaPixel Camera Imagers

POC: Thomas Cunningham

The Division in collaboration with the Rochester Institute of Technology (RIT) and University of Rochester, have developed an ultra-compact, high-resolution camera with 100% fill factor, high efficiency, and low dark current. This is made possible by employing an ultra-thin, high-resolution back-illuminated CMOS imager and a unique capability for hybridizing the imager and readout array, which permits placing them in separate layers.

Semiconductor Laser Development

POC: Siamak Forouhar



CW light-current-voltage characteristics for a 2-mm-long LC-DFB laser operated at various heat-sink temperatures. The solid curves indicate the operating current range of single-mode emission, while the dashed lines are multimode emission. The inset shows laser output power at 300 mA over several hundred hours.

The Division has demonstrated high-performance, single-longitudinal-mode laterally coupled-distributed feedback (LC-DFB) lasers at 2.05 µm wavelength, with output of more than 80 mW of continuous wave (CW) power at -10 ^{O}C. This record performance is attributed to the high quality of the laser's epitaxial growth, device fabrication, and thermal management. These results are an important step toward realizing high-power, frequency-stable semiconductor seed lasers, which can significantly improve the simplicity and reliability of laser transmitters by replacing the solid-state light sources currently in use.

Infrared Sensor Technology

POC: Sarath Gunapala

Infrared image of an industrial facility taken from a HOT BIRD focal plane array. This picture shows the high modulation transfer function (or low pixel to pixel cross talk) of the FPA

The Center for Infrared Sensors develops infrared sensor technologies using heterostructures based on III-V compound semiconductors. Devices under development include, quantum well infrared photodetectors (QWIPs), superlattices, large area focal plane arrays and Barrier InfraRed Detectors (BIRDs). BIRDs have depletion layers only in the wide bandgap barrier material, so Generation-Recombination (G-R) dark current becomes diffusion limited and is nearly eliminated, allowing operating temperatures higher than those of homojunction photodiodes with no performance loss. BIRD VGA format focal planes grown on GaSb substrates with lattice matched InAsSb photo-sensitive layers and lattice-matched AlSbAs barrier layers have been developed, and have shown strong suppression of G-R currents at operating temperatures as high as 150K. This breakthrough development enables passively cooled high-performance infrared instruments for space-borne Earth and planetary science applications. Long-wave infrared antimonide superlattice focal plane arrays based on a complementary barrier infrared detector (CBIRD) design, have also been developed, and recently demonstrated as the first high performance ¼ VGA format LWIR CBIRD focal plane array, yielding a noise equivalent differential temperature of 18.6 mK at an operating temperature of 80K, with 300K background and f/2 cold-stop. These barrier photodetectors have the material robustness and manufacturability of III-V semiconductors, and promise performance superior to InSb and MCT detectors.

Thermopile Development - Demonstration of Large Area Detectors Suitable for Clouds and the Earth's Radiant Energy System (CERES) Measurement

POC: Matt Kenyon

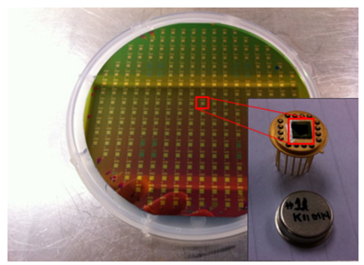


Image of 100 mm wafer of CERES-C prototype detectors.
Inset: Individual detectors were diced from the wafer and mounted into a detector package.

JPL has recently completed a wafer of broadband thermopile detectors, with an absorber area of 1.5x1.5 mm (see image), absorptivity > 90% between 0.3-50 um, a baseline noise equivalent power (NEP) below 7×10^{-9} W between 0.3-30 Hz bandwidth, a response time between 8-9 ms, a responsivity of 65 V/W, and a dynamic range of 0-60 μw. These detectors exceed all the requirements of CERES-C, a continuation of the ERBE/CERES climatological experiment.

Ultralow Leakage and High Quantum Efficiency Solar Blind UV Focal Plane Arrays

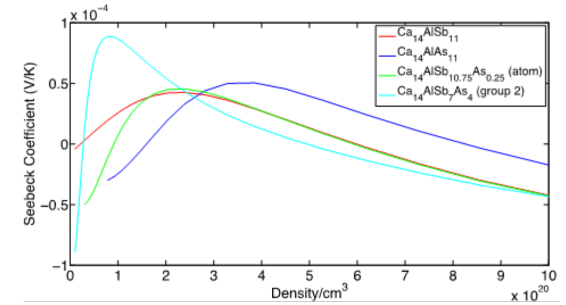
POC: Doug Bell and Shouleh Nikzad, JPL, Prof. Shadi Shahedipour-Sandvik, SUNY-Albany

JPL is developing GaN-based solar-blind UV Focal Plane Arrays. GaN and its alloys have a wide energy gap, so are intrinsically solar blind, more radiation tolerant, and can be operated at higher temperatures. Passivation by Atomic Layer Deposition (ALD), which deposits fine, precisely controlled films, is expected to provide better performance by drastically reducing dark current and enhancing stability. ALD can also be used to obtain negative electron affinity for photocathodes. This will enable solar-blind UV detection with high QE, and will not require that photocathodes be contained in sealed tubes.

Improving the Performance of Thermoelectric Materials

POC: Paul Von Allmen

Thermoelectric materials, which convert heat into electricity, are used in deep space missions for power generation. Our theoretical work aims at improving the efficiency of thermoelectric power conversion devices by using simulations to propose new materials for experimentalists to fabricate and test in the laboratory. In 2011, we have computed the Seebeck coefficient (which determines the thermoelectric figure of merit) for the 14-1-11 zintl materials Yb14MnSb11. By substituting some of the Sb atoms with As, we obtained a 60% increase in the Seebeck coefficient, which will lead to a 120% increase in the material efficiency if the electrical and thermal conductivities remain unchanged. If this material is successfully synthesized, our finding will lead to a significant improvement in thermoelectric power generation.

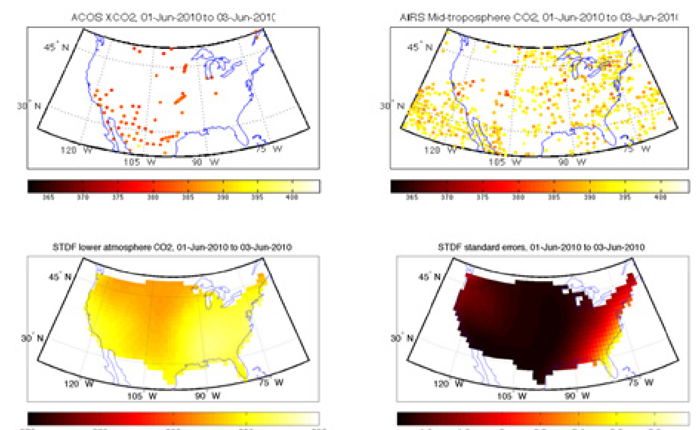


Computed Seebeck coefficient of new thermoelectric material. Note the increase of 60% percent (red curve and teal curve) obtained through partial substitution of Sb atoms with As atoms in the unit cell .

Science Data Algorithm and System Technology

Geostatistical Data Fusion for Remote Sensing Applications

POC: Amy Braverman



The top panels show ACOS and AIRS input data from for one representative three-day period in summer, 2010. The bottom panels show the STDF-estimated lower-atmosphere CO_2 derived by statistically smoothing and differencing the AIRS and ACOS observations (left) and the corresponding standard errors (right).

NASA's satellites carry multiple instruments that view the Earth at varying spatial resolutions and times and with different sampling characteristics and accuracies. To provide a rigorous basis for scientific investigation, JPL has developed the Spatio-temporal Data Fusion algorithm (STDF) for fusing these massive data sets to provide optimal estimates of the underlying fields of interest. STDF uses a hierarchical, spatio-temporal statistical model that relates the true, but not directly observed, fields of interest to actual observations, thereby providing a basis for estimating the underlying fields and calculating their associated uncertainties. STDF, which incorporates a computational breakthrough that processes massive data sets in linear time without making the restrictive assumptions required by other geostatistical approaches, achieves minimum uncertainty by exploiting both spatial and temporal correlations in the observations rather than making *ad hoc* assumptions about how a fused estimate at one location and time should be influenced by observations at nearby locations and times. STDF is currently being applied to data acquired by the Atmospheric Infrared Sounder (AIRS) mission and NASA's Atmospheric CO_2 Observations from Space (ACOS) project to estimate carbon dioxide in the lower atmosphere, an important quantity related to carbon flux that is not observed by any single remote sensing instrument.

Data Mining to Enable Intelligent Data Processing and Anomaly Exploration

POC: Lukas Mandrake

Machine learning and data mining techniques are being developed to create pre-filters to minimize undesired data artifacts and soundings unlikely to yield useful results. This is critically important as the OCO-2 and future Earth science missions will produce orders of magnitude more data than can reasonably be processed given current mission resources. Retrieval anomalies can be explored and related to correlating variables in a post-processing development environment to assist scientists in the rapid identification of algorithm flaws or unexpected data features. This approach can substantially reduce development cost in detecting and remediating performance issues.

Adaptive Data Processing for Fast Detection of Time-Varying Sources with Next-Generation Radio Arrays

POC: Kiri Wagstaff

New methods are being developed for large-scale real-time radio astronomy data analysis to detect novel astronomical radio phenomena. These include methods for adaptive event detection in the time-frequency domain, a single-pulse high-performance computing (HPC) search pipeline for extreme astronomical events, and novel pattern recognition techniques that reduce the computational costs of on-line matched filtering, all of which are being applied on the Very Long Baseline Array. Also included are new techniques to analyze astronomical light curves, including both the automatic estimation of missing data based on historical and instrument contexts, trainable light curve classification for triggering follow up measurements, and new cluster-based meta-level data mining methods for analyzing single-pulse detection logs.

Modeling Comets in Support of MIRO

POC: Paul Von Allmen

The ESA Rosetta spacecraft MIRO instrument will measure rotational lines for several isotopologues of water, CO and methanol. We are developing models that will enable deducing information about the composition of cometary nuclei from these spectra, thereby significantly improving our understanding of early solar system dynamics. A previously developed molecular-line radiative transfer model has been validated, and 3 new models have been developed that respectively provide the thermo-physical properties of the comet's nucleus, the diffusion of gas through its dust mantle, and the temperature and velocity distributions of gas in the coma.

CubeSat On-Board Processing Validation Experiment (COVE)

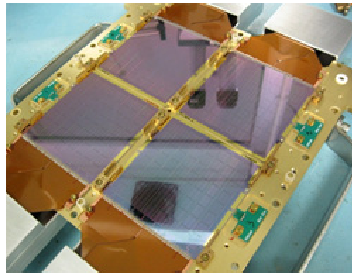
POC: Paula Pingree

COVE, which is integrated into the University of Michigan M-Cubed satellite, is JPL's first CubeSat payload. Its main objective is on-orbit demonstration of the MSPI (Multiangle SpectroPolarimetric Imager) data processing algorithm running on the RadHard Xilinx Virtex-5QV FPGA. COVE, which remains off for most of each orbit in order to conserve power, processes image data from an on-board camera and stores it in flash memory for later downlink to Earth. COVE is designed to allow for on-orbit reprogrammability, allowing its re-use for other experiments once the primary mission is complete. In addition to being the industry-first to fly the Virtex-5QV FPGA, COVE is also demonstrating the use of other advanced technologies, including Magnetoresistive Random Access Memory (MRAM), and Phase-Change Memory (PCM).

CubeSat board.

Superconducting Device and Instrument Technology

Transition Edge Sensors (TESs) for Cosmic Microwave Background (CMB) Detection



First 145GHz Science grade focal plane for the SPIDER balloon experiment

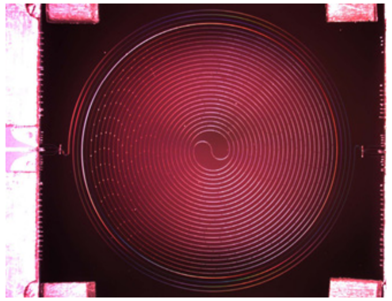
POC: James Bock, 326, with John Kovac, Harvard, Chao-Lin Kuo, Stanford, and William Jones, Princeton

JPL is leading a collaboration to develop instruments of unprecedented sensitivity for detecting a non-zero curl, or B mode, in the CMB polarization, one of the most important challenges in astrophysics. It will provide compelling evidence for cosmological superluminal inflation and gravitational waves. The work involves developing arrays of 1000s of superconducting Transition-Edge Sensors (TESs), which are being used in 3 major astrophysics projects: BICEP2 and Keck, both at the South Pole, and the SPIDER high-altitude balloon instrument, all with the same goal: generating detailed maps of the cosmic microwave background (CMB) polarization. BICEP2 has already been deployed. The final two focal plane arrays for the Keck CMB experiment have been completed, and will be used in the 2012 observation season. Two of the six SPIDER focal planes have been completed, with 4 more scheduled for delivery in late 2012.

Wideband Quantum Limited Amplifiers for the Microwave/mm-Wave Bands

POC: Peter Day with Jonas Zmuidzinas, Caltech

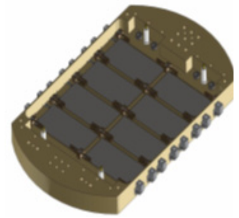
A recent JPL breakthrough in superconducting microwave frequency amplification demonstrated broadband gain in a parametric amplifier that is capable of reaching quantum-limited sensitivity. The amplifier, which achieved an average gain of 10 dB extending over 2 GHz on either side of a 11.5 GHz pump tone, is based on the interaction of a weak signal tone with the stronger pump tone in a nonlinear superconducting (NbTiN) transmission line that provides parametric gain and adds no noise beyond that imposed by quantum mechanics. This is a two order of magnitude bandwidth improvement over state-of-the-art parametric amplifiers based on Josephson junctions. Noise measurements indicate a noise temperature below 1 K, limited by the measurement apparatus. Applications include MKID and TES detector array readout, and the device physics allows for operation at frequencies potentially up to 1 THz. By providing a low noise gain element at millimeter and submillimeter wavelengths, the new amplifier could greatly improve the state-of-the-art of heterodyne receiver systems for these bands.



The traveling wave kinetic inductance parametric amplifier

JPL Developments for MUltiband Submillimeter Inductance Camera (MUSIC)

POC: Henry LeDuc with Sunil Golwala, Caltech and Jason Glenn, U. of Colorado, Boulder

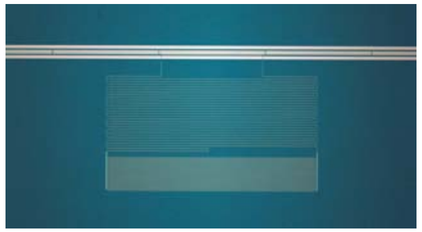


MUSIC focal plane model showing 8 tiles of 6x12 four-color pixels for a total of 2304 channels.

A Division 38 (JPL)/Caltech/University of Colorado consortium is developing MUSIC, scheduled for deployment early in 2012 at the Caltech Submillimeter Observatory. The focal plane comprises 8 identical sensor tiles, each with 6x12 pixel arrays simultaneously observing 4 bands (see image). The first run of devices has been fabricated, with fabrication of the full focal plane underway.

Low-Frequency Kinetic Inductance Detector Research

POC: Henry LeDuc



Low frequency KID resonator consisting of a superconducting NbTiN meandered inductor (top) and an interdigitated capacitor (bottom) coupled to a CPW feedline (running across the top).

Operating Kinetic Inductance Detectors (KIDs) at lower MHz frequencies, compared to the GHz frequencies of earlier work, is being explored as a means to increase the readout system's multiplexing factor and thus to enable higher pixel count arrays. Operating at lower frequencies translates the current high-speed readout electronics' absolute bandwidth to a higher fractional bandwidth, enabling packing more resonators of the same quality factor into the available bandwidth. In addition, the contribution of two-level-system noise is less important at lower readout frequencies, leading to an improvement in detector sensitivity.

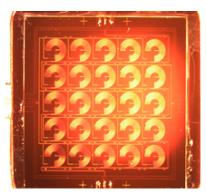
Superconducting Integrated Circuit for Advanced Computing

POC: Alan Kleinsasser

JPL is working with D-Wave Systems to advance Adiabatic Quantum Computation (AQC), which promises significant benefits in addressing difficult computational problems. D-Wave has achieved impressive results in mapping combinatorial optimization problems onto two-dimensional arrays of superconducting quantum interference devices (SQUIDs), exploiting quantum effects to achieve dramatic improvements in calculation speed and accuracy. JPL is prototyping new circuit concepts, supporting and advancing the D-Wave fabrication process, and addressing problems related to decoherence, power reduction, and device physics. This collaboration has significantly advanced JPL's superconductor processing capabilities.

Quantum Capacitance Detector

POC: Pierre Echternach

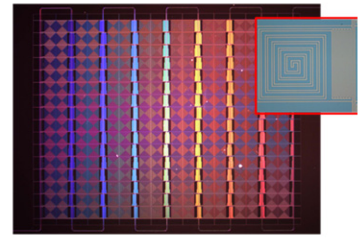


Optical microscope image of a QCD array

The quantum capacitance detector (QCD) is a new photodetector concept in which antenna-coupled radiation breaks Cooper pairs in a superconducting absorber and the then-unpaired electrons tunnel to a Single Cooper pair Box (SCB) embedded in a resonator. This changes the SCB's capacitance, and the resonator's resonant frequency, which is read out by RF techniques. QCDs combine the sensitivity of TESs and the simplified readout of MKIDs: arrays can be frequency multiplexed and read out with a single RF line and do not require biasing each individual pixel. A 5x5 array prototype has been demonstrated, achieving a noise equivalent power of $1x10^{-19} W/H_z^{1/2}$ when illuminated with 200µm radiation displayed a response.

Direct absorption Far-IR MKID arrays

POC: Henry LeDuc

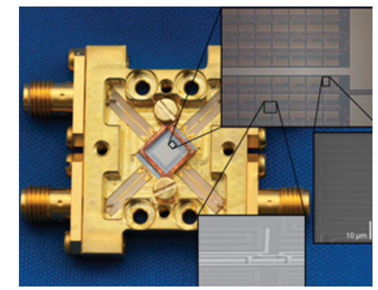


A 16x16 pixel FIR array based on TiN MKIDs. The inset shows a blowup of a single pixel featuring a spiral inductor/absorber and interdigitated capacitor.

16x16 FIR MKID arrays based on TiN and NbTiN demonstrated good detector parameter uniformity across the array. A 200 micron dual-polarization array using a spiral absorber design is shown. A major challenge was reducing the pixel-to-pixel electromagnetic coupling to improve uniformity. This was accomplished by reducing the electric dipole moment of the resonators. The response of the detector to blackbody radiation and the spectral noise were used to determine the sensitivity. The measured optical noise equivalent power (NEP) of these detectors is $2x10^{-16} W/H_z^{1/2}$, comparable to background limit for a ground-based instrument. This array will be the basis of a new demonstration instrument being assembled at Caltech.

NIR/Visible Photon Counting Detector Arrays

POC: Bruce Bumble with Ben Mazin, UCSB



TiN MKID array chip and micro-lens mounted in microwave coupler block.

Division 38, Caltech and UC Santa Barbara are developing ultraviolet, optical, and near-IR focal plane arrays based on Optical Lumped Element (OLE) Microwave Kinetic Inductance Detectors (MKIDs). The past year has seen dramatic progress, including fabricating 1024-pixel arrays with microlenses, improving uniformity sufficiently for science-grade observations, and achieving an energy resolution, E/DE, of 16. ARCONS, the ARray Camera for Optical to Near-infrared Spectrophotometer, was successfully commissioned at the Coudé focus of the Palomar 200" telescope on August 28, 2011.

Ultra Low Noise Detectors Demonstrated for the Background-Limited Infrared Sub-mm Spectrograph (BLISS)

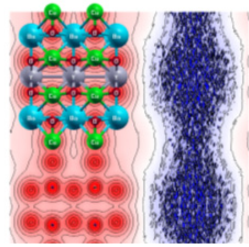
POC: Andrew Beyer, Caltech

The Background-Limited Infrared Sub-mm Spectrograph (BLISS) is an ultra-sensitive, broadband grating spectrometer for space-borne measurements at R ~500 from λ=35µm to 435µm. The superconducting transition edge detectors (TESs) in this instrument operate at T_c=65mK with a time domain SQUID multiplexer readout, with a goal NEP of $5\times10^{-20} W/H_z^{1/2}$. For noise reduction, BLISS optically chops the signal at 5Hz, which requires each TES to have response time $\tau\leq$30ms. Important steps toward achieving the goal NEP and τ included demonstrating Iridium TES (T_c=130mK) arrays with the SQUID MUX with an NEP=$2\times10^{-19} W/H_z^{1/2}$, tantalizingly close to the goal NEP.

Theory of high T_c Superconductors

POC: Paul Von Allmen

A silicon valley startup company, Ambature LLC, fabricated and tested a material that arguably holds promises for room temperature superconductivity. The material system consists of conventional $YBa_2Cu_3O_{7}$-δ material with a proprietary surface treatment. Ambature asked JPL to provide theoretical support that will improve the understanding of the experimental data and further improve the performance. In 2011, we have computed the bulk electronic structure of $YBa_2Cu_3O_7$ and $YBa_2Cu_3O_6$ using first principles methods. We have also started optimizing the positions of the surface atoms in preparation of the study of atomic adsorption processes. In a parallel effort, we are developing a mean-field theory to compute the superconducting properties of these materials.



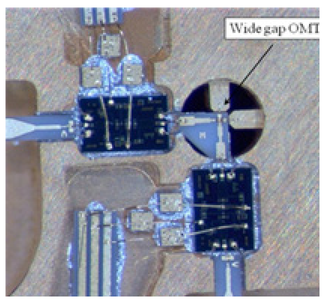
Charge density distribution for $YBa_2Cu_3O_7$ (100) surface.

Heterodyne Instrument Technology

Microwave Research

POC: Pekka Kangaslahti

The Division has developed sensitive room-temperature monolithic microwave integrated circuit (MMIC) low noise (~2-3 db) amplifiers for measuring atmospheric temperature and humidity profiles and characterizing the path delay error in ocean topography altimetry. Receivers using these amplifiers have made it possible to conduct highly accurate airborne measurement campaigns from the Global Hawk unmanned aerial vehicle, develop millimeter wave internally calibrated radiometers for altimeter radar path delay corrections, and build prototypes of large arrays of millimeter receivers for a geostationary interferometric sounder. A broadband single horn receiver front end that enables low noise receiving from 118 GHz to 183 GHz was also developed. This is especially beneficial for large interferometric sounding instruments that can now be integrated with only a single array of receivers for both temperature and humidity sounding.

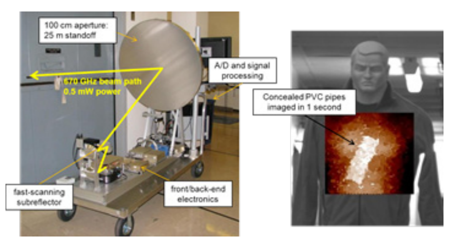


A single antenna receiver and OMT that operates from 118 GHz to 183 GHz

Terahertz (THz) Imaging Radar

POC: Ken Cooper

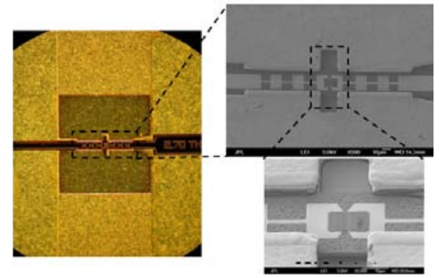
During the past year, the Division has increased the THz imaging radar frame rate five fold, packaged the system for shipping cross-country, and successfully delivered it to the US Navy for evaluation. The imaging rate speed-up required several enhancements, including a new fast-scanning subreflector design, a faster but still low-noise chirp waveform generator, and faster analog-to-digital conversion and signal processing. Real-time threat detection through clothing from 25 meter standoff ranges is now possible with frame rates of 1 Hz. JPL also demonstrated an original means of duplexing submillimeter transmit and receive beams by developing a 285 micron pitch grating cut into a flat aluminum reflector that converts linear to circularly polarized radiation at 670 GHz, achieving a nearly four-fold signal-to-noise improvement. This high-efficiency duplexing technique can be applied to millimeter- and submillimeter-wave radars in a variety of applications, including potential future Earth science missions.



Left: JPL's standoff THz imaging radar can now generate through-clothes imagery of concealed threats (right) in 1 second.

2.7 THz Hot Electron Bolometer (HEB) Receiver

POC: Jon Kawamura



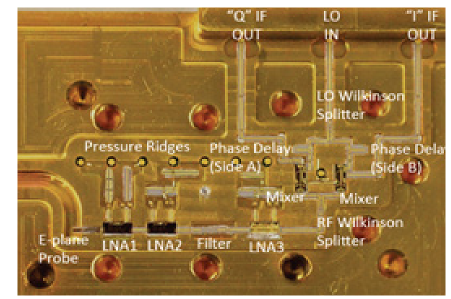
THz receiver waveguide mixer block.

Using conventional machining for large features and silicon micromachining for very small features, JPL has demonstrated a waveguide-based 2.7 THz mixer block which produced uncorrected double sideband (DSB) noise temperature of T_{rec} = 965K @ 2.74 THz, similar to the most sensitive mixers reported in this frequency range. The mixer was also successfully pumped with a solid state local oscillator (LO) at 2.54 THz with a measured a DSB noise temperature of 1350 K.

MMIC- Based Receiver Modules

POC: Lorene Samoska with Rohit Gawande, Rodrigo Reeves, and Kieran Cleary, Caltech

A Division 38 (JPL)-Caltech-Stanford collaboration has developed and tested a compact, scalable heterodyne amplifier module, based on Monolithic Millimeter-Wave Integrated Circuit (MMIC) InP HEMT Low Noise Amplifiers, for use in arrays of hundreds of elements for making spectroscopic measurements at 75-115 GHz. While a single amplifier module has a minimum noise of 25K, a MMIC heterodyne receiver module has achieved a noise temperature of 30K at 98 GHz. These results represent the lowest noise ever reported for a MMIC heterodyne receiver in W-Band.

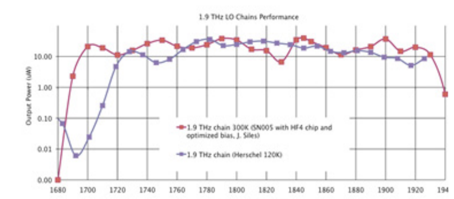


W-Band MMIC receiver module, having 30K noise when cooled to 20K. The module contains state-of-the-art InP 35 nm gate length HEMT LNAs fabricated at NGC.

Broadband Multiplied Sources for 1900 GHz

POC: Imran Mehdi

The Division is developing high-power 1900-2060 GHz local oscillator (LO) chains with the goal of developing a LO scheme that can successfully pump a 16 pixel receiver. Phase one is developing a LO chain that can put out more than 10 microwatts at room temperature, sufficient to pump a 4-pixel linear mixer array, and can be stacked to complete the 16-pixel receiver. Phase two is implementing a single waveguide circuit that includes the mixer as well as the last stage multiplier, which can be biased and will allow



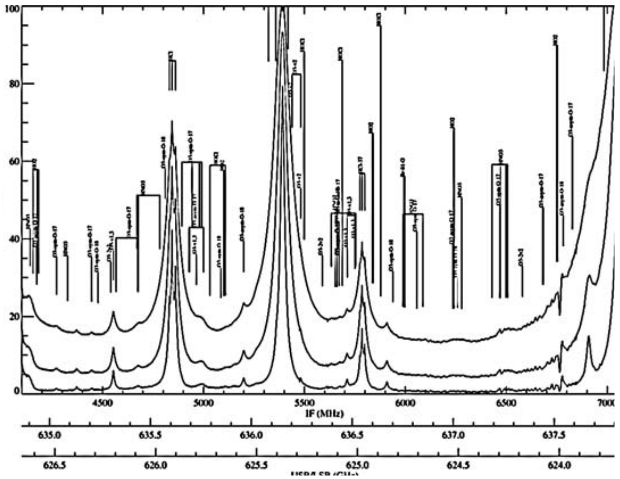
Measured LO performance of the HIFI chain (red) at 120 K and the recently fabricated high-power 1900 GHz chain (violet) at room temperature. The output power is expected to increase 3dB at 120K.

changing the power to each individual mixer element. Recent room temperature measurements of a 1900 GHz chain based on this scheme already show an improvement over the Herschel HIFI instrument.

Broad Band Digital Radiometers

POC: Robert Jarnot

The Division has developed an 8-tap, state-of-the-art, digital polyphase spectrometer with 3 GHz bandwidth and 8192 channels (366 kHz resolution). The spectrometer was recently flown on a high altitude balloon platform with a 600 GHz superconducting (SIS) receiver. Examples of the measurements are shown in the figure, illustrating the outstanding data quality at low atmospheric radiance levels, with none of the typical spectral artifacts observed with systems using previous generation analog spectrometers.



Advanced Optical System Technology

Technology Development for Exoplanet Missions (TDEM)

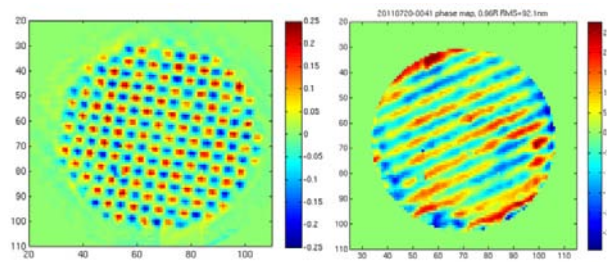
POC: Marie Levine

The TDEM effort develops the technology needed to find and characterize exoplanets. Two main instrument categories are under investigation: Internal Coronagraphs that reject the central star's light through occulting masks or apodization in the observatory and External Occulters that reject starlight by flying a 30m - 50m scale starshade at a distance of about 50,000 km in front of the observatory. State-of-the-art Coronagraphic starlight suppression using the hybrid Lyot masks of Dr. John Trauger (JPL) have now surpassed the performance of any previous starlight suppression instrument, achieving a reduction ratio of 5.2 × 10−10 with a bandwidth of 10%, just a factor of 2 away from that needed for imaging Earth-size exoplanets. Other JPL TDEM demonstrations including Phase-Induced Amplitude Apodization (PIAA) for PI Prof. Olivier Guyon of the University of Arizona, Speckle Sensing for PI Charley Noecker from Ball Aerospace, and External Occulter fabrication tolerance demonstration for PI Prof. Jeremy Kasdin of Princeton University (see, image) have also made significant advances.

Assembly of a full scale 30 m starshade petal. The work, which has demonstrated the fabrication tolerances required for imaging Earth-like planets, is being performed at JPL for TDEM PI Jeremy Kasdin of Princeton University.

Wavefront estimation to improve high contrast image quality for P1640 Project

POC: Gautam Vasisht



DM poking pattern on wavefront sensor for registration (unit = rad)

A sinusoidal wavefront measured by P1640 Calibrator (unit = nm)

The P1640 project, a smaller version of the southern hemisphere 's Gemini Planet Imager (GPI), is a joint effort between JPL, Caltech, and the American Museum of Natural History (AMNH) to use high-contrast images from the Palomar 5-meter Hale Telescope for detecting and observing self-illuminating Jupiter-size planets at infrared wavelengths. High contrast is achieved with a system comprising a coronagraph, the Palomar P3K adaptive optics (AO) system, and the JPL P1640 Calibrator, a post-coronagraph Interferometric sensor that ensures the quality of the wavefront entering the coronagraph. The P1640 Calibrator measures the residual wavefront error and feeds the information back to the AO system's Deformable Mirror (DM), which corrects the wavefront, reducing the brightness of speckles caused by wavefront errors. The figures show the registration between the DM actuators and the P1640 Calibrator camera frame (left) and an injected sinusoidal wavefront measured by the sensor (right).

Micro-Pixel Centroiding Technology

POC: Michael Shao

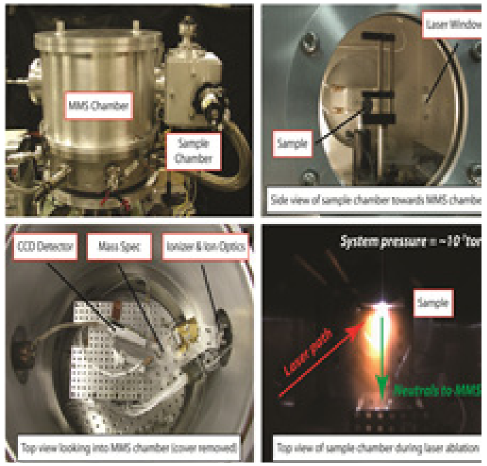
JPL is developing technology that uses a focal plane array to determine changes in image centroid position to micro-pixel precision. This key technology will enable precise astrometry with micro-arcsecond accuracy, and thus the detection of earth-like exoplanets using a 1-meter-class space telescope such as proposed for the Nearby Earth Astrometric Telescope (NEAT). Another application is accurate optical navigation using asteroids as references. Micro-pixel centroiding has two essential elements, sampling the image above the Nyquist frequency so the point spread function (PSF) can be reconstructed using the sampling theorem, and using laser metrology to characterize the focal plane pixel responses to compensate for systematic errors due to focal plane array thermal deformations.

In Situ Instrument Technology

Geochronology Instrument Development

POC: Wayne Zimmerman

The Division and Caltech have made significant progress in demonstrating the feasibility of the K-Ar age-dating protocol, demonstrating that Ar gas is released from silicate samples during low temperature flux-assisted melting, that Ar-isotopic composition can be measured during this fusion procedure, that quenching samples to a glass with a Li-borate matrix is straightforward, and that the resulting glass possesses equilibrated isotope and element ratios. This work has produced an age estimate for a sample of Parana basalt that is within 10% of its known age, and has demonstrated that the elemental composition and relevant isotopic ratios of samples can be reliably measured by the Laser Ablation Magnetic sector Mass Spectrometer LA-MMS), leading to the design of the first capable "small" field-portable geochronology instrument.

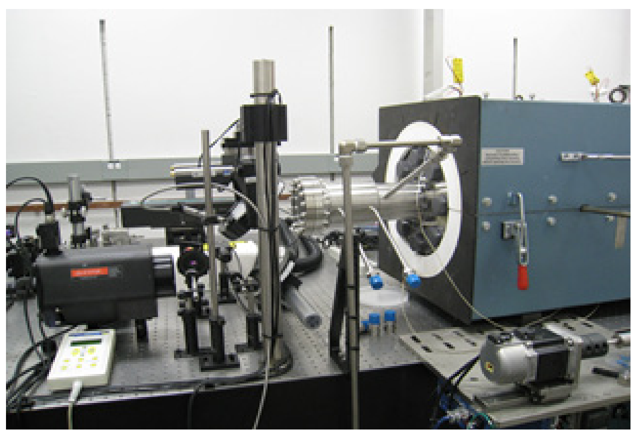


Mass spectrometer and associated recent spectra

Venus Testbed

POC: James Lambert

The Venus testbed is a unique facility that allows conducting optical experiments through a simulated Venusian atmosphere at Venus surface temperature and pressure (VTP). Sapphire windows, each with a 3.8" (97 mm) clear aperture, may be placed on one or both ends of the pressure chamber, enabling experiments involving reflected, backscattered, or transmitted light. A vacuum forechamber simulates the environment of a partially evacuated spacecraft in front of a sapphire viewport in order to minimize beam distortions due to conduction and convection, and a gimbaled mirror directs the focus of a collecting telescope to a 19-element sample holder to allow spectroscopic investigations of mineral or rock samples. The testbed, equipped with two pulsed Nd:YAG lasers with a suite of four spectrometers and synchronously gated CCD detectors, has demonstrated that reliable LIBS and Raman spectroscopy mineral measurements can be made under VTP conditions at the standoff distances expected during a landed mission. The testbed can also be configured to simulate low pressures, and is currently being used to explore the use of LIBS and Raman spectroscopy for quantitative mineralogy on primitive bodies such as icy moons, asteroids, and comets.


Venus Testbed

INSTRUMENTS & SCIENCE DATA SYSTEMS DIVISION

Publications

ANNUAL REPORT FY 2011

Publications:

Due to the large number of publications, this section contains only selected publications. To access the complete listing of over the 280 publications submitted by Division 38 staff during FY 2011, please visit **http://instrument.jpl.nasa.gov/**

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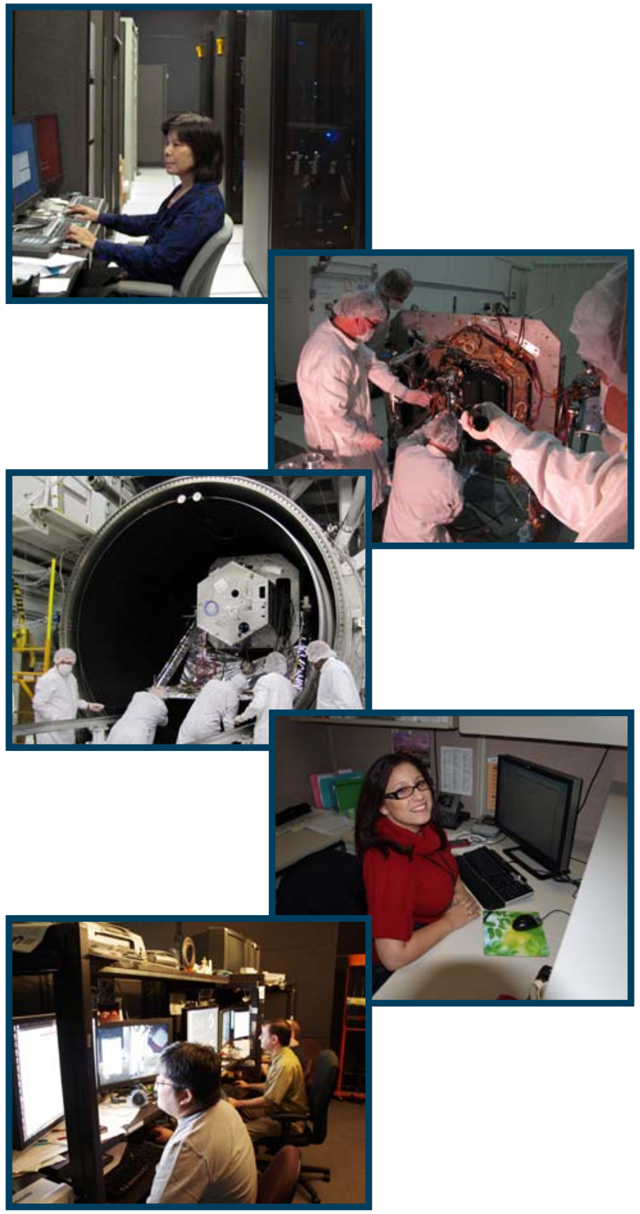
Publications:

Due to the large number of publications, this section contains only selected publications. To access the complete listing of over the 280 publications submitted by Division 38 staff during FY 2011, please visit **http://instrument.jpl.nasa.gov/**



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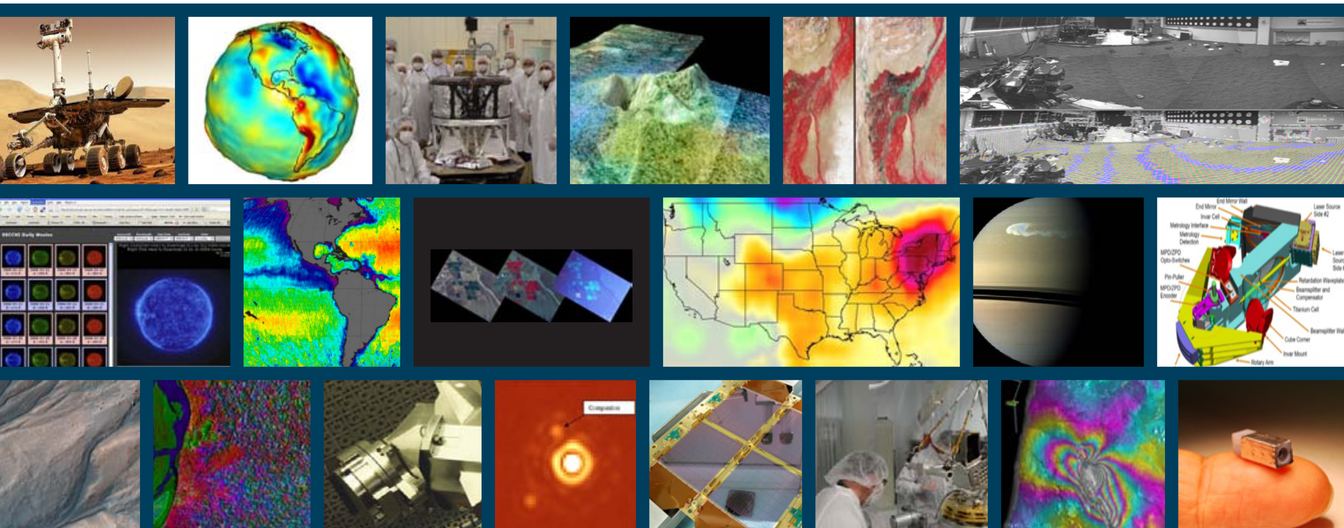

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