National Aeronautics and Space Administration

Instruments Division

Annual Report – FY 2013

Instruments

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Jet Propulsion Laboratory

Instruments Division

Annual Report – FY 2013

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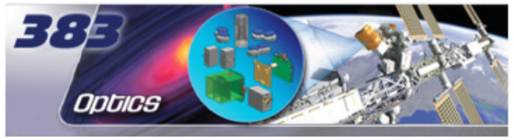

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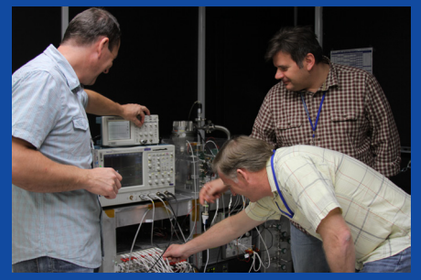

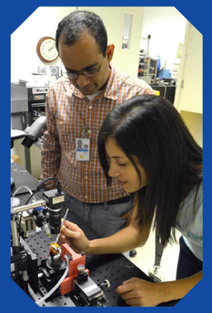

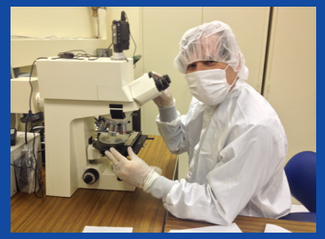

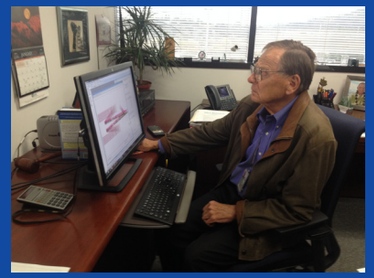

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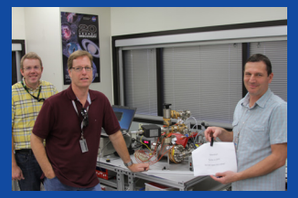
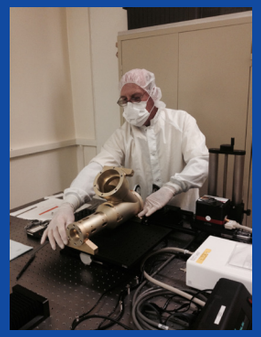




Instruments Division

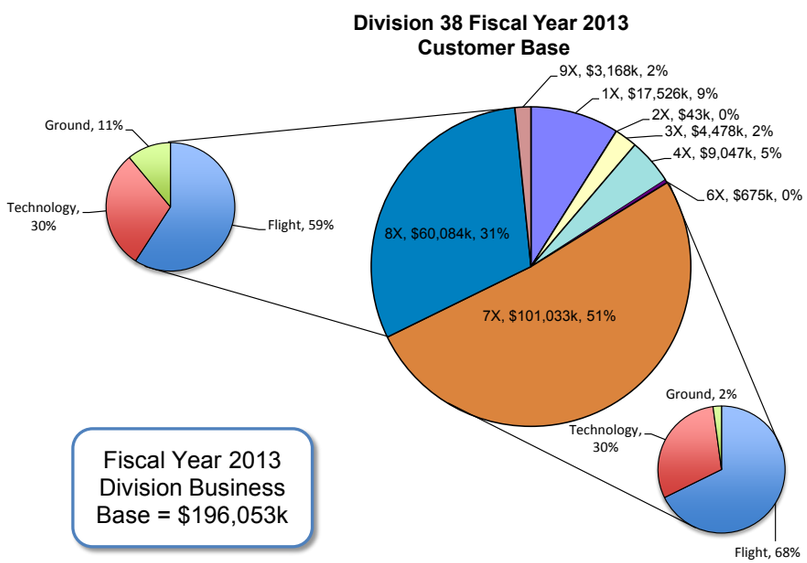
Year in Review

ANNUAL REPORT FY 2013

Year in Review

Fiscal year 2013 was another transitional year for the Division. The Engineering and Science Directorate changed direction from becoming more product-centric back to being essentially more discipline-centric. To that end, there were organizational changes that affected the Division. About one-half of the people who were added from the mechanical and thermal disciplines during fiscal year 2012 were transitioned back to the Mechanical Systems Division in fiscal year 2013. The remaining half were integrated into appropriate sections within the Division. The Division also transferred the Science Data Systems Section out of the Division to the newly formed Mission Systems and Operations Division. The Division was renamed as the Instruments Division and has retained end-to-end instrument development capability for instruments typical of planetary science. For larger instruments, typical of Earth Science and Astrophysics, the Instruments Division will collaborate with other Divisions within the Engineering and Science Directorate for their implementation. The Division has retained all of its advanced technology capability for sensors and instruments of all kinds.

There were two significant personnel changes in the management of the Division. Annette Larson, the Deputy Division Manager over the past nine years, moved on to assume a project leadership role for a new testbed development for the Laboratory. Dr. James Fanson was named the new Deputy Division Manager. Dr. Fanson brings to the Division a wealth of Project Implementation experience at all levels of system development. The business base for the Division correspondingly changed with the change in organization. As in previous years, the Division's primary customers were the Astronomy, Physics and Space Technology Directorate (7X) and the Earth Science Directorate (8X). The breakdown of flight implementation, technology development and operations-centered work changed significantly with the loss of the Science Data Systems Section the split being roughly 55-35-10, respectively.



Much as in the past, the Division continued to develop numerous instrument proposals over the course of the year. This is a trend that we expect to continue for the foreseeable future as instruments, both NASA and non-NASA alike, are and will continue to be selected through competitive processes.

Awards

This year once again we were pleased to see a number of people recognized for their achievements, as individuals and in teams, within JPL, NASA and external organizations.

Fellows

The JPL Fellow classification carries with it an exceptional and sustained history of distinguished leadership and outstanding achievements contributing to the Laboratory's historical stature. People who carry this distinction are highly influential and are expected to play a critical role in shaping and contributing to the future work of JPL. A JPL Fellow is recognized by peers as an authority in his/her field and by management through a history of challenging assignments and/or recognition that contributes to the Lab's internal and external image. This classification continues to be viewed by the Laboratory as the highest acknowledgement of professional achievement.

Tom Glavich's career at JPL spans more than three decades and has been dedicated to the advancement instrument implementation, helping to push JPL into a new dimension of competitiveness.

Just in the last decade, Tom has led the successful development of over $280M of diverse NASA instruments at JPL, each with its own set of technical challenges. Three of these instruments were Visible/IR spectrometers and were well aligned with Tom's technical background.

Tom Glavich

The Tropospheric Emission Spectrometer (TES), a Fourier Transform IR spectrometer, was a centerpiece instrument of the EOS Aura mission, managed by the Goddard Space Flight Center. The Moon Mineralogy Mapper (M^3), a Visible/IR Offner spectrometer, was delivered on cost and schedule to the Indian Chandrayaan-1 mission to the Moon, and exceeded expected performance in spite of unexpected spacecraft thermal challenges.

The Orbiting Carbon Observatory-2 instrument has been delivered to spacecraft integration and test, and this instrument also significantly exceeds the performance of the OCO-1 instrument and instrument performance requirements. A departure from the Visible/IR spectrometers, the CheMin instrument, which Tom was brought in to lead well after significant difficulties in its implementation were encountered, was an X-ray diffraction machine. Tom led this instrument team to a successful completion and this instrument is now functioning as one of the key science instruments on the Curiosity rover.

Tom has received NASA medals for his work on TES and M^3, has been nominated for his work on CheMin, and will be nominated for his work on OCO-2. Tom's contributions are not limited to NASA work. He was requested to step into a project in Building 126, to not only lend his expertise, but to bring credibility to

an important element of the project, and to address concerns of the sponsor. Through his experience developing science instruments, he is well known and respected within the science community as an expert instrument implementer. PIs both internal and external will request Tom by name for their particular proposed investigations. Tom's values reflect JPL's own values and his involvement with work outside of JPL reflects well on JPL. He is an excellent representative of the Laboratory in engineering and science communities alike.

Fellow of the Institute of Electrical and Electronics Engineers (IEEE)

Dr. Sarath Gunapala was elected a Fellow of the IEEE. The IEEE grade of Fellow is conferred by the IEEE Board of Directors upon a person with an outstanding record of accomplishments in any of the IEEE fields of interest. The total number selected in any one year cannot exceed one-tenth of one percent of the total voting membership. IEEE Fellow is the highest grade of membership and is recognized by the technical community as a prestigious honor and an important career achievement.

Sarath Gunapala

Pioneer in Medicine (Technology and Leadership) Award from SBMT (Society for Brain Mapping and Therapeutics)

Shouleh Nikzad was nominated and awarded by the Society for Brain Mapping and Therapeutics (SBMT). The award was presented at the May Annual Congress of the SBMT. Each year, several individuals are honored for their innovation and contributions. Shouleh Nikzad was recognized for leadership, for recognizing and bringing NASA technology into medicine, and for her work for developing ultraviolet imaging technology for non-invasive tumor delineation and bringing the technology to clinical trials. Shouleh was also invited to be a presenter and panelist at the US Congress by the Congressional Caucus on Brain Mapping along with prominent scientists and clinicians who are working toward brain health and in general medical practices. She presented "From Nebulae to Neurons: How NASA Technology Can Have an Impact on Neuroscience, Brain Mapping, Medicine and Healthcare." The event was on May 10, 2013.

Shouleh Nikzad

Distinguished Microwave Lecturer for the Institute of Electrical and Electronics Engineers (IEEE)

The IEEE's Microwave Theory and Techniques Society has selected Goutam Chattopadhyay as a Distinguished Microwave Lecturer. Each year, the society selects recognized experts in various fields from among its worldwide membership to be in its Distinguished Lecturers Program.

Goutam Chattopadhyay

NASA Honor Awards
Exceptional Achievement Medal

Robin English
For outstanding contributions to the design, build, test, and management of the NuSTAR instrument structure.

Thomas Glavich
For leadership on the development, flight delivery and operation of the CheMin instrument as part of the Analytical Laboratory on the Mars Science Laboratory.

Lauren DeFlores
For exceptional technical contributions and leadership in the validation, verification, and operations of the DAN and ChemCam instruments for the Mars Science Laboratory.

John Pearson
For exceptional technical contributions and leadership in the development and test of the Tunable Laser Spectrometer for the Mars Science Laboratory.

Exceptional Engineering Achievement Medal

Carl Liebe
For exceptional engineering achievement in the design, build, and test of the NuSTAR metrology subsystem.

Group Achievement Awards

Airborne Scanning Microwave Limb Sounder Team
Aquarius Science Calibration and Validation Team
ASDC Enhanced Data Access Team
Communication Architecture Research Team
Diviner Lunar Radiometer Science Mission Team
Information in a Photon Team
MSL APXS Instrument Development and Science Team
MSL Assembly, Test, and Launch Operations Team
MSL Avionics Subsystem Development Team
MSL ChemCam Instrument Development & Science Team
MSL CheMin Instrument Development and Science Team
MSL DAN Instrument Development and Science Team
MSL Guidance, Navigation and Control System Team
MSL Mastcam, MAHLI and MARDI Instruments Team
MSL Mechanical Team
MSL Motor Control Team
MSL Payload System Management Team
MSL Project Operations Team
MSL Relay Operations Team
MSL Reliability and Environmental Assurance Team
MSL SA/SPaH Subsystem Development Team
MSL SAM Instrument Development and Science Team
MSL Science Office Development and Operations Team
MSL Simulation and Support Equipment Team
MSL Surface Sampling and Science Systems Team
MSL Surface Systems Engineering Team
MSL Testbed & Simulation Support Equipment Team
MSL Thermal Subsystem Team
NuSTAR Instrument Team
Planetary Geophysical Exploration Testbed Team
Prime Contract Negotiations Team
PRISM Instrument Team
SMAPVEX12 Field Campaign Team
Student and Faculty Programs Team
UCIS Instrument Team

Year in Review

Microdevices Laboratory (MDL)

POC: Siamak Forouhar

The Jet Propulsion Laboratory's Microdevices Laboratory (MDL) is an institutional facility that provides unique research, development, and delivery capabilities. Since its founding in the late 1980s, work at the MDL has focused on innovative, high-payoff concepts with potential applications in future space missions. These include flight-qualified devices that have enabled a wide variety of instruments and missions in Earth science, planetary exploration, and astrophysics. MDL is chartered to enable new and better instruments and mission capabilities for innovative NASA and Department of Defense (DoD) Space Missions and to enhance U.S. competitiveness worldwide.

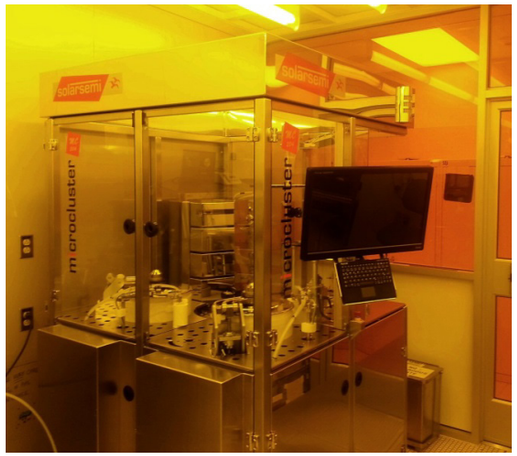
MDL micro- and nano-fabrication processes need sophisticated, state-of-the-art equipment for depositing, patterning, and etching of micro- and nano-structures to enable the fabrication of a variety of devices. As such, MDL houses tools for optical and electron-beam lithography, epitaxial growth of materials, thin-film deposition, wet and dry etching, thermal processing, as well as structural, electronic, and optical characterization. MDL processes not only silicon, but also gallium arsenide and superconducting materials in a wide variety of wafer diameters and thicknesses.

MDL Facility

To maintain the state-of-the-art capabilities and effective operations, MDL facilities require continuous upkeep and investment. MDL has benefited significantly from JPL institutional support to sustain its central processing capabilities and capital investment in new equipment. For example, the capability of creating novel deep analog surface profiles in silicon was significantly enhanced through the acquisition of a Plasmatherm Versaline VLN-LL-DSE Deep Silicon Etcher / Deep Trench Reactive Ion Etcher (DSE/DRIE) in 2013. This capability not only supports existing development efforts for micromachined gyroscopic angular motion detectors for avionic applications and detectors for submillimeter and millimeter-wave detectors for astrophysics, but will also play a significant role in the development of microthruster technologies for miniature satellites (CubeSats).

Plasmatherm Versaline Deep Silicon Etcher / Deep Trench Reactive Ion Etcher

Other 2013 investments in MDL equipment include a SolarSemi MC204 Microcluster Spin Coating System; two Solitec 5110C manual photoresist spinners, a Semitool 870S Dual Spin Rinser Dryer, an MO Exposure Optics upgrade to an existing Suss MA6 Mask Aligner, an upgrade to an existing Veeco Wyko NT9300 Optical Profiler, and a Frontier Semiconductor FSM 128-NT (200 mm) Manual Film Stress and Wafer Bow Mapping System.



SolarSemi MC204 Microcluster Spin Coating System

INSTRUMENTS DIVISION

Advanced Development

ANNUAL REPORT FY 2013

Formulation: Planting the Seeds for Future Instruments and Science Investigations

POC: Robert Staehle

Formulation of new instruments and science investigations was intense during fiscal year 2013, spanning Solar System and Mars exploration, Earth science, astrophysics, space & heliophysics, and non-NASA opportunities. All the Division's larger proposals represented collaborations with other divisions of JPL, universities, and/or other NASA Centers.

While Division-supported instruments operate today on the way to Jupiter, on Mars, around Earth, around our Moon, and aboard aircraft, new ideas are continually offered for our involvement from outside and within the Division. A variety of instrument concepts, ranging from x-ray to microwave wavelengths have been developed and supported at the heart of science, exploration, and civilian applications proposals throughout the year.

Much of the Division's focus is on smaller size, lower power, higher computational capability, inheritance, and other approaches to reducing development time and cost. While larger projects remain front and center, as of the end of fiscal year 2013, JPL is responsible for all or part of ten funded CubeSat-based projects, of which the Division is involved significantly in seven*. Most are undertaken in partnership with at least one university, small business, and/or NASA Center.

- CubeSat Onboard Processor Validation Experiment (COVE-2)*
- Low-Mass Radio Science Transponder (LMRST)
- Intelligent Payload Experiment (IPEX)*
- GEOstationary Coastal and Air Pollution Events (GEO-CAPE) Read Out Integrated Circuit (ROIC) In-Flight Experiment (GRIFEX)*
- Integrated Solar Array and Reflectarray Antenna (ISARA)
- Interplanetary NanoSpacecraft Pathfinder In Relevant Environment (INSPIRE)*
- Radiometer Atmospheric CubeSat Experiment (RACE)*
- CubeSat VHF transmitter to study Ionospheric dispersion of Radio Pulses (CHIRP)
- Lunar Flashlight*
- Near-Earth Asteroid Scoutsat*

Major proposal efforts have been mounted for Earth-observing instruments, airborne science campaigns, and Mars surface science investigations. The Division is involved in five Instrument Concepts for Europa Exploration (ICEE) technology maturation tasks selected under NASA's Research Opportunities for Space and Earth Sciences (ROSES) program. Other funded development activities include those selected under Maturation of Instruments for Solar System Exploration (MatISSE), Instrument Incubator Program (IIP), JPL's Research and Technology Development (R&TD), Strategic University Research Partnerships (SURP), and others. Each of these offers the potential to feed into new capabilities for future instruments for one or more of the Division's customers.

We look forward to working with a variety of new and existing partners throughout the next fiscal year and beyond to identify new opportunities and mature existing ones.

Advanced Development

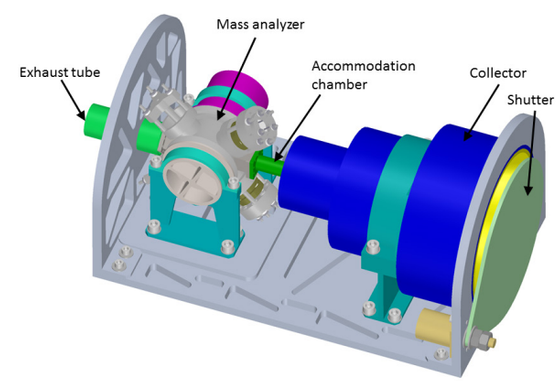
Mass Analyzer for Real-time Investigation of Neutrals at Europa (MARINE)

PI: Murray Darrach

The Division 38 mass spectrometer group's proposal to the NASA Instrument Concepts for Europa Exploration was successfully awarded for the Mass Analyzer for Real-time Investigation of Neutrals at Europa (MARINE) instrument. The goal of this work is to mature the MARINE instrument to the point where it can credibly be proposed for the Europa Clipper Announcement of Opportunity (AO). MARINE uses a Quadrupole Ion Trap Mass Spectrometer (QIT-MS) to achieve an unsurpassed combination of low mass, low power, ultra-high sensitivity, and ultra-high precision, a precision 10 times better than has previously been demonstrated using an ion trap mass spectrometer.

MARINE is capable of not only measuring the abundances of neutral particle species in Europa's exosphere, including H_2O, OH, O_2, CO_2, and SO_2, but also determining their number density profiles at per-second sampling rates as a function of altitude above Europa's surface. The instrument would either detect tracers of potential subsurface biological activity in Europa's exosphere, or place upper limits on their surface abundances. It exceeds all science traceability matrix requirements for the Neutral Mass Spectrometer (NMS) instrument on the Europa Clipper strawman payload while remaining fully compatible with NMS spacecraft accommodation constraints for mass, power, data volume, and field-of-view.

Although MARINE is a new tool for planetary exploration, its core QIT-MS has been under development at JPL over the last decade, and operated successfully on the International Space Station from June 2010 through September 2012 as the main component of the Vehicle Cabin Atmospheric Monitor (VCAM) instrument. The VCAM QIT-MS met all requirements with margin, and exceeded its required 1-year lifetime by over 100%.

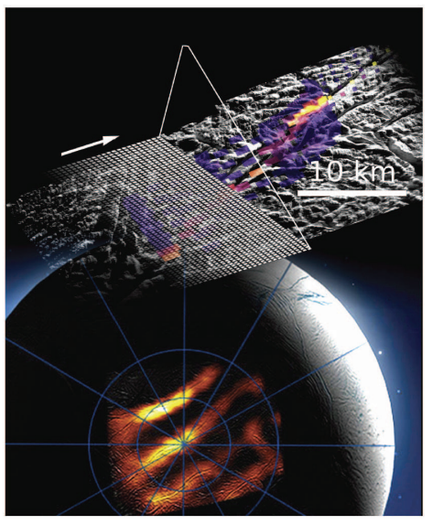


The boom-mounted MARINE sensor head uses a collector to funnel neutrals into an ultra-sensitive Quadrupole Ion Trap Mass Spectrometer. A Remote Electronics Module mounted to the sensor head (not shown) connects to the Mass Spectrometer Instrument Electronics in the science payload electronics chassis.

Development of Large Format Rad-Hard Focal Plane Array & Readout Integrated Circuit (ROIC) for Thermal Radiometer

PI: Matt Kenyon
CoI: Steve Gaalema,
Black Forest Engineering

The Instrument Concepts for Europa Exploration (ICEE) NASA grant focuses on maturing the focal plane technology for the Diviner Europa Radiometer (a multi-spectral, high-spatial resolution radiometer concept designed to fly on Europa Clipper). The plan is to adapt JPL's state-of-the-art thermopile arrays and Black Forest Engineering's readout integrated circuit chips, which are currently flying on Mars Climate Sounder and Diviner, to make them suitable for Europa Clipper. Specifically, this award would fund the development of new larger-format thermopile arrays with smaller pixels and radiation-hardened ROICs to minimize the risk associated with flying Diviner to Europa.



Diviner Europa's spatial coverage and resolution at 200 km range (inset) will enable detailed mapping of thermal anomalies orders of magnitude weaker than the enigmatic and exciting "tiger stripe" endogenic heat source regions seen near the south pole of Enceladus using Cassini's CIRS instrument.

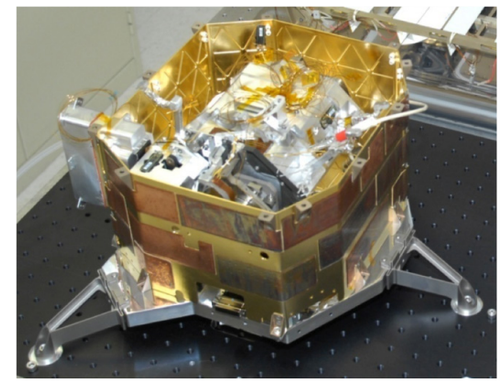
The Diviner Europa radiometer would provide unique and complementary datasets critical to accomplishing the goals of the Europa Clipper science and reconnaissance missions: (i) explore Europa to investigate its habitability, and (ii) collect the precursor data from which to design a lander mission to Europa and to select a safe and scientifically compelling landing site. Diviner Europa would address these goals by investigating the heat-flow anomalies along recently active features (e.g. lineae, chaos) (see figure), physical properties of the surface, surface radiative balance, and surface composition.

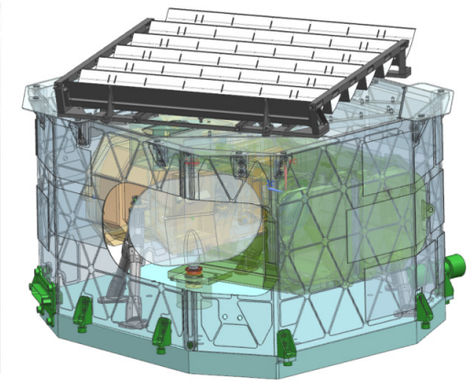
Europa Short Wavelength InfraRed Spectrometer (ESWIRS)

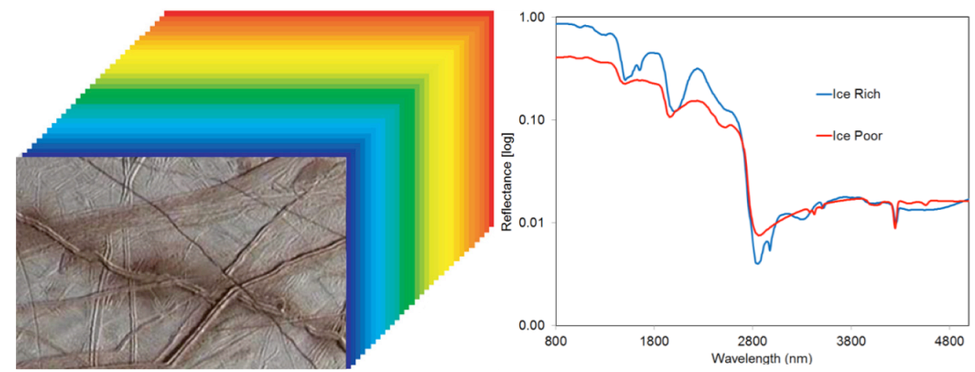
POC: Robert Green

Spectroscopic and imaging capabilities of an imaging spectrometer are required for compositional measurements and mapping contributions to Europa exploration science, as described in the Planetary Science Decadal Survey (Squyres et al. 2011) and Europa Summer Study Final Report, 2013. The Europa Short Wavelength InfraRed Spectrometer (ESWIRS) radiation and planetary protection maturation proposal has been selected as part of the NASA Instrument Concepts for Europa Exploration (ICEE) Program.

Led by Robert O. Green, this activity draws upon unmatched space heritage from the JPL Moon Mineralogy Mapper (M^3) and the APL Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instruments. This effort would (1) deliver a developmental model of the ESWIRS spectrometer; (2) provide an understanding of the impact of radiation on ESWIRS spectra through test and analysis, and update the instrument radiation tools and models; (3) develop and test on-instrument data radiation mitigation, processing, and compression algorithms; (4) develop and test the key element of the ESWIRS along-track scan mirror subsystem; (5) planetary protection process the ESWIRS development model instrument; (6) update the ESWIRS instrument concept and provide a detailed spacecraft accommodation assessment. The figure depicts elements of heritage, current instrument concept, and future measurements delivered by an ESWIRS-type instrument at Europa. The outcome of this work would be a mature and refined ESWIRS instrument concept that could be successfully developed for a future Europa mission to achieve high-priority NASA science objectives.







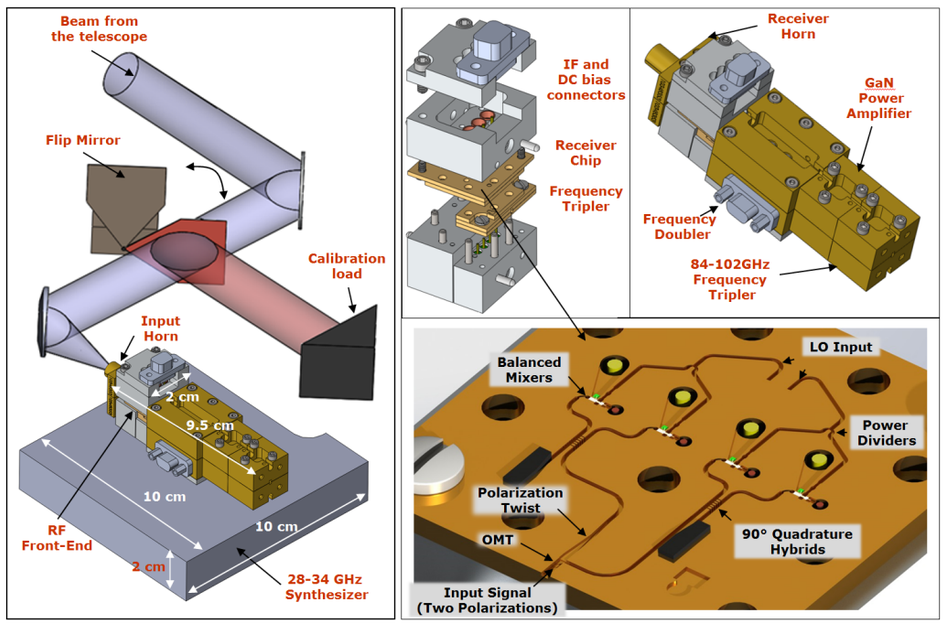
Moon Mineralogy Mapper heritage instrument (upper left), ESWIRS instrument concept (upper right), simulated Europa image cube (lower left), and example model-generated spectra (lower right) of the type that would be delivered by ESWIRS on a future Europa mission to achieve high-priority NASA science objectives.

Planetary Instrument for Submillimeter-wave Surface and Atmospheric Reconnaissance and Research in Orbit (PISSARRO)

PI: Goutam Chattopadhyay

Using newly developed silicon micromachining technology that enables a low-mass and highly integrated receiver, the Planetary Instrument for Submillimeter-wave Surface and Atmospheric Reconnaissance and Research in Orbit (PISSARRO) would provide a state-of-the-art submillimeter-wave radiometer/spectrometer instrument at TRL-6, for planetary orbiter missions to Mars, Venus, Titan, and the Galilean satellites. PISSARO's flexible receiver architecture provides a powerful instrument capability in a compact package weighing less than 7 kg, requiring less than 21 watts, and offering unprecedented sensitivity, spectral coverage, and scalability to meet the scientific requirements of multiple missions. PISSARRO would allow a large number of chemical species, such as water, NO_2, N_2O, NH_3, SO_2, H_2S, CH_4, and HCN, among others, in the atmospheres of Mars, Venus, and Titan to be detected at concentrations below a part per billion.

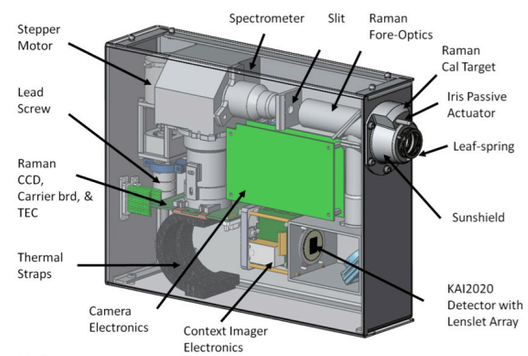
PISSARRO would be a flight-like prototype of a submillimeter-wave combined radiometric and spectroscopic sounder, featuring a dual-polarized, sideband-separating, and balanced-mixer receiver backed by a high-speed digital spectrum analyzer. In exploring planets and their moons from orbit, PISSARRO would gather data on the thermal structure, dynamics and composition of planetary atmospheres and surfaces. The radiometer part of the instrument would measure the polarized thermal emission that encodes key thermophysical properties, such as planetary surface's dielectric constant and temperature, revealing aspects of its chemical composition and physical state. The spectrometer part of the instrument would investigate the sources and sinks of trace gases on Mars and Venus and globally characterize the Martian and Venusian atmospheres with the high spectral, spatial, and temporal resolution that is uniquely available through submillimeter-wave spectroscopy. It would also measure wind speeds, temperature, pressure, and key constituent concentrations in the planetary atmospheres with a higher precision than any other available technology.



Schematic of the instrument concept showing the optical path from the telescope to the front-end receiver (left). Silicon micro-machined integrated front-end components in a low-mass package (right-top). Details of the micro-machined components in the silicon wafer (right-bottom).

Compact Integrated Raman Spectrometer (CIRS)

POC: James Lambert



CIRS

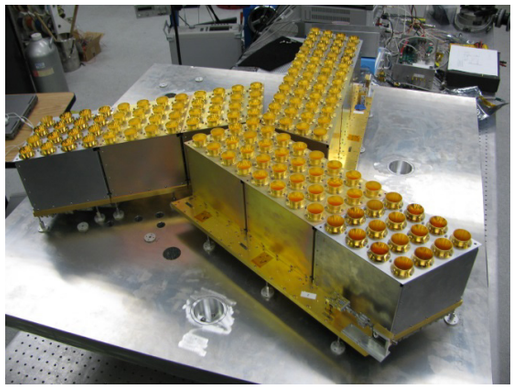
The Compact Integrated Raman Spectrometer (CIRS) was successfully proposed to the NASA's new Maturation of Instrument for Solar System Exploration (MatISSE) Program. The instrument leverages on 18 years of previous development that was used on the Mars Microbeam Raman Spectrometer (MMRS). The CIRS architecture incorporates the MMRS spectrometer and probe head as an integrated unit. This eliminates the need for optical fibers to route laser and Raman collection light to and from a tethered probe head, a perceived risk for turret-mounted instruments. The CIRS instrument is also the first to incorporate a light field-imaging camera. The camera is unique in that it allows scientists to focus on various regions of interest in the field of view after acquisition without a complex autofocus mechanism. The entire optical bench in which the instrument resides can be translated within the housing, allowing the instrument to collect multiple Raman spectra and context images along a linear path. This method provides a means of identifying the various mineral domains contained in a rock sample as well as relating the spatial and spectral features observed. The ultimate goal of this three year project is to develop a brassboard that can be successfully tested in a Mars simulated environment while it is being controlled by commercial off-the-shelf (COTS) electronic subsystems. Such efforts funded under the MatISSE Program promise to mature both new technologies and instrument designs toward deployment in future missions at a rapid pace.

Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) Technology Development for the Precipitation and All-Weather Temperature and Humidity (PATH) mission

POC: Todd Gaier

The NASA Earth Science Decadal Survey PATH mission would provide continuous observations of atmospheric parameters essential to our knowledge of weather and global climate. The mission requires microwave radiometers at geostationary orbit, with a large enough effective aperture to obtain 20 km ground resolution. We have developed the GeoSTAR synthetic thinned aperture radiometer to prototype and reduce the risk of the PATH mission

development. Under NASA ESTO funding, we have developed synthetic aperture radiometers at 50 and 183 GHz and associated receiver and correlator technologies. The prototype has been used to obtain images of a variety of targets. Most recently a subset of the 183 GHz array has been integrated with a low-power ASIC correlator, developed by Omnisys in Sweden, to obtain images of the Sun, demonstrating the system level performance of the GeoSTAR high frequency instrument.

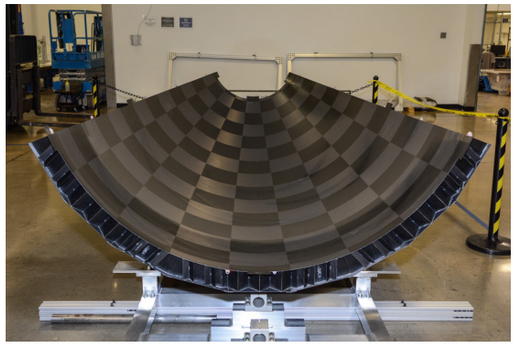


GeoSTAR-III array with 144 receivers at 183 GHz undergoing integration

Post-doctoral Researcher Isaac Ramos observing the sun with the GeoSTAR-III instrument using a state-of-the-art ASIC correlator.

NASA Earth Science Technology Office (ESTO) Instrument Incubator Program (IIP)-10: A 4-meter, 180- to 680-GHz Antenna for the Scanning Microwave Limb Sounder

PI: Richard Cofield



SMLS1: Breadboard Primary Reflector for SMLS. Image courtesy of Vanguard Space Technologies, Inc.

The Scanning Microwave Limb Sounder (SMLS) is a space borne heterodyne radiometer that would measure pressure, temperature and atmospheric constituents from thermal emission between 180 and 680 GHz. SMLS, planned for the Global Atmospheric Composition Mission of the NRC Decadal Survey, uses a novel toric Cassegrain antenna to perform both elevation and azimuth scanning. These provide better horizontal and temporal resolution and coverage than possible with elevation-only scanning at the orbit spacings of two previous MLS satellite instruments.

A 2010 Instrument Incubator Program (IIP) award developed the SMLS antenna in 5 tasks: (1) detailed mathematical modeling of the antenna patterns from which we simulate geophysical parameter retrievals in order to establish field of view performance requirements; and (2) thorough correlation of finite-element-model predictions with temperature-soak measurements made on a demonstration reflector. That reflector resulted from a 2006 Small Business Innovative Research (SBIR) Program task for the full 4-m height and 1/3 the width planned for the spaceflight version. The antenna's deformations, under flight-like thermal gradients, were subsequently measured using high-precision speckle interferometry using a new large-aperture facility at JPL. For the next task (3), the figure shows a recently fabricated full-width primary reflector whose as-built surface figure can be improved, with well-understood techniques, to meet the figure requirements of SMLS; the figure shows it configured for the same thermal gradient tests as for the SBIR reflector. The IIP concludes with the two remaining tasks: (4) integration of the primary with other reflectors, and with residual front ends built in a 2007 IIP, in a breadboard antenna; and finally (5) RF testing of the breadboard on a Near Field Range in a facility maintained by the Division.

SMLS2: Reflector configured for Thermal gradient tests in JPL's Advanced Large Precision Structures Facility.

AIST-11 Onboard Processing (OBP) to Advance the Panchromatic Fourier Transform Spectrometer (PanFTS) Imaging System for GEOstationary Coastal and Air Pollution Events (GEO-CAPE)

POC: Paula Pingree

This is a three-year task (currently in year 2), funded by the Earth Science Technology Office (ESTO), with the following objectives: (1) leverage the capabilities of the Xilinx Virtex-5 FPGA, with the path-to-flight version in the Single event Immune Reconfigurable FPGA (SIRF) device, to meet demanding processing requirements of future space instruments; (2) develop an onboard processing (OBP) platform based on the Virtex-5 to optimize the data processing and instrument design of a Panchromatic Fourier Transform Spectrometer (PanFTS) for the GEO-CAPE mission; and (3) achieve at least 20X magnitude reduction in data rate by converting time-domain interferograms to spectra with a highly parallel instrument digital signal processing (DSP) design.

Marina-3 electronics for PanFTS OBP

Instruments Concept Team

POC: Alfred Nash

Instruments Concepts Team

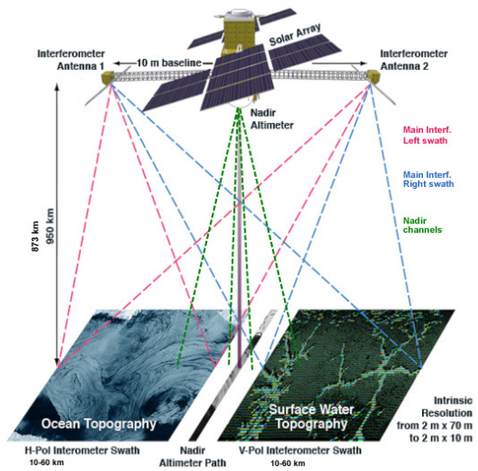
The Division 38-led Instrument Concepts Team (ICT) is a part of JPL's A-Team and Team-X concept formulation and development capabilities. The ICT is a multi-division JPL asset used to rapidly innovate, develop, evaluate, and estimate the costs of space instrumentation concepts. The team draws from over 100 senior experts in all relevant disciplines.

During 2013, the Instrument Concepts Team supported investigators with proposals aimed to respond to Earth Science (Earth Venture Suborbital, Earth Venture Instrument), Astrophysics (Small Explorer, Explorer and Explorer Missions of Opportunity) and Planetary Science (Discovery and Mars 2020) Announcements of Opportunity (AOs). In addition, the ICT has continued to provide support to JPL's instrument and mission concept development through Team-X and for the early stages of formulation through A-Team. The Instrument Concepts Team supported Team-X in many of the 25 mission studies, the 15 Team-X instrument/payload studies, and the 37 A-Team studies that occurred during 2013, which spanned three JPL program directorates: Solar System Exploration, Astronomy and Physics, and Earth Science and Technology.

Surface Water Ocean Topography (SWOT)

POC: Paul Stek

The SWOT mission, with a target launch date of 2020, is one of five second-tier Earth-observing missions recommended by the National Research Council's (NRC) Earth Science Decadal Survey. SWOT is a collaborative mission involving NASA and the French national 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 employs three remote-sensing instruments: Ka-band Radar Interferometer (KaRIn), including the Near-Nadir Interferometer (NNI) or a Ku/C-band nadir altimeter (KNA), and a radiometer. The KaRIn instrument employs two Ka-band Synthetic Aperture Radar (SAR) antennae placed at opposite



SWOT Instrument Fields of Regard

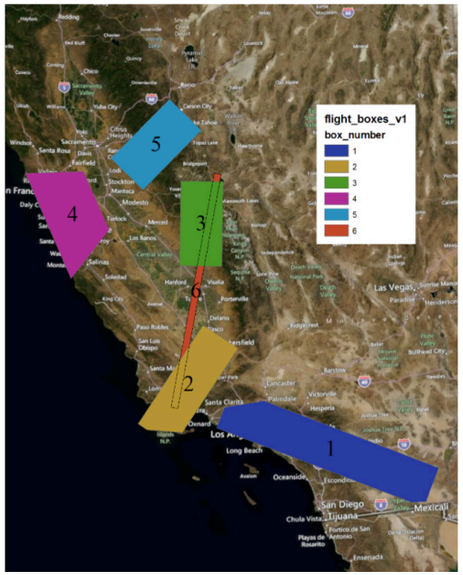
ends of a 10-meter boom. The SWOT spacecraft also carries a Global Positioning System (GPS) receiver to augment in-flight calibration and to provide robust Precision Orbit Determination (POD), together with the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) data. The SWOT advanced microwave radiometer (AMR) is based on the Jason-3 radiometer developed within Division 38. AMR would provide path-delay corrections for KaRIn and the nadir altimeter height measurements.

The SWOT Science Data System (SDS) is expected to ingest 7.3 Tb/day acquired by the KaRIN, the radiometer, and the Nadir altimeter instruments; process the data into 14 product types; and generate on average 21 TB of data products daily. The science data products are to be produced by both CNES and JPL; CNES is to process KaRIn data over Eurasia and all Nadir altimeter data and POD from DORIS, while JPL is to process KaRIn data for the rest of the world and the Radiometer data. JPL's SWOT SDS would be based on the Division's evolving Object Oriented Data Technology (OODT) based Process Control System (PCS) product line, sharing common infrastructure with and adapting common components from forerunning JPL missions, including the Orbiting Carbon Observatory (OCO), the National Polar-Orbiting Environmental Satellite System Preparatory Project (NPP) Sounder Product Evaluation and Analysis Tools Element (PEATE), and the Soil Moisture Active Passive (SMAP) mission.

Hyperspectral Infrared Imager (HyspIRI)

POC: Rob Green

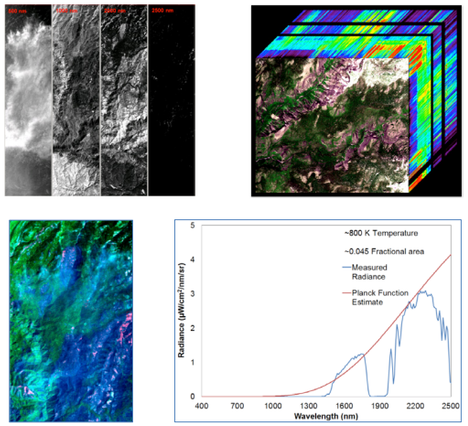
The HyspIRI preparatory airborne campaign began collecting imaging spectroscopy and thermal multi-spectral measurement for six large regions in California in the spring of 2013. HyspIRI is a NASA Decadal Survey mission in pre-formulation with both the imaging spectrometer and thermal infrared concept instruments developed by Division 38. The six regions for this preparatory campaign are shown in the figure. Measurements are planned to be acquired for three seasons and two years to support 14 funded investigations spanning a range of topics: (1) ecosystem composition, function, biochemistry, seasonality, structure, and modeling; (2) coastal ocean phytoplankton functional types and habitat; (3) urban land cover, temperature, and transpiration; (4) surface energy balance; (5) atmospheric characterization and local methane sources; and 6) surface geology, resources, soils, and hazards. These investigations demonstrate the diversity of science and applications that would be achieved by the subsequent global HyspIRI space mission.



Six diverse and extensive regions designated for the NASA HypsIRI preparatory airborne campaign that will be acquired in three seasons for two years.

During 2013 a large portion of the Region 3 near Yosemite California that was measured in the spring has subsequently burned in the historic Rim fire (>400 square miles). These pre-fire data offer an unprecedented opportunity to understand the fuel and ecosystem state before the fire. Subsequent HyspIRI campaign data sets will be used to assess severity as well as predict and monitor recovery. The figure shows measurements from the autumn campaign acquired by the Airborne Visible InfraRed Imaging Spectrometer from 65,000 feet altitude

over the still-burning RIM fire. The results of this HyspIRI preparatory campaign would further demonstrate and refine the data processing and science algorithm that would be used in the ultimate HyspIRI global space mission.



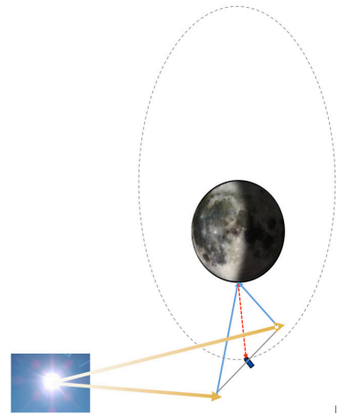
Measurements of the Rim fire, near Yosemite Valley, acquired by the AVIRIS imaging spectrometer during the HyspIRI preparatory airborne campaign. The effects of the still burning are seen through the AVIRIS spectral range at 500, 1000, 2000 and 2500 nm. Active fire temperature is retrieved with a spectroscopic inversion for temperature and area.

Lunar Flashlight

Measurement Lead Investigator: Barbara Cohen/MSFC

POC: Benny Toomarian

Now that the existence of water ice has been proven in lunar polar regions, where might we find operationally useful quantities, and what might we learn from their location and composition? Lunar Flashlight is a new mission designed to address NASA's Human Exploration and Operations Mission Directorate's Strategic Knowledge Gap "Composition / quantity / distribution / form of water/H species and other volatiles associated with lunar cold traps." JPL, in partnership with Marshall Space Flight Center (MSFC), Morehead State University, and Stellar Exploration, formulated and received funding to proceed to the first major review with a low-cost CubeSat-based approach for locating ice deposits in the Moon's permanently shadowed craters.

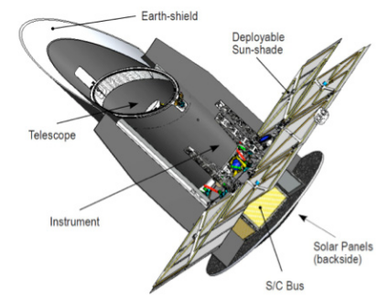


Lunar Flashlight (schematic illustration not to scale). ~50 kW of sunlight is specularly reflected off the sail down to the lunar surface in a ~1º beam. A small fraction of the light diffusely reflected off the lunar surface enters the spectrometer aperture, providing adequate signal-to-noise ratio to distinguish volatile ices from regolith.

Lunar Flashlight is to utilize its solar sail (8.7 m on a side) not only for propulsion but also to reflect ~50 kW of sunlight to the lunar surface, enabling IR spectroscopy of the permanently shadowed areas. Spectral modeling indicates that a point spectrometer with three spectral bands can distinguish between dry regolith, H_2O, CH_4, and CO_2 ices. The 6U spacecraft (~10 x 20 x 30 cm in size, divided into ~2U instrument, ~2U solar sail and 2U spacecraft subsystems) would be based on the partners' predecessor capabilities, including JPL's INSPIRE and spectrometers, Morehead State's CubeSats, and Marshall's launch vehicle integration. Lunar Flashlight would provide an experience-based CubeSat mission architecture, hardware, and software that can be applied to any NASA objective where delivering a 2U-class instrument within the inner Solar System can yield valuable results for human exploration, planetary science, heliophysics, and other applications. If approved for full implementation, launch is slated for 2017.

Fast INfrared Exoplanet Spectroscopy Survey Explorer (FINESSE)

PI: Mark Swain (JPL Science Division)
POC: Muthu Jeganathan



The Division is responsible for delivering FINESSE's single, high-stability payload. The spacecraft bus is built by Ball. The prominent sun-shade and Earth-shield passively cool the payload to <130 K. A cryocooler cools the HgCdTe focal plane array to 75 K and the spectrometer to <90 K for observations out to 5 mm.

FINESSE (Fast INfrared Exoplanet Spectroscopy Survey Explorer) a mission dedicated to exploring new worlds around other stars by understanding the atmospheric conditions, composition, and chemistry of exoplanets as a class of objects had its Site Visit in February 2013. FINESSE was one of five Explorer Mission proposals that were selected by NASA in September 2011 to conduct an 11-month mission concept study. Based on the concept study report (CSR) submitted in 2012, NASA released a set of potential major weaknesses. JPL, the Division and the broader FINESSE team responded to these weaknesses at the all-day Site Visit. Though FINESSE made an excellent presentation and addressed all the review board's concerns, NASA selected the Transiting Exoplanet Survey Satellite (TESS) for implementation. The FINESSE team, with Division support, is now developing a lower-cost implementation to fit within the cost cap of the upcoming Astrophysics Small Explorer (SMEX) opportunity.

Carbon Dioxide Laser Absorption Spectrometer (CO2LAS)

POC: Bob Menzies

JPL has developed the airborne Laser Absorption Spectrometer instrument for the purpose of measuring high-accuracy CO_2 concentrations and variability in the lower atmosphere. This instrument employs continuous wave laser transmitters and coherent detection receivers at wavelengths in the 2.05-µm spectral region. The Integrated Path Differential Absorption (IPDA) method is used to retrieve CO_2 column mixing ratios. Several flights on the NASA DC-8 research aircraft were conducted during summer 2011 and winter 2013 campaigns, supported by the NASA ASCENDS (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons) mission development program.

During 2013, the CO2LAS team refined the data processing and analysis capabilities and generated high-precision CO_2 data products. A peer-reviewed publication is in press. This publication includes the detection of mid-day CO_2 drawdown due to photosynthetically active surface vegetation during an August 10, 2011 flight segment extending from over the Colorado plains into Nebraska during early afternoon. The observation of the relatively small decrease in CO_2 as the aircraft ground track transitioned from barren to vegetated surface type

is a significant step in the validation of the NASA ASCENDS laser-based mission concept. The paper also includes quantitative estimation of the CO_2 emission rate from the Four Corners power plant in New Mexico during an August 9 overpass just downwind. Data analysis products now include CO_2 retrievals over snow-covered landscapes. The ASCENDS objective is improved characterization of the geographical distribution of CO_2 sources and sinks, CO_2 being the most influential greenhouse gas that is directly augmented by human activities.

CO2LAS

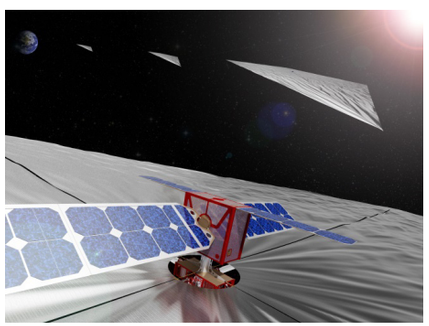
Small Satellite Advanced Concepts

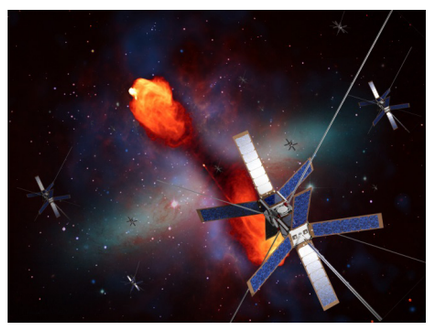
POC: Charles Norton (JPL Mission Systems and Operations Division)

JPL currently participates in ten CubeSat-based technology and science projects with partners around the country, including seven with significant Division involvement. These missions include:

- CubeSat Onboard Processor Validation Experiment (COVE-2)
- Low-Mass Radio Science Transponder (LMRST)
- Intelligent Payload Experiment (IPEX)
- GEOstationary Coastal and Air Pollution Events (GEO-CAPE) Read Out Integrated Circuit (ROIC) In-Flight Experiment (GRIEX)
- Integrated Solar Array and Reflectarray Antenna (ISARA)
- Interplanetary NanoSpacecraft Pathfinder In Relevant Environment (INSPIRE)
- Radiometer Atmospheric CubeSat Experiment (RACE)
- CubeSat VHF transmitter to study Ionospheric dispersion of Radio Pulses (CHIRP)
- Lunar Flashlight
- Near-Earth Asteroid Scoutsat

Our partners include NASA GSFC, NASA MSFC, University of Michigan, Cal Poly San Luis Obispo, Morehead State University, University of Texas at Austin, Naval Postgraduate School, as well as various industry partners that are leaders in CubeSat system development. Laboratory development partnership projects include Propulsion System and Orbit Maneuver Integration in CubeSats and SmallSat Low Mass, Extreme Low Temperature Energy Storage led by Western Michigan University and California State University Northridge, respectively. Most of these missions are manifested or planned for launch between 2013 and 2017, while a few are ground-based technology development projects that would enable new missions in the future. Details on these activities are now published on the recently developed JPL CubeSat website cubesat.jpl.nasa.gov. Furthermore, a new concurrent study team, Team Xc, has been initiated to bring additional focus to CubeSat formulation studies. In addition, infrastructure developments have been made to streamline project development.





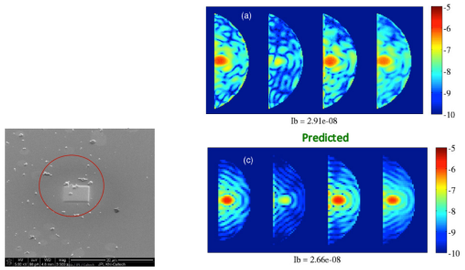
Two nanospacecraft-enabled concepts from Keck Institute for Space Studies (KISS) workshops envisaged science-driven missions at dramatically lower cost than previously thought possible: (left) Fractionated L5 Space Weather Sentinel (POC: Paulette Liewer - Division 32), and (right) a low frequency antenna array system for studying energy transport from black holes to the intergalactic medium (POC: Joe Lazio - Interplanetary Network Directorate).

Throughout the Laboratory, many new formulation activities in Earth science, astrophysics, heliophysics, planetary science, and other areas have been pursued to expand the range and scope of these small platforms for innovative science. Of particular note are mission concepts from the Keck Institute for Space Studies (KISS) Workshops "Small Satellites: A Revolution in Space Science" that have introduced new directions in SmallSat formation flying, navigation, instruments, observations, and new technologies such as in-space assembly and others. Many of these concepts have been published throughout the technical literature and presented at leading conferences. These advanced concepts, as well as others targeting future exploration missions in conjunction with planned planetary science missions, are on the horizon and are continuing to generate deep interest within JPL, NASA, universities, small business, and other organizations.

High Contrast Imaging Testbed

POC: Andreas Kuhnert

The Division operates the High Contrast Imaging Testbed (HCIT) for NASA's Exoplanet Exploration Program (ExEP). The HCIT facility consists of two independent vacuum chambers that support coronagraphic experiments to demonstrate 9-10 orders of magnitude of starlight suppression within a telescope, enough suppression to reveal Jupiter-like and Earth-like planets adjacent to their host stars. During fiscal year 2013, the HCIT team added a Low-Order Wavefront Sensor (LOWFS), upgraded its science cameras, and improved the artificial star stability. Throughout the year, the testbeds were used to support Technology Development for Exoplanet Mission (TDEM) proposal activities, including model validation, the vector vortex coronagraph, low-order wavefront sensing, and Phase Induced Amplitude Apodization (PIAA) coronagraph experiments.



Left: a 6-micron wide platinum spot was placed on a coronagraph mask. Other minor contamination and manufacturing defects are present. Right: the data (top) and model (bottom) are in excellent agreement across a 10% bandwidth. Colors indicate the log of image plane contrast. From Sidick, Shaklan, Krist et al, Proc. SPIE vol 8864, paper 8864Q (2013).

The figure shows an example of the model validation experiment. Coronagraphs use microscopic masks placed at the image of a star. Small defects cause light to leak through the coronagraph. Using the focused ion beam facility at Caltech's Kavli Institute, a calibrated defect was written on the mask and the mask was then inserted in the HCIT coronagraph. The observed and modeled scatter patterns are in agreement, proving that diffraction models are accurate in the high-contrast regime.

While in the past HCIT has been used to demonstrate 5 X 10^{10} contrast in broadband using a hybrid Lyot configuration, progress in fiscal year 2013 included a collaboration with Principal Investigator Olivier Guyon of the University of Arizona to demonstrate 2 X 10^{8} broadband contrast in a PIAA coronagraph at unprecedented small angles of 2-4 Airy rings. The new LOWFS was used to stabilize the PIAA image to just 1/1000 of an Airy ring. In collaboration with Principal Investigator Gene Serabyn of the Science Division, the novel Vector Vortex coronagraph was used to demonstrate 10^{8} contrast in broadband light. These results represent significant progress in the quest to build instruments capable of discovering and characterizing planetary systems around nearby stars.

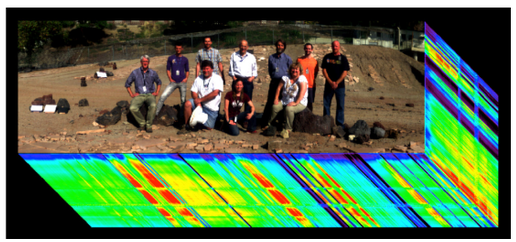
Future plans call for adaptation of the HCIT testbeds to support technology development for the Astrophysics Focused Telescope Assets (AFTA) coronagraph. HCIT would also take delivery of an integral field spectrometer through collaboration with the Space Telescope Science Institute.

Ultra-Compact Imaging Spectrometer (UCIS) for planetary mineralogy

PI: Pantazis Mouroulis

The Ultra-Compact Imaging Spectrometer (UCIS) is the first of its kind kg-class imaging spectrometer, light and flexible enough to be used in mass- and power-constrained in-situ platforms such as a Mars rover, while satisfying stringent performance specifications normally associated with large orbiting instruments. The instrument opens up new ways of performing geologic exploration through its ability to collect wide angle (up to 360°) panoramas and produce high-quality, full-range (500-2,500 nm) diagnostic spectra for every pixel in the image, while acquiring ~500,000 spectra in the same time that previous rover instruments acquire one. UCIS is adaptable to Mars operation while also being a unique Earth-science tool in its own right, capable of collecting data over spatial scales of tens of meters down to tens of micrometers with a microscopic adapter.

A MatISSE grant was awarded to Dr. Diana Blaney (Division 32) to upgrade the calibration and thermal system of UCIS for Mars-compatible operation. Different calibration system options were tested in the JPL Mars Yard and were determined to improve the data quality as well as ease of operation. Also, Dr. Bethany Ehlmann of Caltech is using the instrument in ongoing microscopic mineralogy investigations.



Ultra-Compact Imaging Spectrometer (UCIS) data collected 25 Oct 2013 in the Mars Yard with team.

INSTRUMENTS DIVISION

Instrument Systems Development

ANNUAL REPORT FY 2013

Mars/Planetary

Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)

POC: Carl Bruce

The InSight Project is a geophysical science mission to Mars scheduled for launch in 2016. A lander will carry a seismometer and a drill to Mars and, using a robotic arm, place these two instrument packages on the surface of the Red Planet for at least one Mars year of measurements. Division 38 is providing the Auxiliary Payload Sensor Suite (APSS), which will provide near-continuous environmental data supporting the science investigation of the seismometer. The APSS includes a fluxgate magnetometer, a pressure sensor, a wind sensor and an atmospheric temperature sensor. The Centro de Astrobiología in Spain provided the wind (speed and direction) and temperature sensors (Temperature and Winds for INSight - TWINS). They also provided the MSL Remote Environmental Monitoring units. The InSight Flux Gate (IFG) is being built at UCLA and will monitor fluctuations of the magnetic field for the first time at the Mars surface to 0.1 nano-Tesla. The Pressure Sensor will record pressure and pressure fluctuations to 6 milli-Pascals, the most precise dynamic pressure measurement ever made on another planet. All of these sensors will be controlled by a set of electronics (Payload Auxiliary Electronics, PAE) designed and built at JPL. The APSS will conduct its measurements autonomously for up to 27 hours at a time without contact from the lander or ground teams.

Interplanetary NanoSpacecraft Pathfinder In Relevant Environment (INSPIRE)

PI: Andy Klesh (JPL System Engineering and Formulation Division)
PM: Lauren Halatek

The INSPIRE mission is slated to be the world's first interplanetary CubeSat mission: an identical pair of satellites to be launched on an Earth-escape trajectory. INSPIRE will be ready by the summer of 2014 to open deep space to nanospacecraft technologies, demonstrating that CubeSats can operate, communicate and be navigated far from Earth. Spacecraft components, such as a JPL X-band radio and a miniature vector helium magnetometer, will provide the basis for future high-capability, lower-cost interplanetary missions. These components will enable future supplemental science and educational opportunities at many destinations, such as Mars and Europa.

INSPIRE - Twin CubeSats for deep space

The nominal INSPIRE mission will last for three months and will achieve an expected Earth-probe distance of 1.5 million km. This is dependent upon escape velocity of the host vehicle, as neither spacecraft will have propulsion capability. The project will monitor onboard telemetry; operate, communicate, and navigate with both spacecraft; demonstrate cross-link communications; and demonstrate science utility with an onboard magnetometer and imager. Lessons learned from this pathfinder mission will help to inform future interplanetary nanospacecraft and larger missions that might use nanospacecraft components.

INSPIRE is led by JPL/NASA with partnerships at University of Michigan, University of Texas, Cal Poly San Luis Obispo, University of California Los Angeles, and Goldstone Apple Valley Radio Telescope (GAVRT).

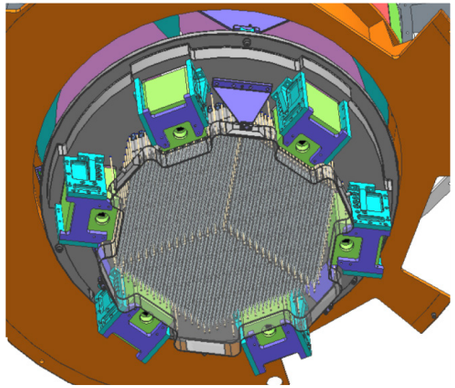
Astrophysics

Prime Focus Spectrograph (PFS)

PIs: Richard Ellis (Caltech),
Michael Seiffert (JPL Science Division)
POC: Mark Schwochert

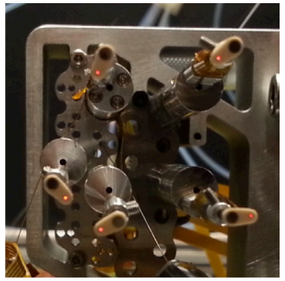
The PFS instrument is uniquely capable of making the necessary advances in our understanding of the two major cosmological mysteries of dark energy and dark matter. It combines (1) the 8.2 meter Subaru telescope aperture with a 1.3 degree diameter corrected field of view, (2) a massively-multiplexed fiber-fed spectrograph capable of recording up to 2,394 simultaneous spectra, (3) rapid reconfiguration for new observing fields, and (4) wavelength coverage from ~350 nm to 1.3 µm necessary to locate all likely spectral diagnostics over the proposed redshift range. This combination ensures greater redshift leverage ($0.4<z<2.4$) for the dark energy applications and improved signal/noise of stellar spectra for the Galactic kinematic and chemical analyses, as compared to current instruments based on 2.4-4.0-m telescopes with only optical capabilities.

PFS instrument development is a collaborative effort between a team from JPL/Caltech and international partners from Japan, Taiwan, France, Brazil, Johns Hopkins University and Princeton University. The Division is providing the fiber positioner system, including drive and control electronics, and systems engineering for the portion of the instrument located at the telescope prime focus. The fiber positioner system is a close-packed hexagonal array of piezo actuators, articulating 2,394 optical fibers at the prime focus. This allows simultaneous collection of spectra from a large number of targeted astronomical objects.



Optical bench with 2,394 fiber positioners in a close-packed hexagonal array.

The project completed a successful preliminary design review (PDR) in February 2013 with subsequent JPL/Caltech efforts focused on preparation for receiving and testing 30 engineering model (EM) fiber positioners and associated drive electronics. The EMs will be used to verify that the positioner



Five prototype positioners undergoing performance tests.

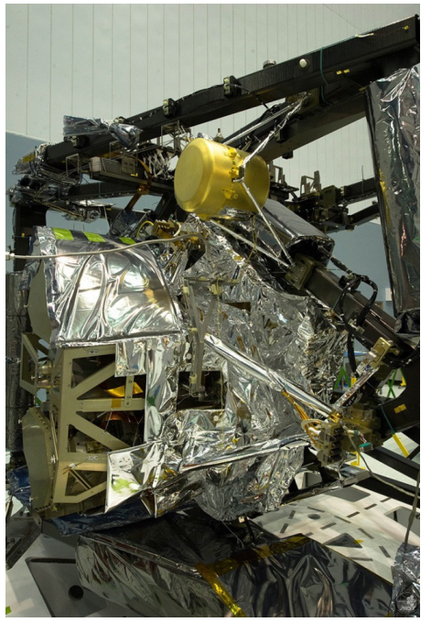
performance is acceptable to meet science requirements and to demonstrate assembly and test techniques needed to build the complete positioner system. Plans for 2014 include starting the large-scale positioner production contract and detailed design of the positioner bench, supporting structure, drive and control electronics.

James Webb Space Telescope (JWST) Mid-InfraRed Instrument (MIRI) Cryocooler

POC: Konstantin Penanen

Development of the JWST/MIRI Cryocooler accelerated in fiscal year 2013. The first delivered component for space flight, the 6 kelvin Heat Exchanger Assembly (6K HX), has been integrated with the MIRI Optical Module (OM) as part of JWST Integrated Science Instrument Module (ISIM) Integration and Test (I&T) activities. A non-flight Heat Exchanger Stage Assembly (HSA) and a set of non-flight refrigerant lines and line supports (RLS) have also been integrated with ISIM to support the first of three ISIM-level cryogenic vacuum (CV) tests. CV1-RR (Risk Reduction) has been completed with the Cooler providing the requisite thermal environment for the MIRI OM, which houses the three Focal Plane Modules (FPM). CV1-RR data review is ongoing.

In the meanwhile, flight HSA and RLS have been built and are in acceptance testing at the vendor (Northrop Grumman Aerospace Systems, NGAS) facility. The build-up of the remaining thermo-mechanical unit (TMU) components, chiefly the Cryocooler Compressor Assembly (CCA), also continues, with several delays in finalizing the design of the CCA Pulse Tube (PT) precooler. Other TMU components in spaceflight build are the Refrigerant Line Deployable Assembly (RLDA), developed by the Division, and the Cooler Tower Assembly (CTA), developed by Goddard Space Flight Center (GSFC). A long-standing cryogenic valve issue has been resolved, with qualification testing on Division-developed Piloted Bypass Valve completed and qualification testing on Solenoid Latched Bypass valves nearing completion at NGAS. Cooler Electronics development has also progressed. The PT Cooler Control Electronics (CCE) Engineering Model (EM) and the embedded flight software have been completed. Division-developed Cooler Software Application has also been completed and tested with the embedded Cooler electronics flight software. The flight build of PT and Joule-Thomson (JT) CCEs is ongoing and will incorporate heater/valve drive boards, already delivered by the Division. Flight and flight spare units of the Relay Switch Assembly (RSA) have been delivered by NGAS to JPL for participation in the Cooler subsystem (CCE Assembly and CCA) Acceptance Test Program.



Flight-like HSA (gold-plated cylindrical enclosure) and the flight model 6K HX integrated with MIRI OM and ISIM at Goddard Space Flight Center.

Preparations for the Cooler I&T effort at JPL have also seen significant progress. A CV chamber being prepared for the integrated subsystem test has been refurbished and has undergone initial vacuum checkouts. A MIRI OM surrogate, Thermal Optical Module (TOM) built by the MIRI European Consortium (EC) to be thermally representative of the flight Optical Bench Assembly (OBA) and upgraded with a JPL flight-like Focal Plane Module (FPM), has arrived at JPL and is being prepared for the End-to-End MIRI Thermal System test.

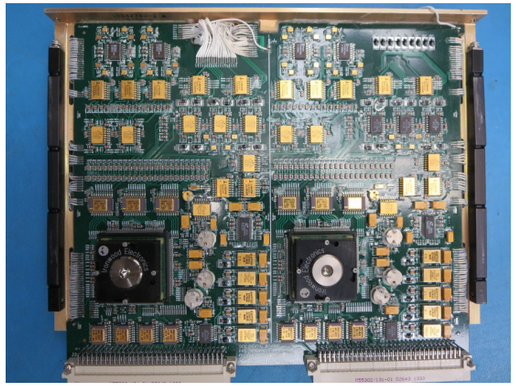
James Webb Space Telescope (JWST) Mid-InfraRed Instrument (MIRI) Electronics

POC: Brian Franklin

MIRI is the mid-infrared instrument for the James Webb Space Telescope and provides imaging, coronagraphy and integral field spectroscopy over the 5-28 micrometer wavelength range. The short- and long-wavelength spectrometers and the imager each have a FPM housing a single Sensor Chip Assembly (SCA) containing a 1024 × 1024-pixel Si:As detector array and readout electronics.

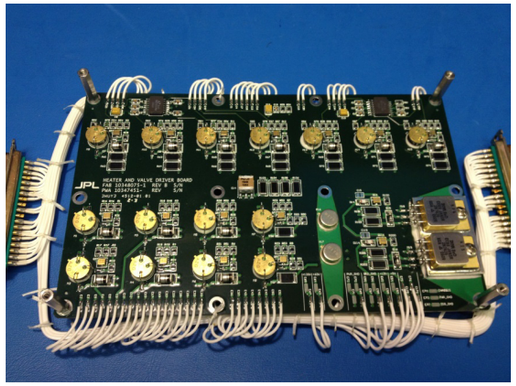
The Focal Plane Electronics (FPE) responds to observation setup commands, produces the precision clocks and biases necessary to drive the detectors and readout electronics, monitors and controls the temperature of each FPM and controls the detector annealing heaters, receives the analogue signals from the detectors, amplifies and digitizes those signals, and transmits the science and housekeeping data to the ICDH over a high-speed SpaceWire interface.

The Division designed, built, tested and delivered to NGAS the flight Heater and Valve Driver Boards (HVDB) in the beginning of the year. The HVDBs reside within the Cooler Electronics units and are responsible for powering various heaters and driving the cryogenic bypass valves that control coolant flow throughout the MIRI cryocooler system.



Flight Heater and Valve Driver Board

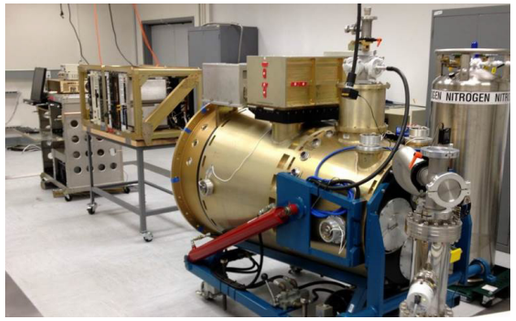
Last summer/fall the Division designed, built, and tested the EM-redesigned Focal Plane Electronics (FPE) Signal Chain Electronics (SCE) digital board and FPGA. The SCE digital boards and FPGAs are at the heart of MIRI. They are responsible for interfacing to the three infrared detectors, generating the many precision clocks and biases, and digitizing the science data video streams, in addition to command and data handling and detector temperature control.



Focal Plane Electronics Signal Chain Electronics

High-resolution Airborne Wideband Camera Plus (HAWC+) for SOFIA Airborne Observatory

PI: C. Darren Dowell (Science Division)
POC: Louise Hamlin



The HAWC+ upgrade will enable SOFIA to make polarimetric observations at far-infrared wavelengths.

HAWC+ is an astronomical camera, operating in the far-infrared wavelengths (40-300 µm) that will fly aboard NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) airborne observatory. An upgrade to the camera currently underway in Division 38 will allow HAWC+ to measure polarization in diverse objects throughout the universe, such as galaxies, star-forming clouds and the interstellar medium. This will help astronomers better understand how stars, planets and galaxies form and evolve. The upgrade consists of a sensitive, large-format detector array developed at Johns Hopkins University and a polarimeter developed here at JPL, capable of making observations at far-infrared wavelengths. The HAWC+ project successfully passed its Mission Requirements Review (MRR) in May 2013 and Preliminary Design Review (PDR) in August 2013. The project will continue with Critical Design Review (CDR) in January 2014 and delivery to SOFIA in Fall 2015.

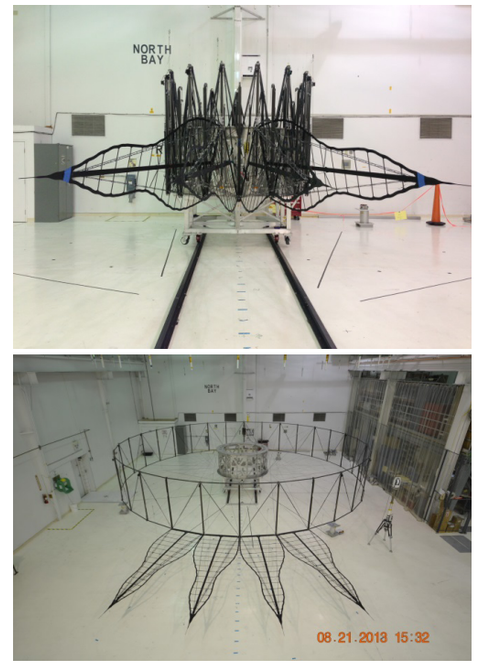
SOFIA is a highly modified Boeing 747SP aircraft that carries a telescope with a 100-inch (2.5-meter) diameter mirror that conducts astronomy research not possible with ground-based telescopes. "SOFIA has the ability to become a world-class airborne observatory that complements the Hubble, Spitzer and Herschel space telescopes," said John Grunsfeld, NASA's Science Mission Directorate Associate Administrator. "This upgrade will greatly broaden SOFIA's capabilities."

SOFIA is the largest airborne observatory in the world. It is a 747SP aircraft carrying a 2.5 meter-diameter telescope dedicated to astronomical research.

Starshade Technology

PI: Jeremy Kasdin (Princeton University)
POC: Stuart Shaklan

Direct imaging and characterization of planets orbiting nearby stars is one of NASA's most fascinating and challenging goals. A planet-like Earth when seen by a spaceborne telescope appears to be 10 billion times fainter than its star. One approach to seeing the planet light without being blinded by the starlight is to use a flower-shaped starshade positioned between the star and the telescope. The starshade's shape, consisting of a central disk and 24-30 radial petals, is designed to control diffraction at visible wavelengths. The starshade is 30-40 m in diameter and positioned 30,000-50,000 km in front of the telescope. From that distance, the starshade is seen as a tiny speck blocking the star, while the planet light passes around the side of it. The Division, in collaboration with Division 35, Princeton University, and Northrop Grumman Aerospace Systems (NGAS), has been developing starshade technology, including the successful 2012 demonstration of a flight-like petal that exceeded the requirements for detection of Earth-like planets. With the petal problem solved, the next step is to show that the petals are deployed on a circle to within a 0.5 mm tolerance. The figure shows in-progress tests of four petals mounted on a perimeter truss originally designed for a space antenna application. The truss and petals have been outfitted with laser metrology and photogrammetry targets to allow precise measurement of the shape of the deployed truss and the petal positions. NASA funded the experiment under the Technology Development for Exoplanet Missions (TDEM) opportunity.

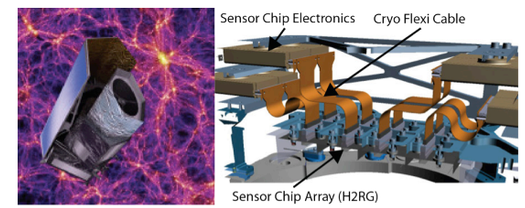


Four JPL-designed and built petals are attached to an Astro Aerospace (a part of NGAS) 12-m diameter perimeter truss for deployment tests in Goleta, CA. The goal of the tests is to show that the petals are deployed to a precision of ~0.5 mm. The top image shows the petals attached to the stowed truss. The 12-m diameter truss has been fully deployed in the bottom image.

In addition to the petal and deployment positioning developments, the Division has also participated in diffraction model validation tests by providing to Princeton University miniature starshade masks fabricated at JPL's Micro Devices Laboratory. Other key technologies being pursued are modeling and measurement of petal edge scatter and diffraction, including the development of a scatterometry lab at JPL. In collaboration with Division 35, the Division is working with the Exoplanet Exploration Program probe mission study team and its external Science and Technology Definition Team to design a probe-class (<$1B) starshade mission.

Euclid

PI: Jason Rhodes (JPL Science Division)
Project Scientist: Michael Seiffert (JPL Science Division)
POC: Warren Holmes



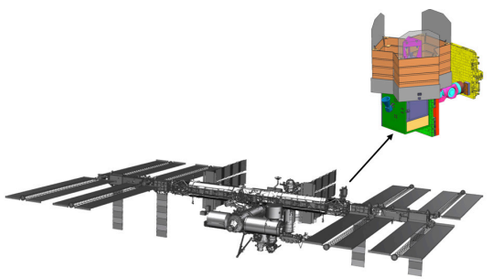
Right: Graphic of the Euclid spacecraft. Left: A cutaway view of the NISP focal plane showing the 3 components of each Sensor Chip Systems.

Euclid is a medium-class mission selected for a late 2019 launch as part of ESA's Cosmic Visions program. The objective of Euclid is to elucidate the geometry and the nature of the dark energy and dark matter components of the universe, with unprecedented accuracy, in a large survey of the

extragalactic sky by two complementary techniques using a visible imager and a near-infrared spectrometer. The US will contribute the 16 flight and four flight spare Sensor Chip Systems (SCS) for the Near Infrared Spectrophotometer Instrument (NISP) aboard Euclid. Each SCS consists of a sensor chip array (Teledyne H2RG), cryogenic flexi cable and cryogenic readout electronics (Teledyne SIDECAR ASIC). JPL is managing the systems engineering, procurement of the SCS from Teledyne Imaging Sensors and the test of the SCS at the Detector Characterization Lab at Goddard. In 2013, the US Euclid project passed PDR and was authorized by NASA to proceed with the space flight build.

Optical Testbed and Integration on ISS Experiment (OpTIIX)

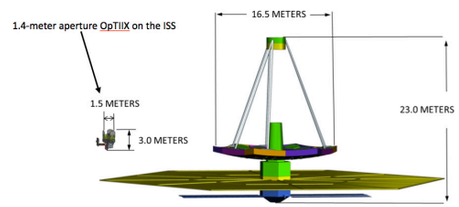
POC: Renaud Goullioud



The Optical Testbed and Integration on ISS Experiment (OpTIIX) on board the International Space Station.

The Optical Testbed and Integration on ISS Experiment (OpTIIX) project was defined through preliminary design review (PDR, in 2012 October) to demonstrate, at a system level, technologies to enable the assembly, alignment, phasing, and upgrade of very large optical apertures in space. Key technologies include: robotic assembly of a telescope system to mechanical tolerances; diffraction-limited post-assembly alignment, phasing and maintenance of the telescope system's optical performance using actuated hybrid mirrors; laser metrology; and wavefront sensing and control.

OpTIIX was envisaged as a cost-effective Class D mission to assemble, test, and operate a 1.45 m segmented-mirror telescope aboard the ISS. Variations of the implementation around the PDR design were developed and submitted to NASA and other potential customers for consideration. A study on how the OpTIIX technologies could feed forward to the development of a 16-meter free-flying space telescope was also completed. For the lack of funding, the project was closed in 2013. However, the techniques developed for use by multiple Division customers now appear to be applicable in combination in a manner that can substantially reduce the cost of assembling large apertures from smaller segments into a system that can operate at the required optical quality across visible wavelengths.



The OpTIIX technologies feed-forward to the development of a 16-meter free-flyer space telescope.

Earth Science

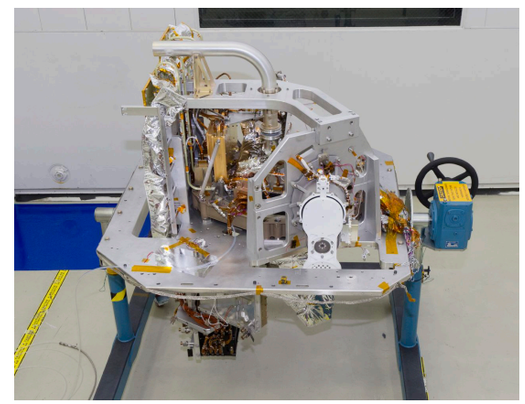
Orbiting Carbon Observatory-2 (OCO-2)

POC: Tom Glavich

The Division, in collaboration with the OCO-2 Project Office, delivered the flight OCO-2 instrument to Orbital Sciences Corporation (OSC) for integration with the OCO-2 Spacecraft. Prior to delivery, the instrument went through extensive environmental and performance testing and calibration. The delivered instrument met all science and interface requirements. Division workforce is supporting integration activities at OSC as we prepare for a July 2014 launch.

The OCO-2 instrument consists of three accurately aligned grating spectrometers, sharing a common input telescope. The three spectrometers look at two CO_2 bands and one Oxygen band. It will provide the first high-precision global measurements of the column abundance of CO_2.

The OCO-2 Science team is led by Michael Gunson of JPL, with participating scientists from several other organizations.

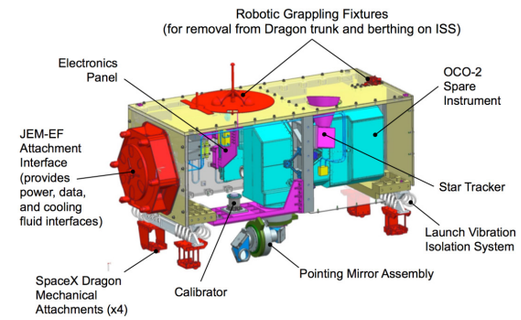


OCO-2

Orbiting Carbon Observatory 3 (OCO-3)

PI: Annmarie Eldering (JPL Science Division)

OCO-3 is an International Space Station (ISS) payload that will continue the OCO program's measurements of CO_2 while offering new insights on diurnal variation and urban emissions. The preliminary design of the payload is well underway after completing a successful System Requirements and Mission Definition Review in June 2013. The team's focus since that time has been centered on the design of the subsystems that support the operation of the inherited OCO-2 spare instrument. These subsystems include the payload structure, thermal control system, power conditioning electronics, flight computer and software, pointing control system, and the 2-axis pointing mirror assembly. The OCO-3 team is also designing a new telescope and onboard calibration system for the inherited instrument to make it compatible with its new orbit and platform constraints.



OCO-3

In addition to the hardware and software design, the team has also been preparing for the Phase 1 Safety Review (an important ISS safety gate review) and developing the interface control documents with the ISS program (primarily covering robotic handling and communication interfaces), JAXA (primarily covering robotic handling, power, and thermal interfaces), and SpaceX (covering launch vehicle interfaces). The team has also been working on the Mission Operations Plan, which will define how and when science data will be collected and downlinked before processing it through the project's Science Data Operations System.

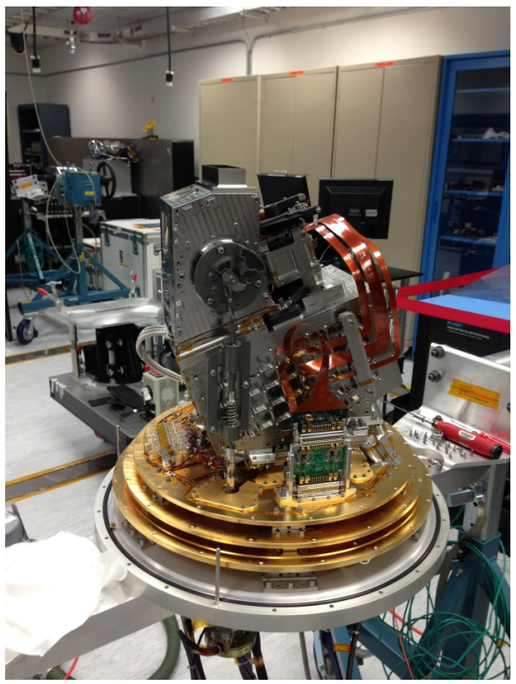
OCO-3 is manifested for launch on the SpaceX CRS-12 resupply vehicle in August 2016. Once robotically berthed on the Japanese Experiment Module-Exposed Facility of ISS (JEM-EF), OCO-3 will collect CO_2 measurements for three years. The next major milestones for the project during this design phase will be the Phase 1 Safety Review in February 2014 and the Preliminary Design Review in March 2014.

Next Generation Imaging Spectrometers (NGIS)

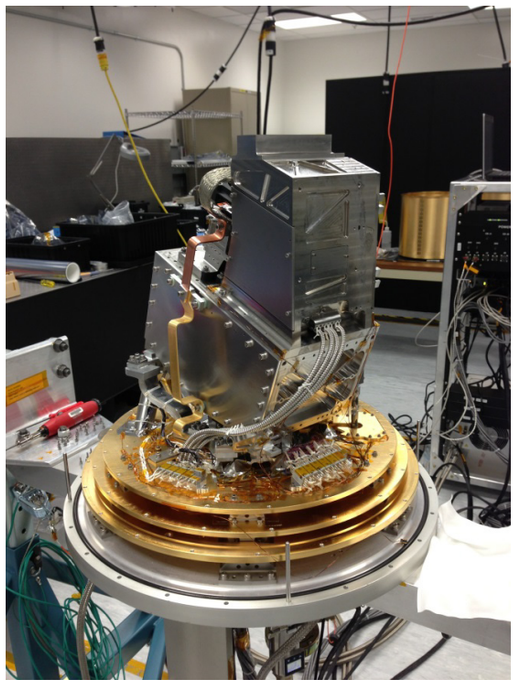
POC: Todd Shelton
PI: Tom Kampe (NEON) and Greg Asner (Carnegie Institution of Washington)

These high-fidelity airborne instruments are used by the National Ecological Observatory Network (NEON Inc.) of Boulder, Colorado and the Carnegie Institution of Washington based in Washington, DC to study, explore and conserve ecosystems on large geographic scales.

The NEON Airborne Observatory will collect and synthesize ecological data across North America for 30 years. Data products are designed to address the impacts of climate change, land use change and invasive species on natural resources and biodiversity. When complete, data will be collected from 60 sites across the US (including Alaska, Hawaii and Puerto Rico) through field sampling, aerial towers and the three airborne platforms. NEON will also allocate resources for Principal Investigator-driven science and natural disaster responses.



NGIS1



NGIS2

The NEON Airborne Observation Platform (AOP) consists of the JPL-provided Visible-to-Shortwave Infrared (VSWIR) imaging spectrometer, a Light Detection and Ranging (LiDAR) instrument, and a high-definition camera. The first NEON imaging spectrometer, the NEON Imaging Spectrometer Design Verification Unit (NISDVU), was delivered in December 2011. The first of two follow-on units, the NEON Imaging Spectrometer #1 (NIS-1), was delivered in April 2013, followed by the second, the NEON Imaging Spectrometer #2 (NIS-2), in September. Over the summer, the NIS-1 unit was operated in field campaigns in northern California, Nevada, and Colorado. The NEON Imaging Spectrometer Design Verification Unit (NISDVU) will be returning later this year to receive technical upgrades developed since its delivery.

The Carnegie Airborne Observatory (CAO) consists of the JPL-provided Visible-to-Shortwave Infrared (VSWIR) imaging spectrometer, a Light Detection and Ranging (LiDAR) system, and a high-resolution Visible-to-Near Infrared (VNIR) imaging spectrometer. The CAO unit returned in 2013 for several technical upgrades that were developed since its original delivery in 2011. After receiving these upgrades, it performed field campaigns in Peru and Panama.

Compact Ocean Wind Vector Radiometer (COWVR)

PI: Shannon Brown
PM: Amarit Kitiyakara

In 2013, JPL was selected to develop the Compact Ocean Wind Vector Radiometer (COWVR) for the US Air Force. The COWVR mission objective is the on-orbit demonstration of a novel low-cost, highly integrated compact microwave radiometer system for operationally measuring ocean vector winds. Ocean surface vector winds support marine wind and wave forecasting, tropical cyclone prediction and Naval operations, including ship movement and positioning, aircraft deployment, and aircraft carrier operations, among others. The COWVR design leverages significantly from the state-of-the-art, highly integrated Millimeter Wave Monolithic Integrated Circuits (MMIC) radiometer technology developed by the Division for the NASA Jason-3 altimeter mission.

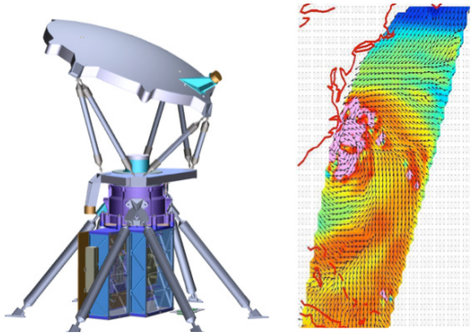


Illustration of the COWVR instrument (left) and the wind vector product (right).

COWVR is a fully polarimetric microwave radiometer operating at 18.7, 23.8 and 33.9 GHz, which promises a factor-of-six reduction in mass and power from the legacy WindSat sensor, which is currently on-orbit providing wind vector measurement for the Department of Defense (DoD). The enabling features include the use of a single multi-frequency feed horn, permitting a simple antenna rotating about the feed axis, as opposed to having to spin the entire radiometer system and pass power and data across the mechanism. Internal calibration sources eliminate the need for an external warm-load and cold-sky reflector simplifying the mechanical design. A compact MMIC receiver implementation that lowers the system mass and power makes the system well

suited for deployment on smaller-class satellites. The polarimetric measurement is made using an integrated, fully-polarimetric receiver that cross-correlates dual-linearly polarized inputs to form the complete set of polarimetric measurements as opposed to single independent radiometers for each polarimetric channel, as was done on WindSat. The successful demonstration of the COWVR instrument on-orbit will lead to a new generation of low-cost weather sensors supporting DoD operations.

Division 38 is building COWVR. It successfully completed its Instrument Requirements Review on August 8, 2013 and plans an instrument PDR on January 9, 2014. The CDR is scheduled for June 2014 with delivery in September of 2015.

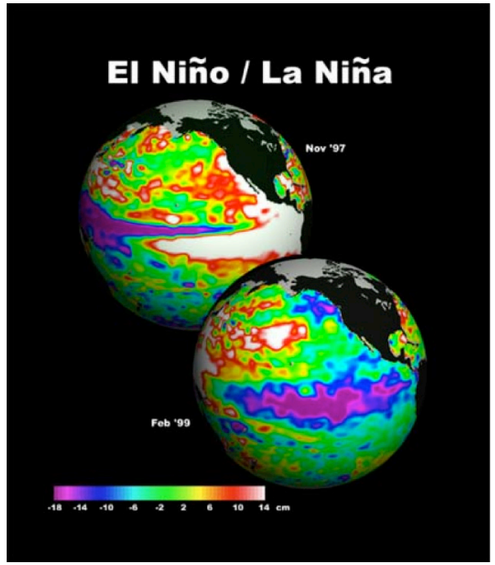
Jason-3 Advanced Microwave Radiometer (AMR)

POC: Ami Kitiyakara

Jason Heritage

The Jason-3 JPL Team

Supporting a continuation of the multi-decadal ocean topography measurements of Jason-1 and Jason-2, the Division delivered the Jason-3 Advanced Microwave Radiometer (AMR) for spacecraft integration and test in April 2013, with a planned launch in early 2015.



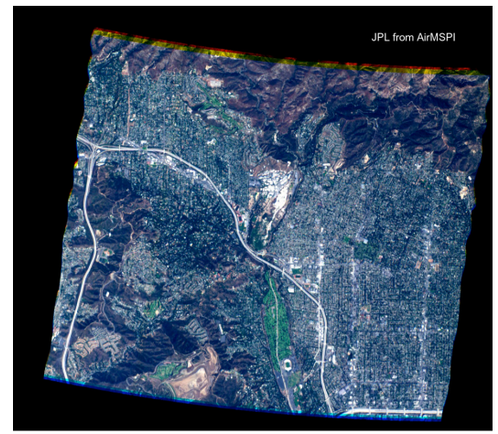
El Niño/La Niña

Signaling a transition to operational ocean altimetry, the National Oceanic and Atmospheric Administration (NOAA) and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) now lead the Jason-3 mission, with NASA/JPL and Centre National d'Études Spatiales (CNES) providing implementation support. Among Jason's key roles is 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 for hurricane forecasting and individual storm severity.

The AMR measures the altimeter signal-path delay due to tropospheric water vapor, a key requirement in meeting the Jason-3 objectives. The Jason-3 AMR maximizes the design inheritance from the successful Ocean Surface Topography Mission (OSTM) AMR instrument, while incorporating innovations in design, microassembly processes and radiometric screening that reduce both development and performance risk. These improvements, derived from lessons learned on both OSTM AMR and Juno Microwave Radiometer (MWR), help position the Division as a leader in ultra-stable radiometer design.

Airborne Multi-angle SpectroPolarimetric Imager (AirMSPI)

PI: David Diner (JPL Science Division)
POC: Sven Geier



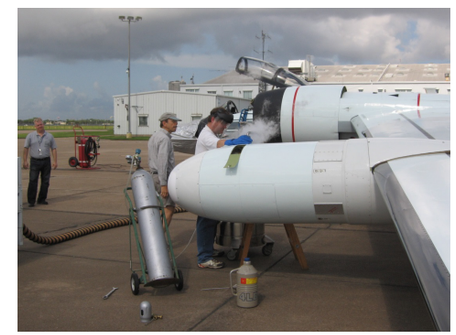
JPL and the Rose Bowl as seen from ~70,000 ft. altitude by AirMSPI's R, G and B, visual light channels.

AirMSPI was flown successfully in three independent campaigns: (1) the Polarimeter Definition Experiment (PODEX) in conjunction with two other polarimeters, Hyperspectral Infrared Imager (HySPIRI) and Airborne Visible InfraRed Imaging Spectrometer (AVIRIS); (2) MODIS/ASTER Airborne Simulator (MASTER) for cross and mutual calibration and to inform aerosol retrieval and finally (3) Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) from Houston, TX, as part of a suite of 41 instruments flown on several airplanes over the course of a couple of months to study the composition of clouds and their interaction with aerosols, smoke, smog, and the relationship with hurricane formation.

Meanwhile, work on the AirMSPI2 successor that will extend the high-precision imaging polarimetry into the short-wave infrared continued to the stage of Focal Plane Array (FPA) testing and filter integration. The new optical bench has been finished and aligned, with test flights of the new instrument are planned for the early months of calendar year 2014.

Airborne Scanning Microwave Limb Sounder (A-SMLS)

PI: Nathaniel Livesay
(JPL Science Division)
POC: Paul Stek



JPL engineers top off the liquid helium in A-SMLS immediately before a test flight on NASA's WB-57.

The Airborne Scanning Microwave Limb Sounder (A-SMLS) is a new airborne atmospheric composition sensor developed through the Earth

Science Technology Office (ESTO) Instrument Incubator Program (IIP). A-SMLS was developed as a prototype and component test bench for advanced microwave limb sounders such as the one proposed for the Global Atmospheric Composition Mission (GACM) in the 2007 Earth Science Decadal Survey. It also can serve as a valuable tool for focused field campaigns measuring composition (humidity, O_3 and CO concentrations, for example) and transport in the upper troposphere/lower stratosphere (UT/LS). Mounted in a spear pod on the wing of NASA's high-altitude WB-57 aircraft, A-SMLS measures thermal molecular emission in the 220 to 250-GHz frequency band horizontally in front of the aircraft. A hemispherical High Density Polyethylene (HDPE) radome with an antireflective Porex coating replaces the standard spear pod nose cone. A 20-cm gimbaled mirror scans the instrument's field of view ±5° in elevation and ±30° in azimuth. The incoming beam is then focused into a sideband separating superconducting insulator superconducting (SIS) mixer developed with devices from the Division's Microdevices Laboratory (MDL), where it is downconverted to a band from 6 to 18 GHz. A chopper, scan mirror, and partially-reflecting beam-splitter within the optical path allow the receiver to be calibrated using a zenith cold-sky view, an 80 dB return-loss calibration load, and a swept calibration tone. The bands of interest are then selected with a bandpass filter, downconverted to baseband, and analyzed using two 3-GHz-wide digital polyphase spectrometers. Four test flights have been flown. It is currently being upgraded for operation on NASA's ER-2.

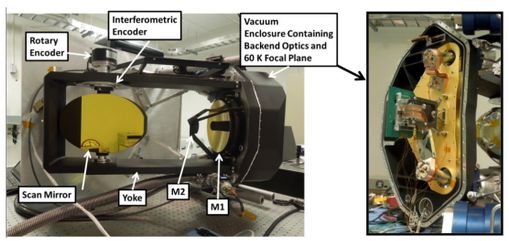
Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)

PI: Simon Hook (JPL Science Division)
POC: Renaud Goullioud

The Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) is an engineering model of the thermal infrared radiometer on the future Hyperspectral Infrared Imager (HyspIRI) mission. PHyTIR is developed under the Earth Science Technology Office Instrument Incubator Program (IIP) in order to reduce cost and risk for the HyspIRI thermal instrument.

In fiscal year 2013, the fabrication and integration of the prototype radiometer was completed. Teledyne delivered two copies of the focal plane containing the custom 13.2-µm-cutoff mercury-cadmium-telluride (MCT) infrared detector arrays. One detector array has been integrated in the radiometer, with three spectral filters on the focal plane, covering 3 spectral bands in the 4-12 µm range. Functional testing of the constant-speed rotating double-sided scan mirror that allows the telescope to view the large nadir crosstrack swath as well as two internal blackbody calibration targets is under way.

Performance testing of the Prototype HyspIRI Thermal Infrared Radiometer will be completed by April 2014.

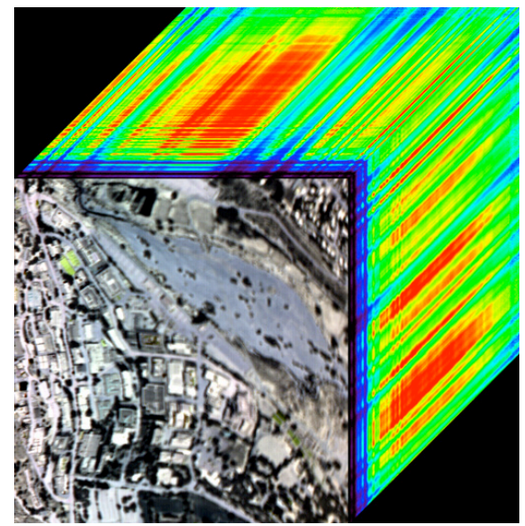


The Prototype HyspIRI Thermal Infrared Radiometer (left) undergoing testing. Zoom inside the back-end vacuum enclosure (right).

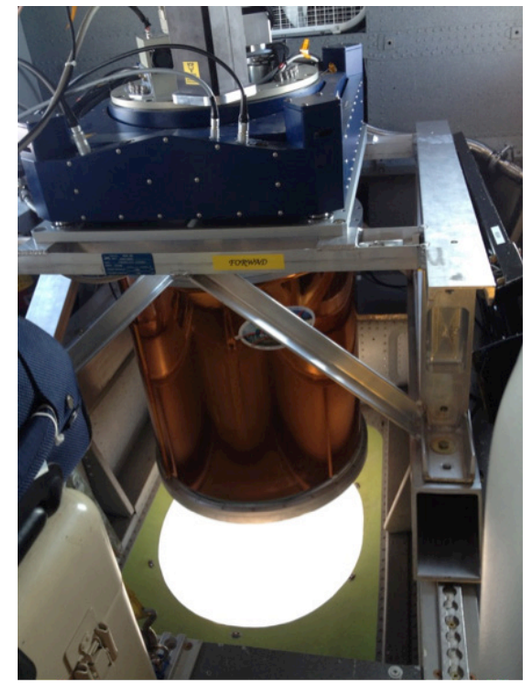
Hyperspectral Thermal Emission Spectrometer (HyTES)

PI: Simon Hook (JPL Science Division)
POC: William R. Johnson

Division 38 is in collaboration with the Earth Surface Science Group and the Instrument Software and Science Data Systems section (JPL Division 39) to develop the Hyperspectral Thermal Emission Spectrometer (HyTES). HyTES is the premier airborne Earth-observing thermal imaging spectrometer for Earth science. It was developed under NASA's Instrument Incubator Program (IIP) and would not be possible without numerous essential components developed at the Division's Microdevices Laboratory (MDL). At its heart is an MDL-fabricated quantum well infrared photodetector (QWIP) array that provides unsurpassed uniform response of both spatial and spectral information. This is the first science-grade, dual-band sensor that provides extended coverage for the complete long-wave infrared atmospheric window. A compact Dyson optical relay is used to spread light across an MDL electron-beam-fabricated concave diffraction grating. The grating provides very high efficiency across the instrument's 7.5- to 12-mm passband. The incoming field rays from the instrument's telescope are perfectly sliced using an MDL-made slit. The slit is formed using reactive ion etching and is a standard with respect to precision. This component allows the spectrometer in part to have essentially zero crosstalk between spectral channels. All of these technologies combined to create an instrument that sets itself apart from others. In April 2013, HyTES made its first science flight on a Twin Otter aircraft. It flew over test and calibration sites such as Cuprite, Nevada, Death Valley, and Lake Tahoe. The remotely-sensed measurements from HyTES agree well with in-situ field measurements both in temperature retrieval and material characterization. HyTES was also able to positively detect ammonia (NH_3) leaks from the Salton Sea active fumaroles, and methane (CH_4) seeps off the Santa Barbara coast. Preliminary data analysis indicates excellent spectrometer radiometric performance.



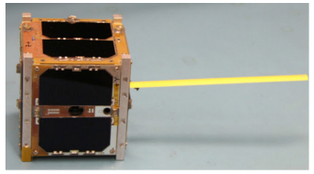
HyTES spectral image cube of JPL.



HyTES mounted in Twin Otter aircraft looking NADIR during flight.

CubeSat Onboard Processing Validation Experiment (COVE-2)

PI: Paula Pingree



(L) Michigan Multipurpose Minisatellite (MCubed-2), the CubeSat developed by the University of Michigan that hosts the COVE-2 payload. (R) The COVE-2 payload developed by JPL/Section 389, which features the Xilinx Virtex-5QV FPGA.

This technology validation task was funded by NASA's Earth Science Technology Office (ESTO) as a re-flight mission for $250K that successfully launched on December 5, 2013 from Vandenberg Air Force Base (VAFB) as a secondary payload of the L-39 GEMSat mission. The original MCubed/COVE was launched as a secondary payload of the NPP mission from VAFB on October 28, 2011. That mission experienced an on-orbit anomaly that resulted in the inability to command the CubeSat, thereby prohibiting demonstration of the COVE payload. MCubed-2 conforms to the CubeSat 1U specification (1U = 10 cm x 10 cm x 10 cm) and contains a primary camera payload. COVE-2 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 (Principal Investigator: Dave Diner - Division 32). The COVE board interfaces to the University of Michigan's M-Cubed spacecraft processor to receive Earth image data from the onboard camera that is then processed by the algorithm. The image, onboard image processing results, and housekeeping telemetry are to be downlinked for validation of the Virtex-5 FPGA and the MSPI algorithm.

GEOstationary Coastal and Air Pollution Events (GEO-CAPE) Readout Integrated Circuit (ROIC) In-flight performance Experiment (GRIFEX)

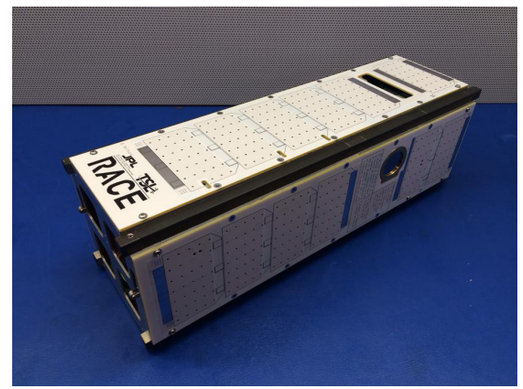
PI: David Rider (JPL Science Division)
OC: Paula Pingree

(L) Assembled Engineering Model GRIFEX payload with Marina board, ROIC Detector board, and spider mount with commercial camera lens. (M) Marina processing board. (R) ROIC Detector board.

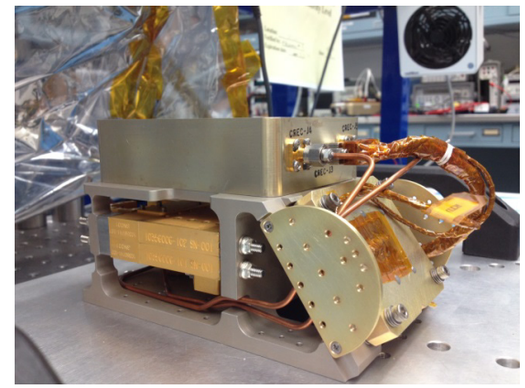
The Division, in collaboration with the GRIFEX Principal Investigator, is nearing launch in 2014 of a CubeSat flight validation experiment for space-borne performance verification of a state-of-the-art 128 x 128 fast frame ROIC/Focal Plane Assembly (FPA). The ROIC was developed for the Panchromatic Fourier Transform Spectrometer (PanFTS, Principal Investigator Stanley Sander – Division 32), a JPL instrument under development for the GeoCAPE mission. Funded by the Earth Science Technology Office (ESTO), the GRIFEX high-throughput digital Focal Plane Array (FPA) dramatically reduces the size, power, mass, risk, and cost of FPA and signal chain electronics for certain Earth-observing measurements. The ROIC was developed with ESTO 2008 Advanced Components Technology (ACT) funding and contains an innovative analog-to-digital converter (ADC) circuit built into each of the 16,384 pixels to provide direct digital output proportional to the irradiance at high readout rates. The GRIFEX payload packages the hybrid FPA with a commercial camera lens and interfaces it to a compact data acquisition and processing system called Marina. Marina is the next generation of the payload processor platform called COVE (CubeSat On-board processing Validation Experiment), based on the Virtex-5 FPGA. The Marina and ROIC Detector electronics boards were designed and developed by Section 389 engineers. The 1U (10x10x10-cm) JPL-developed GRIFEX payload will be delivered to the University of Michigan for integration into a 3U (10x10x30-cm) CubeSat. GRIFEX has been manifested by the NASA CubeSat Launch Initiative (CLI) as a secondary payload of the SMAP mission, scheduled for launch from Vandenberg Air Force Base in October 2014.

Radiometer Atmospheric CubeSat Experiment (RACE)

PI: Boon Lim
POC: Alexander Kadesch



Race Spacecraft



Race Instrument

JPL is developing RACE, which consists of a water vapor radiometer integrated on a 3U (10x10x30cm) CubeSat platform. RACE will measure two channels of the 183-GHz water vapor line, and will be used to validate new low-noise amplifier technology and internal calibration methodology. RACE will advance the Technology Readiness Level (TRL) of the 183-GHz receiver subsystem from TRL 4 to TRL 6 and a CubeSat 183-GHz radiometer system from TRL 4 to TRL 7. JPL is partnered with the University of Texas at Austin, which is providing the CubeSat, and will integrate the 1.5U payload. RACE will be launched by the NASA CubeSat Launch Initiative (CSLI), with expected launch in the second quarter of 2014.

INSTRUMENTS DIVISION

Operational Missions

ANNUAL REPORT FY 2013

Astrophysics

Herschel Heterodyne Instrument for the Far-Infrared (HIFI)

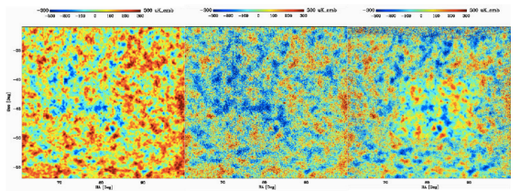
PI: Frank Helmich (Space Research Organization of the Netherlands)
US PI: Thomas Phillips (Caltech)
POC: John Pearson

The Herschel Space Observatory (a European Space Agency mission with NASA participation) completed its operational phase in April 2013, when the onboard liquid helium was exhausted. The mission successfully completed all scientific and technical objectives, and the spacecraft has been successfully disposed. Division 38 supplied advanced local oscillator and detector components to the Heterodyne Instrument for Far Infrared, HIFI. All JPL-supplied components successfully completed the mission with no failures or measureable performance changes in any component after 4 years of on-orbit operations. The required 3-year operation was exceeded by several months allowing many of the priority 2 observations to be executed. Overall, the HIFI instrument was revolutionary to long-wavelength astrophysics and leaves an extensive legacy of technical and scientific successes. Many observational results are only beginning to be understood.

The remaining tasks for HIFI are capturing the state-of-the-art instrument calibration and preparing the data archive. HIFI calibration errors are dominated by standing waves changing the ratio of upper and lower sidebands in the receivers. In HIFI, this error is typically on the order of 5% in absolute flux. The results of modeling and data reduction are being implemented in the data pipeline and will result in an improved calibration for the archival data products. Phase F of HIFI will be completed in 2016, when the science data archive is completed.

Planck High & Low Frequency Instruments (HFI & LFI)

LFI PI: Reno Mandeloi
(Instituto Astrofisica Spaziale E Fisica Cosmica, Bologna, Italy)
LFI US PI: Charles Lawrence
(JPL Science Division)
HFI PI: Jean Loup Puget
(Institute Astrophysique Spatiale, Université Paris XI)
HFI US PI: James Bock (Caltech)
POC: Warren Holmes



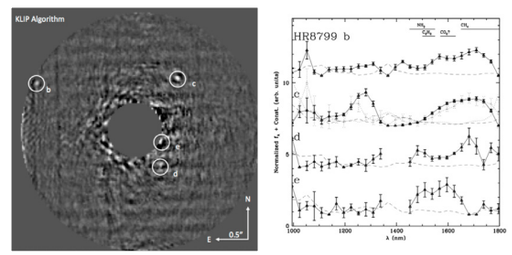
Comparison of Planck 143 GHz band with the same region of sky covered by WMAP (center) and Boomerang. Spiderweb bolometers (SWBs) and polarization-sensitive bolometers (PSBs) made in the Division's Microdevices Laboratory were used for Planck and Boomerang.

The shutdown command to the ESA-managed Planck spacecraft was sent on October 23, 2013. Planck was launched on May 14, 2009. Planck consists of a radiometer-based Low Frequency Instrument (LFI) and a bolometric High Frequency Instrument (HFI), which together have mapped the intensity and polarization of the entire sky in nine discrete frequency bands from 30 to 857 GHz. The Division-made 20K sorption cooler, which operates continuously up to the end of the mission, cools the LFI. The HFI contains Division-made spiderweb bolometers (SWB) and polarization-sensitive bolometers (PSBs) cooled to 100 mK by a continuous-cycle dilution refrigerator operated through to January 16, 2012. In total, HFI completed five full-sky surveys and LFI completed nearly nine, far exceeding the mission goal of two full-sky surveys. In addition, the SWB and PSB met goal sensitivities in each detector set by the statistics of the photon flux.

On March 21, 2013, the complete maps of the intensity measured in each of the nine bands from the first year of the Planck survey were released to the public. The Planck sky maps are now the benchmark measurements of the mm-wave Universe, replacing Wilkinson Microwave Anisotropy Probe (WMAP) as shown in the figure. Analysis of the Planck data is consistent with inflation and shows that the Universe is slightly older than thought. Additionally, a benchmark mm and sub-mm wavelength emission of the zodiacal light, planetary flux and point sources were released. Twenty-two manuscripts detailing analysis and results from the Planck maps were submitted for journal publications and are expected to be published in 2014. Additional public release of the full Planck survey will occur in late 2014.

Palomar Adaptive Optics

POC: Rick Burruss



Left: HR8799 star system, with exoplanets B, C, D, and E marked. Right: The spectra of the B, C, D, and E exoplanets.

PALM3000 is a facility-class adaptive optics instrument at Palomar Observatory, developed as a joint project between JPL and Caltech. The system Graphic Processing Unit (GPU) enables a 3,388-actuator deformable mirror controlled by real-time software running on multiple GPU processors. To date, PALM3000 has achieved an average Strehl ratio of 83% on stars brighter than 7th magnitude (mv) in the Ks band, and 15% on stars as faint as 14.5 mv. For reference, a 7th mv star may be just barely visible to the naked eye even in the darkest skies, and a 14th mv star is a thousand times fainter than that.

Five science instruments are available to astronomers working with PALM3000, one of which is the P1640 coronagraph / integral field spectrograph (developed at the American Museum of Natural History) coupled with a wavefront sensing calibration unit, also developed at JPL. The P1640/PALM3000 team published results in early 2013 showing the first simultaneously-recorded spectra of multiple planets orbiting the star HR8799. The P1640 team is now conducting a survey of other potential exoplanet systems, and will be releasing new results soon. The PALM3000 team is working in fiscal year 2014 on instrument optimizations, including the ability to guide on stars as faint as 16th mv.

Earth Science

Portable Remote Imaging SpectroMeter (PRISM)

PI: Pantazis Mouroulis

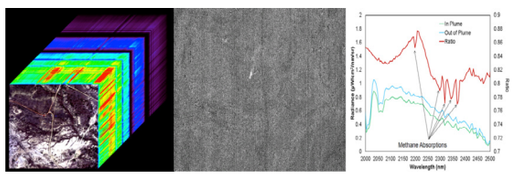
The coastal zone is home to a high fraction of humanity and is increasingly affected by natural and human-induced events from tsunamis to toxic tidal blooms. Current satellite data provide a broad overview of these events but do not have the necessary spectral, spatial and temporal resolution to characterize and understand these events. To address this gap, a compact, lightweight, airborne Portable Remote Imaging SpectroMeter (PRISM) compatible with a wide range of piloted and Uninhabited Aerial Vehicle (UAV) platforms is currently being developed at JPL. Operating between

the spectral range of 350 nm and 1050 nm, PRISM will offer high-temporal-resolution and below-cloud flight altitudes to resolve spatial features as small as 30 cm. The sensor performance exceeds the state of the art in light throughput, spectral and spatial uniformity, and polarization insensitivity by factors of 2-10, while at the same time extending the spectral range into the ultraviolet. PRISM will also have a two-channel spot radiometer at the short-wave infrared (SWIR) band (1240 nm and 1640 nm). It will be in co-alignment with the spectrometer in order to provide accurate atmospheric correction of the ocean color measurements.

The development of the PRISM instrument is supported by NASA Earth Science Division's the Ocean Biology and Biogeochemistry, Earth Science Technology, and Airborne Sciences programs within NASA's Earth Science Division.

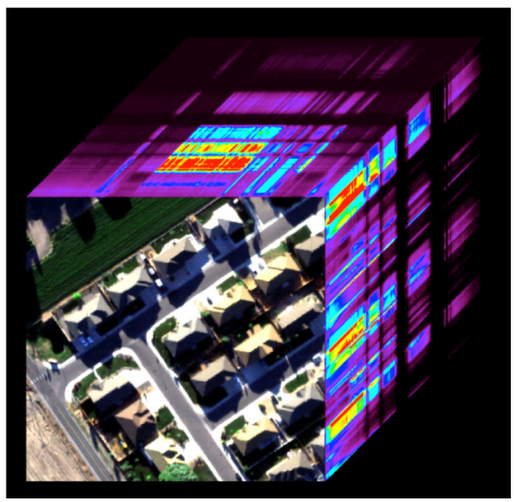
Next Generation Airborne Visible & InfraRed Imaging Spectrometer (AVIRIS-NG)

PI: Robert Green



AVIRIS-NG image cube over methane release area (left). Methane plume map derived from AVIRIS-NG spectra (center). AVIRIS-NG measured spectra in and out of the methane plume and a ratio showing the enhanced methane absorption above the natural background in the plume.

The Next Generation Airborne Visible & InfraRed Imaging Spectrometer (AVIRIS-NG) was calibrated and deployed with a new high-rate data-capture system to support the methane-release experiment led by Dr. Andrew Aubrey at the Department of Energy's Rocky Mountain Oil Field Test Center (RMOTC). AVIRIS-NG measures across the spectral range from 380 to 2510 nm at 5 nm spectral sampling with a calibrated, high-signal-to-noise-ratio spectrum measured for every spatial sample in the image. With rapid data turnaround, methane was detected and measured by AVIRIS-NG at RMOTC in the 2,150- to 2,400-nm spectral range. This capability to detect and measure methane point sources with imaging spectroscopy is of interest both for greenhouse gas research and natural resource exploration. In conjunction with this experiment, AVIRIS-NG demonstrated a new real-time cloud-screening algorithm applicable for space imaging spectrometer missions. At the conclusion of the RMOTC deployment, AVIRIS-NG validated its high-spatial-resolution capability with 200-mm spatial sampling. AVIRIS-NG is being prepared for experiments in the 2014 flight season for NASA's science and applications research.

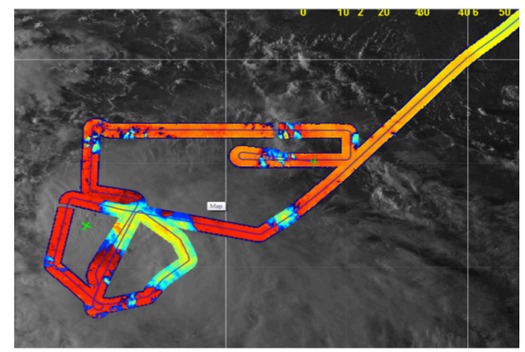


New high spatial resolution imaging spectroscopy measurement capability demonstrated by AVIRIS-NG in 2013. Ground sampling distance of 200 mm achieved for the first time.

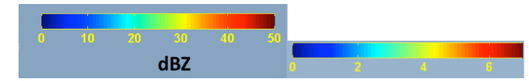
High Altitude MMIC Sounding Radiometer (HAMSR)

PI: Bjorn Lambrigtsen (JPL Science Division)
Instrument Manager & POC: Shannon Brown

In 2013, HAMSR, a state-of-the-art microwave sounder built and operated by JPL, once again ventured back east to Wallops Flight Facility to peer into the inner workings of hurricanes from high above on the Global Hawk Unmanned Aerial Vehicle. However, while HAMSR was ready to show off its newest technology, nature wasn't so cooperative. This season was the 2nd flight year of the Hurricane and Severe Storm Sentinel (HS3) NASA Earth Ventures Mission and the first hurricane season since 2002 without a named hurricane in August. In fact, the first hurricane of the season didn't form until September 11, toward the end of the campaign. But HAMSR did participate in 5 flights, two of which sampled tropical storm systems that ultimately didn't form into strong storms, which is just as scientifically valuable as observing storms that do strengthen. During these flights, the upgraded HAMSR real-time data system was revealing the thermodynamic state and storm structure that was used by the mission scientists and pilots to guide the plane toward meteorologically-interesting targets.



HAMSR



HAMSR

An example of one of the new displays, showing an overlay of precipitation with total precipitable water vapor (TPW), is shown in the figure. The plot shows that the atmosphere was fairly moist in and around the storm (TPW >5cm), but slightly drier in the rest of the Gulf (TPW ~4cm), and that most of the precipitation was observed on the northeast side of the storm, with some isolated convective cells to the north and south of the storm center.

Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)

PI: Charles Miller (JPL Science Division)
Project Manager and POC: Steve Dinardo

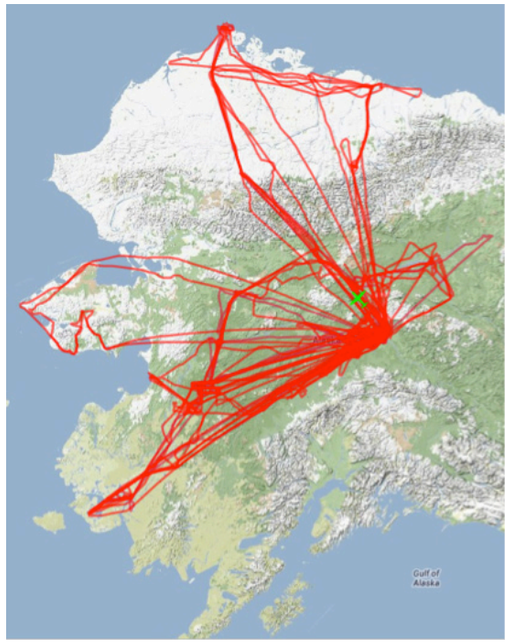
The Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) quantifies correlations between atmospheric and surface state variables for the Alaskan terrestrial ecosystems through intensive seasonal aircraft campaigns, ground-based observations, analysis and modeling sustained over its 5-year duration. The data will be used in a multidisciplinary investigation to determine spatial and temporal patterns, sensitivity to change, and potential responses of Arctic carbon budgets to observed and projected climate change.

The 2013 CARVE instrument system includes CARVE's custom navigation and logging system, which time-tags and geolocates data from the following probes and instruments: outside air temperature, relative humidity probes and ozone sensor, two Picarro real-time gas analyzers (CH_4, CO_2, CO, H_2O), a Fourier Transform Spectrometer (FTS), two Programmable Flask Packages (PFP) and a Forward Looking Infrared (FLIR) (1024 x 1024) Thermal Infrared camera.

The CARVE aircraft was deployed to Fairbanks, Alaska from April to October 2013. During this entire period, once a month for a two-week period, the CARVE flight crew observed over various locations, including the North Slope, Barrow, Prudhoe Bay, Nome, Unalakleet, Innoko Valley, Minto Valley, Fort Yukon, Bethel, and Bettles.

In 2013, CARVE achieved the following major milestones: all 2012 level-2 data were released to the public; CARVE flew over 260 Alaskan science flight hours, in 45 flight days; and on July 6, 2013, CARVE exceeded the Program-Level Requirements Appendix (PLRA) Threshold requirement of flying 320 science flight hours.

CARVE is very close to the next major milestone, the PLRA Baseline requirement of 500 science flight hours in three years. Currently, CARVE's combined science flight hours for 2012 and 2013 total 465 hours. The CARVE team is looking forward to making these measurements again in Alaska in 2014 and 2015.



CARVE 2013 flight tracks, radiating from Fairbanks, AK.

Instruments Division

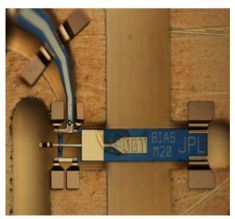
Technology Development

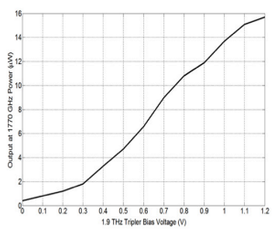
ANNUAL REPORT FY 2013

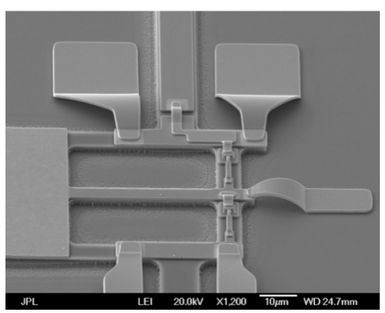
Demonstration of a bias-able 1.9 THz source

POC: Imran Mehdi

Measurements of the C+ molecule have been a key feature of the HIFI instrument on Herschel, and for future missions it would be desirable to have multi-pixel arrays to increase science throughput. The single-pixel 1.9THz receiver on the Herschel HIFI (HIgh FIdelity) instrument used a bias-less 1.9THz tripler, and thus it was not easy to adjust the power coupling between the local oscillator chain and the mixer. During fiscal year 2013 Division technologists designed, fabricated and demonstrated a 1.9THz tripler with biasing capability. The chip, mounted in a waveguide block, is shown in the frame along with a scanning electron micrograph of the anode area of the chip. The measured results show that the output power at 1.9THz can be controlled with bias. This is an important development for multi-pixel receiver architectures for future missions.



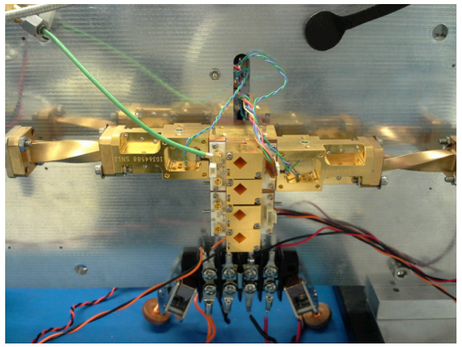




Demonstration of a 4-Pixel 340GHz Radar Transceiver Array

POC: Ken Cooper

Previously, submillimeter-wave radar transceivers were built piecemeal from discrete components, with each housed in its own machined-metal block. Now, Division technologists working in the Microdevices Laboratory have combined silicon micromachining technology with an innovative, fully-integrated packaging design to build a 340GHz radar transceiver array with a volume that is two orders of magnitude smaller than before. The figure shows a four-element transceiver array that includes integration in silicon of eight 120GHz power amplifiers, eight 340GHz triplers, four 340GHz mixers, and four 340GHz waveguide hybrid couplers. This system may enable high-pixel density, video-rate radar imaging for national security as well as scientific applications.

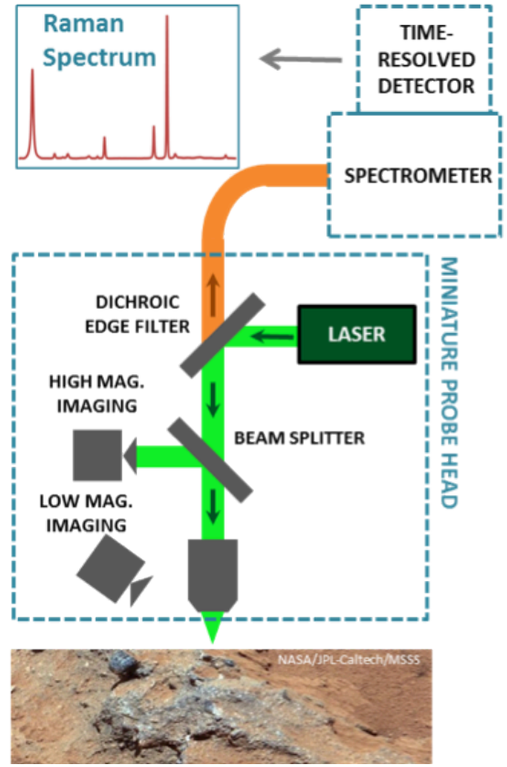


Four-element transceiver array

Time-resolved Raman Spectroscopy for Planetary Surface Exploration

POC: Jordana Blacksberg

Raman Spectroscopy has been steadily gaining support as a means for using laser spectroscopy to identify mineral phases and their composition, as well as organic compounds present within the mineral matrices. With a laser spot size smaller than the mineral grains of interest, microscopic Raman spectroscopy can provide surface mapping of mineralogy while preserving morphology. A very small laser spot size (~1 µm) is often



Time-resolved Raman spectroscopy

necessary to identify minor phases that can be of greater interest than the matrix phases. In addition to the difficulties that can be posed by fine-grained material, fluorescence interference from the very same material is often a serious problem. This is particularly true for many minerals of interest that form in environments of aqueous alteration. By exploiting the time difference between the Raman and later fluorescence responses to a laser pulse, the Division is developing a next-generation instrument that builds on the widely used 532-nm Raman technique to provide a means for performing Raman spectroscopy. Time-resolved laser spectroscopy eliminates the bright-fluorescence interference that can often dominate faint Raman spectra. The most significant advance leading to the feasibility of a compact, time-resolved Raman spectrometer is the development of a custom solid-state detector capable of sub-nanosecond time resolution.

Mars Microbeam Raman Spectrometer

POC: Jim Lambert

In June 2013, the Mars Microbeam Raman Spectrometer and a light field imaging camera were integrated with a carousel drill system on a rover during two weeks of field-testing in the Atacama Desert, Chile. The rover autonomously controlled the drill, carousel, and both the camera and spectrometer as it searched for subterranean signatures of life and characterized subsurface geology over a 50-km trek. The light field imaging system provided a means of performing synthetically focused macroscopic imaging of the drill samples using no moving parts (postprocessing only) while the Raman instrument

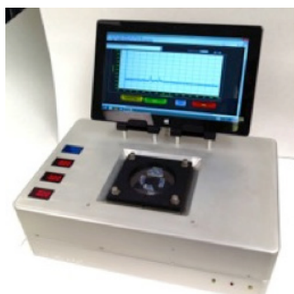
Mars Microbeam Raman spectrometer at the Atacama Desert

provided the capability of identifying biogenic materials and minerals conducive to microbial life, such as hydrated sulfates and carbonates. This effort and others like it are used to field-test instruments in a simulated Martian environment as they are being matured for future development into flight instruments.

Microfluidics

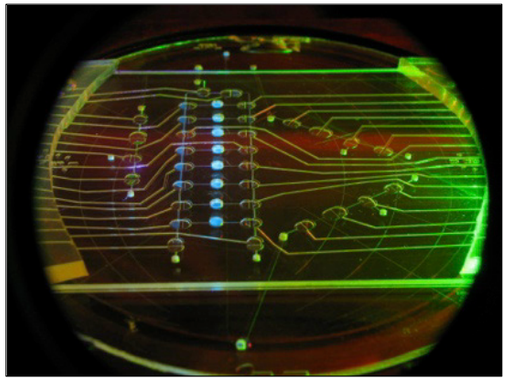
POC: Peter Willis

The Division's goal in developing lab-on-a-chip technologies is to provide chemical analysis systems that are capable of performing high-sensitivity chemical investigations on liquid samples, especially those that contain non-volatile organic compounds (such as amino acids) that are not readily analyzed by standardized gas-phase chromatography techniques. In 2013 the Division, along with SBIR partners at Los Gatos Research, developed several new methods for analyzing liquid samples, packaging



The Chemical Laptop, a reprogrammable portable microfluidics workstation.

them into a portable instrument called the Chemical Laptop. This versatile instrument, which uses a standardized microchip, can easily be configured for different analyses merely by changing reagents and "reprogramming" the sequence of operations. In addition to developing the Chemical Laptop system, the Division also developed new methods for automated chemical analysis of sulfur-bearing thiol compounds, long-chain amine species and fatty acids, as well as several new analysis methods that,

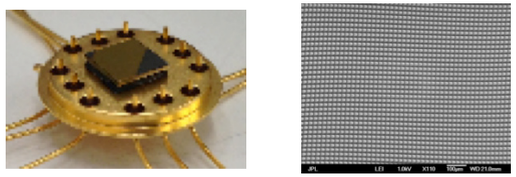


Standardized microchip for analyzing liquid samples.

instead of aqueous solutions, use ethanol and other organic solvents. These can be cooled far below zero Celsius without freezing, enabling an extended range of operational conditions during in situ missions.

Active and Passive Components for Harsh/ Extreme Environments

POC: Harish Manohara



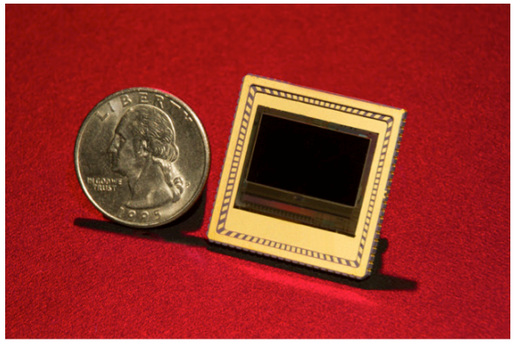
(Left) Triode electrode stack created using the micro-assembly process (first version delivered and tested at the sponsor site.) (Right) Scanning electron micrograph of a micromachined, multilayered silicon post capacitor (delivered and tested at the sponsor site.)

By integrating Division-developed carbon nanotube field-emission electron sources with micro-machined silicon, ceramic, and/or metal components, a new class of vacuum microelectronic devices has been developed for harsh/extreme environments such as Venus and Jovian neighborhoods, as well as for oil/gas, geothermal, and defense applications. The devices are fabricated by employing a combination of monolithic fabrication and hybrid micro-assembly processes. The active devices are carbon nanotube-based vacuum diodes and triodes that have been demonstrated as vacuum-packaged stand-alone devices with emission currents tending to 1.2 mA. The passive components are high-temperature capacitors with capacitance ranging from tens to hundreds of nF, fabricated in the Microdevices Laboratory using micro-machined silicon post arrays with multiple metal and dielectric layers. These have been shown to suffer less than 1% degradation when tested at ~200° C for 1000 hours.

Infrared Focal Plane Arrays

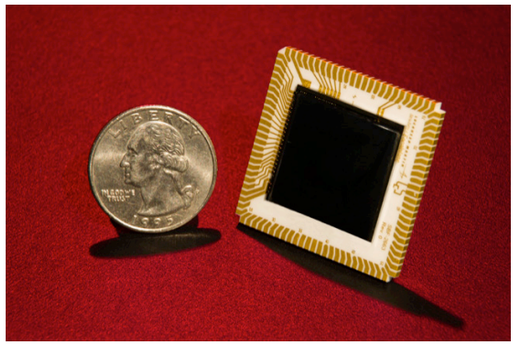
POC: Sarath Gunapala

The Division's Center for Infrared Photodetectors (CIP) developed and delivered both High-Definition



The first antimonides superlattice-based HDTV-format long-wavelength infrared focal-plane array delivered to the customer for the infrared imaging application.

Television (HDTV) format and megapixel mid-wave infrared high-operating-temperature Barrier InfraRed Detector (HOT-BIRD) focal plane arrays (FPAs) to several customers. In addition, the CIP has developed and delivered the first BIRD-based long-wave infrared HDTV-format FPAs. Both HDTV and megapixel FPAs had >99% pixel



The first antimonides superlattice-based megapixel long-wavelength infrared focal-plane array developed in Microdevices Laboratory (MDL).

operability. This in-house infrared FPA development is very important for JPL instruments, as it will help JPL rapidly develop and prototype low-cost, high-performance imaging and spectral imaging instruments for astrophysics, Earth, and planetary science applications.

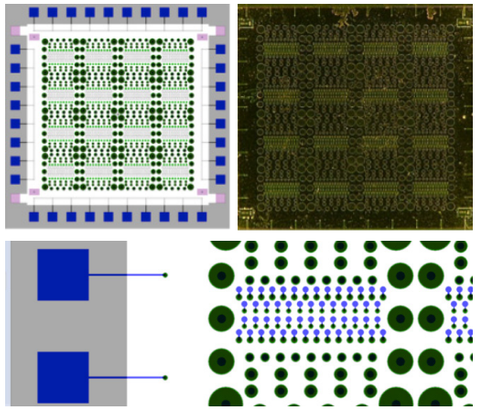
Solar Blind UV detectors with GaN and AlGaN avalanche photodiode arrays and photocathodes

POC: Shouleh Nikzad

In an effort funded under the NASA Planetary Instrument Definition and Development Program (PIDDP), the Division is developing high-performance avalanche photodiode arrays by employing design parameters selected to optimize detection and multiplication functions, processing

and Atomic Layer Deposition (ALD) passivation techniques, and improved materials that were developed in collaboration with SUNY-Albany.

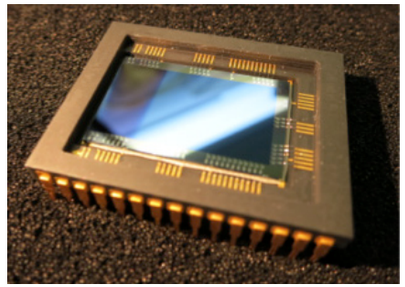
The Division is also pursuing a unique approach, recently funded under the NASA Astronomy and Physics Research and Analysis (APRA) Program, for developing GaN and AlGaN photocathodes without requiring the use of highly reactive cesium. These photocathodes are slated for use in photoemissive solar blind UV detectors.



UVdetector top right, UVdetector top left, UVdetector bottom: High-efficiency ultraviolet/visible/NIR array detector arrays for photon counting and broadband application.

In collaboration with Caltech, Columbia University, and Arizona State University, the Division is also developing detectors for future missions with factors of five or more efficiency improvement over detectors previously flown.

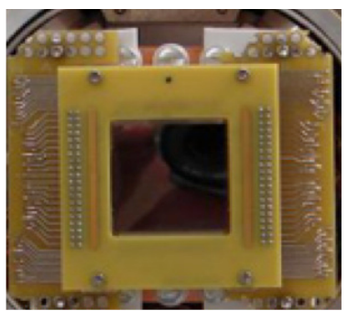
In addition, the Division is developing delta-doped, Electron Multiplied Charge-Coupled Device (EMCCD) photon-counting detectors enhanced with AntiReflection (AR) coatings. A two-megapixel version has recently been fabricated and is being prepared for a high-altitude balloon flight as part of the Faint Intergalactic Redshifted



Two-megapixel FIREBall EMCCD array

Experiment Balloon (FIREBall) mission to map faint emissions from the intergalactic medium.

The Division is developing a broadband (NUV-to-NIR) detector for future missions such as MIDEX-Orion (Paul Scowen, PI at ASU), which requires two broadband detectors to cover the entire 200-1000 nm range in a dichroic instrument. The detectors employ delta doping and Atomic Layer Deposition (ALD)-deposited custom AR coatings in a fully depleted, thick silicon imager. A 3.5K x 3.5K version of the detector has been delivered to the University of Colorado for flight in the Colorado High-resolution Echelle Stellar Spectrograph (CHESS) is a rocket-borne instrument that will serve as a pathfinder for future high-sensitivity, high-resolution UV spectrographs.

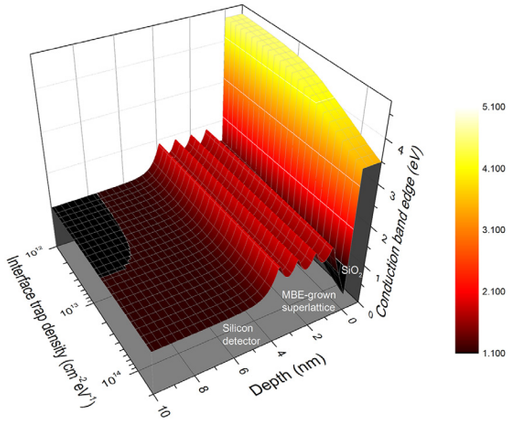


3.5-K X 3.5-K AR-coated broadband CCD for use in the Colorado High-resolution Echelle Stellar Spectrograph.

High-Performance, Deep UV Camera with a Superlattice-Doped CMOS Imaging Detector

POC: Michael Hoenk

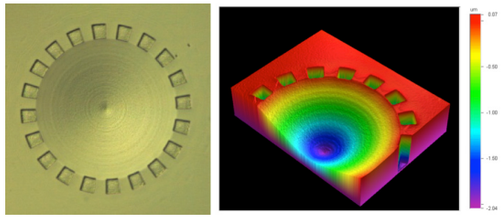
The Division and Alacron have recently developed a high-performance, deep-UV (DUV) camera with a superlattice-doped complementary metal–oxide–semiconductor (CMOS) imaging detector. Superlatticed-doped detectors achieve nearly 100% internal quantum efficiency in the deep- and far-ultraviolet, and a single-layer Al2O3 antireflection coating enables 64% external quantum efficiency at 263nm. In lifetime tests performed at Applied Materials using 263-nm pulsed, solid-state, and 193-nm pulsed excimer lasers, the quantum efficiency and dark current of the JPL/Alacron camera remained stable to better than 1% precision during long-term exposure to several billion laser pulses, with no measurable degradation, no blooming, and no image memory at 1000 frames per second. The technology is being transferred to industry for deep-UV wafer and reticle inspection.



Superlattice doping comprises multiple two-dimensional sheets of dopant atoms within a few nanometers of the detector surface, which screen the detector from DUV-induced damage up to interface-trap densities exceeding 10^{14} cm^{-2}eV^{-1}.

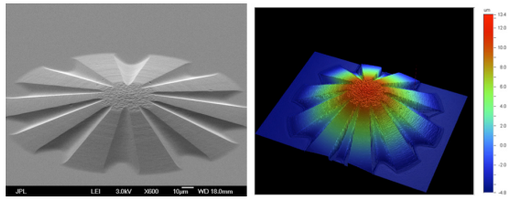
Grayscale Etched Silicon Surfaces

POC: Dan Wilson



Kevin Newman (Subaru Telescope and Univ. of Arizona)

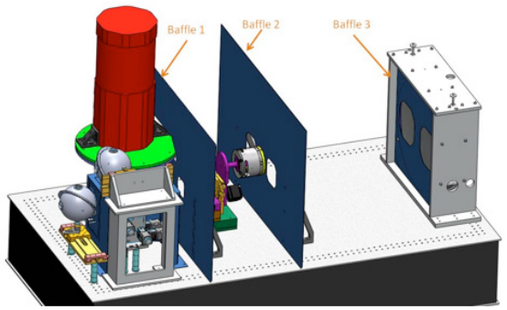
The Division developed a grayscale electron-beam lithography and plasma etching process for fabricating three-dimensional surface-relief profiles in silicon substrates. The etching process amplifies the depth of the grayscale e-beam resist pattern and thus can be used to realize shaped silicon structures that are tens of micrometers deep. This fabrication technique was successfully used to deliver achromatic infrared coronagraph occulting masks for testing at Subaru Telescope (for Olivier Guyon and Kevin Newman, University of Arizona). The technique is also being used as part of the process to fabricate shaped silicon needles for electrospray propulsion thrusters (Principal Investigator: Colleen Marrese-Reading, JPL).



Prototype silicon tips that are part of a process to fabricate shaped needles for electrospray propulsion thrusters (PI: Colleen Marrese-Reading, JPL).

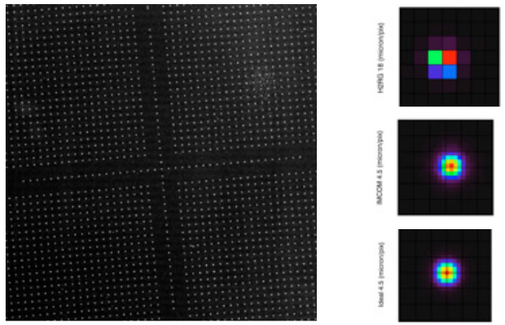
Projection System for Wide-Field Infrared Survey Telescope (WFIRST) Mission

PI: Jason Rhodes (JPL Science Division)
Co-I: Roger Smith
(Caltech Optical Observatories)
POC: Suresh Seshadri



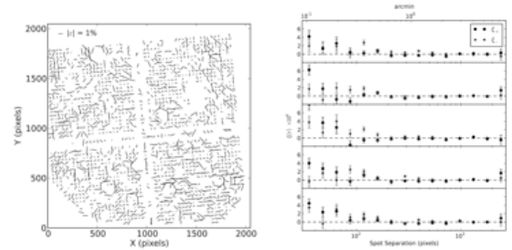
Schematic diagram of a high-fidelity projection system that is capable of emulating precision photometric, spectroscopic, astrometric and shape observations planned for future astronomy missions and mission concepts.

The Division, in collaboration with the Science Division and Caltech Optical Observatories, has built a projection system capable of performing precision photometric, spectroscopic, astrometric and shape measurements across the full field of visible and near-infrared image sensor arrays. This system is currently being used to emulate weak gravitational lensing observations for the NASA Wide-Field Infrared Survey Telescope (WFIRST) mission concept. A primary goal of WFIRST is performing cosmological observations to understand dark matter and dark energy, which together make up ~96% of the known matter and energy density of the universe. Weak gravitational lensing observations, which measure distortions in the shapes of background galaxies by foregrounding dark matter, are expected to be the most powerful probe of both dark matter and dark energy, provided that systematic measurement effects are understood and mitigated. The science goal is to show that reducing the residual correlation in complex galaxy shapes can be limited to $O(10^{-7})$. Our laboratory emulation will provide experimental data to identify effects important to the science and to develop sufficiently accurate calibration models to meet these very difficult accuracy requirements, which cannot be validated with simulations alone because of the presence of



(Left) Gravitational weak lensing emulation experiments measured the shapes of a grid of many thousands of 3-µm-dia. pinhole spots that simulate an under-sampled star field. (Right) (top) Normalized intensity profile of a single spot on the left. (Middle) Reconstructed image obtained from multiple, dithered images using the IMCOM algorithm. (Bottom) An ideal, simulated reference image is on the right illustrating the high quality of the reconstruction.

unmodeled and other artifacts in real detectors. Residual correlation in the shape of a relatively simple grid of pinholes simulating star fields, projected onto a candidate near-infrared array with spot position dithering to overcome raw image under-sampling, has been shown to be within $O(10^{-7})$ in scales of interest. In addition, the Caltech/JPL-developed IMage COMbination (IMCOM) algorithm used to reconstruct the images prior to shape measurements has been shown to create no significant distortions when the relative offsets between dithered images are precisely known.



(Left) Plot of the magnitude and angle of the ellipticity of each of the spots in figure above. (Right) Plot shows the residual correlation in shapes versus spot separation distance for five independent emulation experiments. The residual correlation is $O(10^{-7})$ for spot distances >0.5 arcmin, the WFIRST scale of interest.

Personal Alert and Tracking System (PATS)

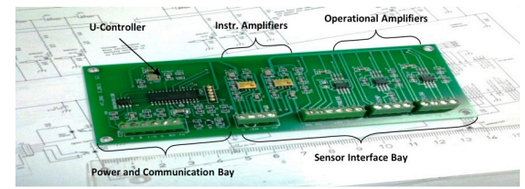
POC: Jim Lambert

PATS left & PATS right

The Personal Alert and Tracking System (PATS) network is an autonomous wireless sensor network that monitors and provides alerts to wildland firefighters in the field. PATS consists of multiple sensor nodes, a base station node and a Graphical User Interface (GUI). The sensor nodes and base station use the same hardware, but with minor variations to accommodate their different functionalities. The PATS network is accessed through a JPL-developed web-based GUI called Situational Awareness and Prediction (SAP), which is a client-server base application to provide the web-based capability. PATS was successfully tested by firefighters in March 2013 as part of controlled burn exercise in the Cleveland National Forest. The Division received a certificate of appreciation from the Department of Homeland Security in recognition of the successful development effort.

High-Temperature Electronics for Down-Hole Sensor Instrumentation in Oil Wells

POC: Mohammad Mojarradi



High-temperature board developed for the interface and data acquisition from down-hole sensors.

Using low-cost commercial components, the Division has developed first-generation data acquisition (DAQ) electronics for monitoring the critical environmental parameters (temperature, pressure, composition) that affect the flow of petroleum from oil well production zones. The figure shows the DAQ board, which is capable of digitizing and transmitting data from eight separate discrete sensors. It is designed to support operation in typical oil well production zones with ambient temperatures of 150ºC. Additional characterization has shown that the board is capable of operating successfully at temperatures as high as 200ºC. The development of the DAQ board is part of a larger JPL effort to develop a "smart pipe" for the oil industry, which will have utility for sensing, valve actuation, and communication with the wellhead.

INSTRUMENTS DIVISION

Publications

ANNUAL REPORT FY 2013

1. Achberger, C.; Foster, Julie; Grigoryan, Valentina; Leduc, Henry; MacDonald, Daniel; Muller, Richard; Siegel, Peter; Stephenson, Robert; Toole, Nicholas; Zhao, Feng et al.; *State of the Climate in 2011 Special Supplement to the Bulletin of the American Meteorological Society Vol. 93, No. 7, July 2012*. Bulletin of the American Meteorological Society, 93: (7) S1-+, 2012.

2. Ade, P.A.R.; Holmes, Warren et al.; *Planck intermediate results: IX. Detection of the galactic haze with planck*. Astronomy and Astrophysics, 554: A139, 2013.

3. Ade, P.A.R.; Holmes, Warren et al.; *Planck intermediate results: XI. the gas content of dark matter halos: The sunyaev-zeldovich-stellar mass relation for locally brightest galaxies*. Astronomy and Astrophysics, 557: A52, 2013.

4. Aikin, R.W.; Day, Peter; Megerian, Krikor; Turner, Anthony et al.; *Antenna-coupled TES bolometers for the Keck Array, Spider, and Polar-1*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84521G, 2012.

5. Alonso-DelPino, M.; Chattopadhyay, Goutam; Jung-Kubiak, Cecile; Mehdi, Imran et al.; *Design Guidelines for a Terahertz Silicon Micro-Lens Antenna*. IEEE Antennas and Wireless Propagation Letters, 12: 84-87, 2013.

6. Anderson, M.S.; Feldman, Jason et al.; *In situ cleaning of instruments for the sensitive detection of organics on Mars*. Review of Scientific Instruments, 83: (10) 105109, 2012.

7. Araujo, D.; Gaier, Todd; Kangaslahti, Pekka et al.; *Second Season QUIET Observations: Measurements of the Cosmic Microwave Background Polarization Power Spectrum at 95 GHz*. Astrophysical Journal, 760: (2) 145, 2012.

8. Armstrong, Edward M.; Vazquez-Cuervo, Jorge; Chin, Toshio M.; Wagner, Grant; *Comparisons of regional satellite sea surface temperature gradients derived from MODIS and AVHRR sensors*. International Journal of Remote Sensing, 33: (21) 6639-6651, 2012.

9. Asner, Gregory P.; Green, Robert; Eastwood, Michael et al.; *Carnegie Airborne Observatory-2: Increasing science data dimensionality via high-fidelity multi-sensor fusion*. Remote Sensing of Environment, 124: 454-465, 2012.

10. Bach, Wolfgang; Coleman, Max et al.; *The oxygen isotope equilibrium fractionation between sulfite species and water*. Geochimica Et Cosmochimica Acta, 120: 562-581, 2013.

11. Bae, Youngsam; Korniski, Ronald; Manohara, Harish et al.; *New technique of three-dimensional imaging through a 3-mm single lens camera*. Optical Engineering, 51: (2) 21106, 2012.

12. Bagheri, Mahmood; Briggs, Ryan M.; Frez, Clifford; Ksendzov, Alexander; Forouhar, Siamak; *Sub-kHz linewidth GaSb semiconductor diode lasers operating near 2 micrometers*. Conference Digest - IEEE International Semiconductor Laser Conference, 20-21, 2012.

13. Bahrami, Poyan; Bae, Youngsam; Korniski, Ronald; Shearn, Michael; Manohara, Harish et al.; *Development of a miniature single lens dual-aperture stereo imaging system towards stereo endoscopic imaging application*. Optical Engineering, 51: (10) 103202, 2012.

14. Bartlett, J. G.; Holmes, Warren et al.; *Planck intermediate results X. Physics of the hot gas in the Coma cluster*. Astronomy and Astrophysics, 554: A140, 2013.

15. Bartlett, J. G.; Holmes, Warren et al.; *Planck intermediate results VI. The dynamical structure of PLCKG214.6+37.0, a Planck discovered triple system of galaxy clusters*. Astronomy and Astrophysics, 550: A132, 2013.

16. Bartlett, J. G.; Holmes, Warren et al.; *Planck intermediate results VIII. Filaments between interacting clusters*. Astronomy and Astrophysics, 550: A134, 2013.

17. Bartlett, J. G.; Holmes, Warren et al.; *Planck intermediate results V. Pressure profiles of galaxy clusters from the Sunyaev-Zeldovich effect*. Astronomy and Astrophysics, 550: A131, 2013.

18. Bartlett, J. G.; Holmes, Warren et al.; *Planck intermediate results III. The relation between galaxy cluster mass and Sunyaev-Zeldovich signal*. Astronomy and Astrophysics, 550: A129, 2013.

19. Bartlett, J. G.; Holmes, Warren et al.; *Planck intermediate results IV. The XMM-Newton validation programme for new Planck galaxy clusters*. Astronomy and Astrophysics, 550: A130, 2013.

20. Bayer, Todd; Dekens, Frank et al.; *Update on the model based systems engineering on the europa mission concept study*. IEEE Aerospace Conference Proceedings, 6496855, 2013.

21. Bekker, Dmitriy L.; McKinney, Colin; Werne, Thomas; Wu, Amy; Wu, Yen-Hung et al.; *Command and data handling system for the panchromatic fourier transform spectrometer*. IEEE Aerospace Conference Proceedings, 6187224, 2012.

22. Belton, Michael J. S.; Klaasen, Kenneth et al.; *The origin of pits on 9P/Tempel 1 and the geologic signature of outbursts in Stardust-NExT images*. ICARUS, 222: (2) 477-486, 2013.

23. Belton, Michael J. S.; Klaasen, Kenneth et al.; *The complex spin state of 103P/Hartley 2: Kinematics and orientation in space*. ICARUS, 222: (2) 595-609, 2013.

24. Bennett, Sarah A.; Coleman, Max et al.; *Trophic regions of a hydrothermal plume dispersing away from an ultramafic-hosted vent-system: Von Damm vent-site, Mid-Cayman Rise*. Geochemistry, Geophysics, Geosystems, 14: (2) 317-327, 2013.

25. Bersanelli, Marco; Gaier, Todd; Kangaslahti, Pekka et al.; *A coherent polarimeter array for the Large Scale Polarization Explorer balloon experiment*. Proceedings of SPIE - The International Society for Optical Engineering, 8446: 84467C, 2012.

26. Besse, S.; Green, Robert et al.; *One Moon, many measurements 2: Photometric corrections*. ICARUS, 226: (1) 127-139, 2013.

27. Beyer, Andrew D.; Beyer, Andrew; Echternach, Pierre; Kenyon, Matthew; Runyan, Marcus; Bumble, Bruce; Holmes, Warren et al.; *Effect of Mo/Cu superconducting bilayer geometry on ultra-sensitive transition-edge sensor performance*. IEEE Transactions on Applied Superconductivity, 23: (3) 6363550, 2013.

28. Beyer, Andrew D.; Kenyon, Matthew; Holmes, Warren et al.; *Development of fast, background-limited transition-edge sensors for the Background-Limited Infrared/Sub-mm Spectrograph (BLISS) for SPICA*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84520G, 2012.

29. Bhandari, Pradeep; Liu, Yuanming et al.; *Performance of the mechanically pumped fluid loop rover heat rejection system used for thermal control of the mars science laboratory curiosity rover on the surface of mars*. 43rd International Conference on Environmental Systems, 2013.

30. Bischoff, C.; Gaier, Todd; Kangaslahti, Pekka et al.; *The Q/U Imaging Experiment Instrument*. Astrophysical Journal, 768: (1) 9, 2013.

31. Bock, J.J.; Day, Peter; Turner, Anthony et al.; *Suppressing beam systematics in antenna-coupled TES bolometers for CMB polarimetry*. Journal of Low Temperature Physics, 167: (41337) 497-503, 2012.

32. Bogucki, D.J.; Spiers, G.; *What percentage of the oceanic mixed layer is accessible to marine lidar? Global and the Gulf of Mexico prospective*. Optics Express, 21: (20) 23997-24014, 2013.

33. Boussaha, Faouzi; Kawamura, Jonathan; Skalare, Anders; White, Victor et al.; *Terahertz-frequency waveguide HEB mixers for spectral line astronomy*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 845211, 2012.

34. Boussaha, Faouzi M.; Kawamura, Jonathan H.; Stern, Jeffery A.; Skalare, Anders; White, Victor; *A low noise 2.7 THz waveguide-based superconducting mixer*. IEEE Transactions on Terahertz Science and Technology, 2: (3) 284-289, 2012.

35. Bowman Jr., R.C.; Pearson, David et al.; *Characterization and analyses of degradation and*

recovery of LaNi4.78Sn0.22 hydrides following thermal aging. Journal of Alloys and Compounds, 580: S207-S210, 2013.

36. Bradford, C.M.; Beyer, Andrew; Kenyon, Matthew; Bumble, Bruce; Echternach, Pierre; Holmes, Warren et al.; *Progress toward BLISS, the background-limited infrared-submillimeter spectrograph for SPICA*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84420P, 2012.

37. Bradford, Samuel Case; Agnes, Gregory; Ohara, Catherine; Green, Joseph; Shi, Fang et al.; *Controlling wavefront in lightweight active reflector systems using piezocomposite actuator arrays*. 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2013.

38. Braun, Scott A.; Brown, Shannon et al.; *NASA's genesis and rapid intensification processes (GRIP) field experiment*. Bulletin of the American Meteorological Society, 94: (3) 345-363, 2013.

39. Briggs, Ryan M.; Frez, Clifford; Bagheri, Mahmood; Borgentun, Carl; Forouhar, Siamak et al.; *Single-mode 2.65 mu m InGaAsSb/AlInGaAsSb laterally coupled distributed-feedback diode lasers for atmospheric gas detection*. Optics Express, 21: (1) 1317-1323, 2013.

40. Briggs, Ryan M.; Frez, Clifford; Forouhar, Siamak; May, Randy D.; Ruff, Gary A.; *Portable 4.6 micrometers laser absorption spectrometer for carbon monoxide monitoring and fire detection*. 43rd International Conference on Environmental Systems, 2013.

41. Brown, Shannon; *Maintaining the long-term calibration of the Jason-2/OSTM advanced microwave radiometer through intersatellite calibration*. IEEE Transactions on Geoscience and Remote Sensing, 51: (3) 1531-1543, 2013.

42. Bucher, M.; Holmes, Warren et al.; *Planck intermediate results II. Comparison of Sunyaev-Zeldovich measurements from Planck and from the Arcminute Microkelvin Imager for 11 galaxy clusters*. Astronomy and Astrophysics, 550: A128, 2013.

43. Cable, Morgan L.; Stockton, Amanda M.; Mora, Maria F.; Willis, Peter A.; *Low-temperature microchip nonaqueous capillary electrophoresis of aliphatic primary amines: Applications to titan chemistry*. Analytical Chemistry, 85: (2) 1124-1131, 2013.

44. Cabrol, N.A.; Bekker, Dmitriy et al.; *Smart, texture-sensitive instrument classification for in situ rock and layer analysis*. Geophysical Research Letters, 40: (16) 4188-4193, 2013.

45. Carcich, Brian; Klaasen, Kenneth; Brown, David et al.; *Stardust-NExT NAVCAM calibration and performance*. ICARUS, 222: (2) 436-452, 2013.

46. Cardoso, J. -F.; Holmes, Warren et al.; *Planck intermediate results VII. Statistical properties of infrared and radio extragalactic sources from the Planck Early Release Compact Source Catalogue at frequencies between 100 and 857 GHz*. Astronomy and Astrophysics, 550: A133, 2013.

47. Carr, Gregory A.; del Castillo, Linda; Mojarradi, Mohammad et al.; *Extreme environment capable, modular and scalable power processing unit for solar electric propulsion*. IEEE Aerospace Conference Proceedings, 6497406, 2013.

48. Cernicharo, J.; Pearson, John et al.; *Detection of the Ammonium Ion in Space*. Astrophysical Journal Letters, 771: (1) L10, 2013.

49. Chang, George; Shams, Khawaja; Callas, John; Kern, Alex; *A novel approach to automated, secure, reliable, and distributed backup of MER tactical data on clouds*. IEEE Aerospace Conference Proceedings, 6187355, 2012.

50. Chen, Ke; Kleinsasser, Alan et al.; *Multiple Andreev reflection in MgB2/MgO/MgB2 Josephson junctions*. Applied Physics Letters, 100: (12) 122601, 2012.

51. Chesley, S. R.; Klaasen, Kenneth et al.; *An updated rotation model for Comet 9P/Tempel 1*. ICARUS, 222: (2) 516-525, 2013.

52. Choi, Jae Kyu; Gill, John; Mehdi, Imran; Karasik, Boris et al.; *THz Hot-Electron Micro-Bolometer Based on Low-Mobility 2-DEG in GaN Heterostructure*. IEEE Sensors Journal, 13: (1) , 2013.

53. Christensen, L. E.; Spiers, G. D.; Menzies, R. T.; Jacob, J. C.; *Tunable laser spectroscopy of CO2 near 2.05 mu m: Atmospheric retrieval biases due to neglecting line-mixing*. Journal of Quantitative Spectroscopy and Radiative Transfer, 113: (10) 739-748, 2012.

54. Chutjian, A.; Madzunkov, Stojan et al.; *Collision physics in the atomic and molecular universe*. Journal of Physics: Conference Series, 388: (PART 1) 12042, 2012.

55. Cohen, Edward A.; Drouin, Brian J.; Brown, Linda R.; Oh, Jung Jin; *Terahertz and infrared spectra of carbonyl fluoride, COF2: Vibration-rotation analyses of the four lowest bands, 2 nu(6), and nu(6) hot bands; (COF2)-C-13 ground state and nu(6) band*. Journal of Quantitative Spectroscopy & Radiative Transfer, 114: 13-19, 2013.

56. Cohen, Edward A.; Drouin, Brian J.; *Submillimeter wave spectrum of sulfuric acid, H2SO4*. Journal Of Molecular Spectroscopy, 288: 67-69, 2013.

57. Contreras, Michael T.; Trease, Brian P.; Bojanowski, Cezary; Kulak, Ronald F.; *Characterizing wheel-soil interaction loads using meshfree finite element methods: A sensitivity analysis for design trade studies*. 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2013.

58. Cook, Brant T.; Blando, Guillermo; Wolff, John et al.; *High altitude supersonic decelerator test vehicle*. AIAA Aerodynamic Decelerator Systems (ADS) Conference 2013, 2013.

59. Crawford, Tim; Cooper, Ken; Dengler, Robert; Chavez, Marcoanto; Chun, William et al.; *Submillimeter wave spectrometry for in-situ planetary science*. IEEE Aerospace Conference Proceedings, 6187067, 2012.

60. Dalton III, J.B.; Kamp, Lucas et al.; *Exogenic controls on sulfuric acid hydrate production at the surface of Europa*. Planetary and Space Science, 77: 45-63, 2013.

61. Daly, A. M.; Pearson, John et al.; *Laboratory Characterization and Astrophysical Detection of Vibrationally Excited States of Ethyl Cyanide*. Astrophysical Journal, 768: (1) 81, 2013.

62. Davidsson, Bjorn J. R.; Klaasen, Kenneth et al.; *Thermal inertia and surface roughness of Comet 9P/Tempel 1*. ICARUS, 224: (1) 154-171, 2013.

63. De Beck, E.; Pearson, John et al.; *On the physical structure of IRC+10216 Ground-based and Herschel observations of CO and C2H*. Astronomy and Astrophysics, 539: A108, 2012.

64. De Luca, M.; Gupta, Maneesh; Pearson, John et al.; *Herschel/HIFI Discovery Of HCL+ in the Interstellar Medium*. Astrophysical Journal Letters, 751: (2) L37, 2012.

65. DeBoer, David R.; Gaier, Todd et al.; *Radio Frequencies: Policy and Management*. IEEE Transactions on Geoscience and Remote Sensing, 51: (10) 4918-4927, 2013.

66. Deems, Elizabeth; Swan, Chris; Weiss, Barry; *End-to-end data flow on the Soil Moisture Active Passive (SMAP) mission*. IEEE Aerospace Conference Proceedings, 6187175, 2012.

67. Dekany, Richard G.; Roberts, Jenny; Burruss, Rick; Palmer, Dean; Troy, Mitchell; Truong, Tuan et al.; *Results from the PALM-3000 high-order adaptive optics system*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 84470Y, 2012.

68. Dekany, Richard G.; Fisher, Charles; Braun, David; Kaluzny, Joel et al.; *Developments in high-density Cobra fiber positioners for the Subaru Telescope's Prime Focus Spectrometer*. Proceedings of SPIE - The International Society for Optical Engineering, 8450: 845017, 2012.

69. Deroo, Pieter; Swain, Mark R.; Green, Robert O.; *Spectroscopy of exoplanet atmospheres with the FINESSE explorer*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 844241, 2012.

70. Diestelhorst, Ryan M.; Mojarradi, Mohammad et al.; *A new approach to designing electronic*

systems for operation in extreme environments: Part i-The SiGe Remote Sensor Interface. IEEE Aerospace and Electronic Systems Magazine, 27: (6) 25-34, 2012.

71. Diner, David J.; Geier, Sven et al.; *Exploration of a Polarized Surface Bidirectional Reflectance Model Using the Ground-Based Multiangle SpectroPolarimetric Imager*. ATMOSPHERE, 3: (4) 591-619, 2012.

72. Diner, David J.; Hodos, Rachel; von Allmen, Paul et al.; *An optimization approach for aerosol retrievals using simulated MISR radiances*. Atmospheric Research, 116: 1-14, 2012.

73. Dobrea, E. Z. Noe; Wray, J. J.; Calef, F. J., III; Parker, T. J.; Murchie, S. L.; *Hydrated minerals on Endeavour Crater's rim and interior, and surrounding plains: New insights from CRISM data*. Geophysical Research Letters, 39: (23) L23201, 2012.

74. Donnellan, Andrea; Granat, Robert; Suzuki, Shigeru et al.; *QuakeSim: Integrated modeling and analysis of geologic and remotely sensed data*. IEEE Aerospace Conference Proceedings, 6187219, 2012.

75. Donnellan, Andrea; Green, Joseph et al.; *High resolution imaging of dynamic surface processes from the ISS*. IEEE Aerospace Conference Proceedings, 6497162, 2013.

76. Drouin, Brian J.; Pearson, John C.; Yu, Shanshan; Gupta, Harshal; *Characterization and use of a 1.3-1.5 THz multiplier chain for molecular spectroscopy*. IEEE Transactions on Terahertz Science and Technology, 3: (3) 314-321, 2013.

77. Emboras, A.; Briggs, Ryan et al.; *Efficient coupler between silicon photonic and metal-insulator-silicon-metal plasmonic waveguides*. Applied Physics Letters, 101: (25) 251117, 2012.

78. England, T. D.; Mojarradi, Mohammad et al.; *A new approach to designing electronic systems for operation in extreme environments: Part II - The SiGe remote electronics unit*. IEEE Aerospace and Electronic Systems Magazine, 27: (7) 29-41, 2012.

79. Faghihi, Azin; Gibson, Steve; Tesch, Jonathan; *Identified state-space prediction model for aero-optical wavefronts*. Optical Engineering, 52: (7) 71419, 2013.

80. Feaga, Lori M.; Klaasen, Kenneth et al.; *Cometary Volatiles and the Origin Of Comets*. Astrophysical Journal, 758: (1) 29, 2012.

81. Feldman, Yuri; Colonius, Tim; Pauken, Michael T.; Hall, Jeffrey L.; Jones, Jack A.; *Simulation and Cryogenic Experiments of Natural Convection for the Titan Montgolfiere*. AIAA Journal, 50: (11) 2483-2491, 2012.

82. Fraisse, A. A.; Holmes, Warren; Turner, Anthony et al.; *SPIDER: probing the early Universe with a suborbital polarimeter*. Journal of Cosmology and Astroparticle Physics, (4) 47, 2013.

83. Franz, Kale J.; Briggs, Ryan; Frez, Clifford; Ksendzov, Alexander; Bagheri, Mahmood; Forouhar, Siamak et al.; *Laterally coupled distributed-feedback GaSb-based diode lasers for atmospheric gas detection at 2 micrometers*. 2012 Conference on Lasers and Electro-Optics, CLEO 2012, 6326277, 2012.

84. Gaier, Todd C.; *MMICs and remote sensing science instruments - A technology success story*. Technical Digest - IEEE Compound Semiconductor Integrated Circuit Symposium, CSIC, 6340096, 2012.

85. Gao, J.; Leduc, Henry et al.; *A titanium-nitride near-infrared kinetic inductance photon-counting detector and its anomalous electrodynamics*. Applied Physics Letters, 101: (14) 142602, 2012.

86. Gdoutos, E.; Daraio, C.; Shapiro, A.A.; *Thin and Thermally Stable Periodic Metastructures*. Experimental Mechanics, 53: (9) 1735-1742, 2013.

87. Give'on, Amir; Shaklan, Stuart; Kern, Brian; Noecker, Martin et al.; *Electric field reconstruction in the image plane of a high-contrast coronagraph using a set of pinholes around the Lyot plane*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84420B, 2012.

88. Golwala, Sunil R.; Day, Peter; Leduc, Henry et al.; *Status of MUSIC, the MUltiwavelength Sub/millimeter Inductance Camera*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 845205, 2012.

89. Goodall, Jonathan; Geller, Gary et al.; *Integrated environmental modeling: A vision and roadmap for the future*. Environmental Modelling and Software, 39: 3-23, 2013.

90. Goullioud, Renaud; Kuan, Gary; Moore, James et al.; *Wide Field Infrared Survey Telescope [WFIRST]: Telescope design and simulated performance*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84421U, 2012.

91. Greenwood, Arin R.; Lee, Christine M.; Noell, Aaron C.; Ponce, Adrian; *High-density, homogeneous endospore monolayer deposition on test surfaces*. Journal of Microbiological Methods, 94: (3) 245-248, 2013.

92. Greer, Frank; Hoenk, Michael; Jones, Todd; Dickie, Matthew; Monacos, Steve; Nikzad, Shouleh et al.; *Atomically precise surface engineering of silicon CCDs for enhanced UV quantum efficiency*. Journal of Vacuum Science and Technology A: Vacuum, Surfaces and Films, 31: (1) 01A103, 2013.

93. Greer, Frank; Nikzad, Shouleh; Traub, Wesley; *Mirror coatings with atomic layer deposition: Initial results*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84421J, 2012.

94. Greer, Frank; Baker, Layton; Fisher, Anita; Keo, Sam; Soibel, Alexander; Khoshakhlagh, Arezou; Ting, David; Gunapala, Sarath et al.; *Fundamental interface studies of GaSb and InAs substrates with atomic layer deposition*. Proceedings of SPIE - The International Society for Optical Engineering, 8511: 851108, 2012.

95. Greer, Frank; Lee, Michael C.; Nikzad, Shouleh; Traub, Wesley; Beasley, Matthew; *Enabling high performance mirrors for astronomy with ALD*. ECS Transactions, 50: (13) 141-148, 2012.

96. Gregorio, A.; Pearson, David et al.; *In-flight calibration and verification of the Planck-LFI instrument*. Journal of Instrumentation, 8: T07001, 2013.

97. Groussin, O.; Klaasen, Kenneth et al.; *The temperature, thermal inertia, roughness and color of the nuclei of Comets 103P/Hartley 2 and 9P/Tempel 1*. ICARUS, 222: (2) 580-594, 2013.

98. Gunapala, Sarath; Rafol, Sir; Ting, David; Soibel, Alexander; Liu, John; Khoshakhlagh, Arezou; Keo, Sam; Mumolo, Jason et al.; *Modulation transfer function of QWIP and superlattice focal plane arrays*. Infrared Physics and Technology, 59: 64-71, 2013.

99. Gunapala, S.D.; Gunapala, Sarath; Ting, David; Rafol, Sir; Soibel, Alexander; Khoshakhlagh, Arezou; Liu, John; Mumolo, Jason; Keo, Sam et al.; *Modulation transfer function measurements of QWIP and superlattice focal plane arrays*. Proceedings of SPIE - The International Society for Optical Engineering, 8631: 86310S, 2013.

100. Gupta, H.; Drouin, B. J.; Pearson, J. C.; *The Rotational Spectrum of HCl+*. Astrophysical Journal Letters, 751: (2) L38, 2012.

101. Guyon, Olivier; Shaklan, Stuart; Nemati, Bijan et al.; *Simultaneous Exoplanet Characterization and Deep Wide-Field Imaging with a Diffractive Pupil Telescope*. Astrophysical Journal, 767: (1) 11, 2013.

102. Guyon, Olivier; Mennesson, Bertrand; Serabyn, Eugene; Martin, Stefan; *Optimal Beam Combiner Design for Nulling Interferometers*. Publications of the Astronomical Society of the Pacific, 125: (930) 951-965, 2013.

103. Guyon, Olivier; Cady, Eric; Wilson, Daniel et al.; *How ELTs will acquire the first spectra of rocky habitable planets*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 84471X, 2012.

104. Guyon, Olivier; Shaklan, Stuart et al.; *Characterization of habitable exoplanets with simultaneous coronagraphy and astrometry with a single aperture telescope*. Proceedings of SPIE - The

International Society for Optical Engineering, 8442: 84420K, 2012.

105. Hacker, J.; Lin, Robert; Skalare, Anders; Mehdi, Imran et al.; *400 GHz HBT Differential Amplifier Using Unbalanced Feed Networks*. IEEE Microwave and Wireless Components Letters, 22: (10) 536-538, 2012.

106. Hai Nguyen; Braverman, Amy; Cressie, Noel; Cressie, Noel; *Spatial Statistical Data Fusion for Remote Sensing Applications*. Journal of the American Statistical Association, 107: (499) 1004-1018, 2012.

107. Hallinan, G.; Hartman, Frank et al.; *Looking for a Pulse: A search for Rotationally Modulated Radio Emission from the Hot Jupiter, Tau Bootis B*. Astrophysical Journal, 762: (1) 34, 2013.

108. Hardman, Sean; Freeborn, Dana; Springer, Paul; Chafin, Brian et al.; *Enabling earth science through cloud computing*. IEEE Aerospace Conference Proceedings, 6187356, 2012.

109. Hart, Andrew F.; Verma, Rishi; Mattmann, Chris; Ramirez, Paul; Goodale, Cameron et al.; *Developing an open source, reusable platform for distributed collaborative information management in the Early Detection Research Network*. Proceedings of the 2012 IEEE 13th International Conference on Information Reuse and Integration, IRI 2012, 263-270, 2012.

110. Hecht, Michael; Coleman, Max; Neidholdt, Evan; Sinha, Mahadeva; Zimmerman, Wayne et al.; *In situ geochronology as a mission-enabling technology*. IEEE Aerospace Conference Proceedings, 6187053, 2012.

111. Hicks, Brian C.; Hartman, Frank et al.; *A Wide-Band, Active Antenna System for Long Wavelength Radio Astronomy*. Publications of the Astronomical Society of the Pacific, 124: (920) 1090-1104, 2012.

112. Hinkley, Sasha; Roberts, Jenny; Roberts, Lewis; Burruss, Rick; Cady, Eric et al.; *High-Resolution Infrared Imaging and Spectroscopy of the Z Canis Majoris System during Quiescence and Outburst*. Astrophysical Journal Letters, 763: (1) L9, 2013.

113. Hoffman, James Patrick; Del Castillo, Linda; Hunter, Don; Miller, Jennifer; *Robust, reworkable thermal electronic packaging: Applications in high power TR modules for space*. IEEE Aerospace Conference Proceedings, 6187085, 2012.

114. Hoglund, Linda; Ting, David; Soibel, Alexander; Keo, Sam; Khoshakhlagh, Arezou; Hill, Cory; Mumolo, Jason; Gunapala, Sarath et al.; *Superlattice and Quantum Dot Unipolar Barrier Infrared Detectors*. Journal of Electronic Materials, 42: (11) 3071-3079, 2013.

115. Hoglund, Linda; Khoshakhlagh, Arezou; Ting, David; Hill, Cory; Keo, Sam; Soibel, Alexander; Gunapala, Sarath et al.; *High performance long-wave type-II superlattice infrared detectors*. Journal of Vacuum Science and Technology B: Microelectronics and Nanometer Structures, 31: (3) 03C122, 2013.

116. Hsiao, Frank; Chang, Mau-Chung Frank; Tam, Sai-Wang; Berenguer, Roc; Tang, Adrian; *A 10-Bit 2-GS/s DAC-DDFS-IQ-Controller Baseband Enabling a Self-Healing 60-GHz Radio-on-Chip*. IEEE Transactions on Circuits and Systems II-Express Briefs, 60: (8) 457-461, 2013.

117. Hughes, Richard; Chamberlain, Neil; Jakoboski, Julie; Petkov, Mihail; *Mechanical development of a very non-standard patch array antenna for extreme environments*. IEEE Aerospace Conference Proceedings, 6187093, 2012.

118. Isaacson, Peter J.; Green, Robert; Lundeen, Sarah et al.; *Development, importance, and effect of a ground truth correction for the Moon Mineralogy Mapper reflectance data set*. Journal of Geophysical Research-Planets, 118: (3) 369-381, 2013.

119. Jau, Bruno M.; *The proposed ExoMars Climate Sounder instrument*. IEEE Aerospace Conference Proceedings, 6187158, 2012.

120. Jepsen, Peter Uhd; Cooke, David G.; Siegel, Peter H.; *Introduction to the special issue on terahertz spectroscopy*. IEEE Transactions on Terahertz Science and Technology, 3: (3) 237-238, 2013.

121. Jiang, Xun; Licata, Stephen et al.; *Influence of El Nino on Midtropospheric CO2 from Atmospheric Infrared Sounder and Model*. Journal of the Atmospheric Sciences, 70: (1) 223-230, 2013.

122. Johnson, William R.; Hook, Simon J.; Foote, Marc; Eng, Bjorn T.; Jau, Bruno; *Infrared instrument support for HyspIRI-TIR*. Proceedings of SPIE - The International Society for Optical Engineering, 8511: 851102, 2012.

123. Jones, Dayton L.; Wagstaff, Kiri; Thompson, David; Mattmann, Chris; Rebbapragada, Umaa et al.; *Big data challenges for large radio arrays*. IEEE Aerospace Conference Proceedings, 6187090, 2012.

124. Jones, Jack A.; Lam, Adrienne S.; Bruce, Allan; *Advanced hydraulic wind energy*. IEEE Green Technologies Conference, 140-146, 2013.

125. Kasdin, N.J.; Shaklan, Stuart; Cady, Eric; Martin, Stefan; Marchen, Luis et al.; *Technology demonstration of starshade manufacturing for NASA's Exoplanet Mission Program*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84420A, 2012.

126. Kasdin, N.J.; Shaklan, Stuart; Cady, Eric; Martin, Stefan et al.; *Recent progress on external occulter technology for imaging exosolar planets*. IEEE Aerospace Conference Proceedings, 6497155, 2013.

127. Kaul, Anupama B.; Coles, James B.; Eastwood, Michael; Green, Robert O.; Bandaru, Prabhakar R.; *Ultra-high optical absorption efficiency from the ultraviolet to the infrared using multi-walled carbon nanotube ensembles*. Small, 9: (7) 1058-1065, 2013.

128. Keihm, Stephen; Kamp, Lucas; Lee, Seungwon et al.; *Interpretation of combined infrared, submillimeter, and millimeter thermal flux data obtained during the Rosetta fly-by of Asteroid (21) Lutetia*. ICARUS, 221: (1) 395-404, 2012.

129. Keihm, Stephen et al.; *Reconciling main belt asteroid spectral flux density measurements with a self-consistent thermophysical model*. ICARUS, 226: (1) 1086-1102, 2013.

130. Kernasovskiy, S.; Turner, Anthony et al.; *Optimization and sensitivity of the Keck Array*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84521B, 2012.

131. Key, Richard; Bekker, Dmitriy; Wu, Yen-Hung et al.; *The geostationary carbon process mapper*. IEEE Aerospace Conference Proceedings, 6187029, 2012.

132. Key, Richard; Bekker, Dmitriy; Wu, Yen-Hung et al.; *The geostationary fourier transform spectrometer*. Proceedings of SPIE - The International Society for Optical Engineering, 8515: 851506, 2012.

133. Khoshakhlagh, Arezou; Ting, David; Soibel, Alexander; Rafol, Sir; Keo, Sam; Mumolo, Jason; Gunapala, Sarath et al.; *Type-II InAs/GaSb superlattice detectors based on CBIRD design*. Proceedings of SPIE - The International Society for Optical Engineering, 8512: 85120I, 2012.

134. Kim, Won S.; Redick, Richard et al.; *Mars science laboratory CHIMRA/IC/DRT flight software for sample acquisition and processing*. Proceedings of 2013 8th International Conference on System of Systems Engineering: SoSE in Cloud Computing and Emerging Information Technology Applications, SoSE 2013, 117-122, 2013.

135. Kisiel, Zbigniew; Pearson, John et al.; *Broadband rotational spectroscopy of acrylonitrile: Vibrational energies from perturbations*. Journal of Molecular Spectroscopy, 280: 134-144, 2012.

136. Klaasen, Kenneth P. et al.; *EPOXI instrument calibration*. ICARUS, 225: (1) 643-680, 2013.

137. Klesh, Andrew; Halatek, Lauren et al.; *INSPIRE: Interplanetary nanoSpacecraft pathfinder in relevant environment*. AIAA SPACE 2013 Conference and Exposition, 2013.

138. Knight, David; Shams, Khawaja; Chang, George; Soderstrom, Tom; *Evaluating the efficacy of the cloud for cluster computation*. IEEE Aerospace Conference Proceedings, 6187359, 2012.

139. Kolawa, Elizabeth A.; Mojarradi, Mohammad M.; Weber, Carissa Tudryn; Hunter, Don J.;

Chen, Yuan; *A motor drive electronics assembly for Mars Curiosity Rover: An example of assembly qualification for extreme environments*. IEEE International Reliability Physics Symposium Proceedings, 2E.2.1-2E.2.9, 2013.

140. Koresko, C.; Kuchner, M. J.; Serabyn, E.; Mennesson, B.; Colavita, M. M.; *The Keck Interferometer Nuller*. Astrophysical Journal, 748: (1) 55, 2012.

141. Kovacs, Attila; Chattopadhyay, Goutam; Day, Peter; Leduc, Henry et al.; *SuperSpec: Design concept and circuit simulations*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84522G, 2012.

142. Kremens, Robert; Thompson, David R.; Johnson, William; *Multiple-Frame Subpixel Wildfire Tracking*. IEEE Geoscience and Remote Sensing Letters, 9: (4) 639-643, 2012.

143. Krista, John; Lawson, Peter et al.; *On advanced estimation techniques for exoplanet detection and characterization using ground-based coronagraphs*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 844722, 2012.

144. Kuai, L.; Lee, Michael et al.; *Profiling tropospheric CO2 using Aura TES and TCCON instruments*. Atmospheric Measurement Techniques, 6: (1) 63-79, 2013.

145. Kudryavtsev, Vitaly A.; Spooner, Neil J.C.; Fung, Cora; Gluyas, Jon; Coleman, Max; *Monitoring subsurface CO2 emplacement and security of storage using muon tomography*. International Journal of Greenhouse Gas Control, 11: 21-24, 2012.

146. Ladizinsky, Eric; Kleinsasser, Alan; Chui, Talso; Bumble, Bruce; *Critical current density and temperature dependence of Nb-Al oxide-Nb junction resistance and implications for room temperature characterization*. IEEE Transactions on Applied Superconductivity, 23: (3) 6355628, 2013.

147. Larour, Eric; Schiermeier, John et al.; *Ice flow sensitivity to geothermal heat flux of Pine Island Glacier, Antarctica*. Journal of Geophysical Research-Earth Surface, 117: F04023, 2012.

148. Leal-Sevillano, Carlos A.; Reck, Theodore; Jung-Kubiak, Cecile; Chattopadhyay, Goutam et al.; *Silicon micromachined canonical E-plane and H-plane bandpass filters at the terahertz band*. IEEE Microwave and Wireless Components Letters, 23: (6) 288-290, 2013.

149. Leal-Sevillano, Carlos A.; Montejo-Garai, Jose R.; Rebollar, Jesus M.; Ruiz-Cruz, Jorge A.; Cooper, Ken B.; *A 225 GHz circular polarization waveguide duplexer based on a septum orthomode transducer polarizer*. IEEE Transactions on Terahertz Science and Technology, 3: (5) 574-583, 2013.

150. Lee, Choonsup; Chattopadhyay, Goutam; Reck, Theodore; Cooper, Ken; Lin, Robert; Mehdi, Imran et al.; *Silicon microlens antenna for multipixel THz heterodyne detector arrays*. 2013 7th European Conference on Antennas and Propagation, EuCAP 2013, 1745-1746, 2013.

151. Lee, Daren; Yanovsky, Igor et al.; *CUDA optimization strategies for compute- and memory-bound neuroimaging algorithms*. Computer Methods and Programs in Biomedicine, 106: (3) 175-187, 2012.

152. Lee, Jaesung; Feng, Philip X.-L.; Kaul, Anupama B.; *Characterization of plasma synthesized vertical carbon nanofibers for nanoelectronics applications*. Materials Research Society Symposium Proceedings, 1451: 117-122, 2013.

153. Li, Jian-Yang; Klaasen, Kenneth et al.; *Photometry of the nucleus of Comet 9P/Tempel 1 from Stardust-NExT flyby and the implications*. ICARUS, 222: (2) 467-476, 2013.

154. Li, Jian-Yang; Klaasen, Kenneth et al.; *Photometric properties of the nucleus of Comet 103P/Hartley 2*. ICARUS, 222: (2) 559-570, 2013.

155. Liewer, K.; Martin, S.; Serabyn, E.; *Demonstration of coherent imaging through a phased array of single-mode optical fibers*. Optics Letters, 38: (14) 2452-2454, 2013.

156. Liewer, P. C.; Hall, J. R.; Misrak, A.; Hernandez, I. Gonzalez; Thompson, W. T.; *Comparison of Far-Side STEREO Observations of Solar Activity and Active Region Predictions from GONG*. Solar Physics, 281: (1) 3-20, 2012.

157. Liewer, P. C.; Hall, J. R.; Panasenco, O.; *Stereoscopic Analysis of the 31 August 2007 Prominence Eruption and Coronal Mass Ejection*. Solar Physics, 182: (1) 201-220, 2013.

158. Lindler, Don J.; Besse, Sebastien; Carcich, Brian; Hermalyn, Brendan; Klaasen, Kenneth P.; *Interpretation of results of deconvolved images from the Deep Impact spacecraft High Resolution Instrument*. ICARUS, 222: (2) 571-579, 2013.

159. Lipa, John A.; Gutt, Gary; Hein, Randall et al.; *Corner-cube retro-reflector instrument for advanced lunar laser ranging*. Experimental Astronomy, 36: (41276) 105-135, 2013.

160. Llombart, N.; Echternach, Pierre; Stone, Kristjan; Day, Peter; Wilson, Daniel; Megerian, Krikor et al.; *Photon shot noise limited detection of terahertz radiation using a quantum capacitance detector*. Applied Physics Letters, 103: (5) 53510, 2013.

161. Llombart, N.; Chattopadhyay, Goutam; Jung-Kubiak, Cecile; Mehdi, Imran et al.; *Silicon micromachined lens antenna for THz integrated heterodyne arrays*. IEEE Transactions on Terahertz Science and Technology, 3: (5) 515-523, 2013.

162. Luong, Ed; Soibel, Alexander; Mumolo, Jason; Liu, John; Rafol, Sir; Keo, Sam; Johnson, William; Willson, Reginald; Hill, Cory; Ting, David; Gunapala, Sarath et al.; *Multi-color QWIP FPAs for hyperspectral thermal emission instruments*. Proceedings of SPIE - The International Society for Optical Engineering, 8511: 851105, 2012.

163. Lupinacci, A.; Minor, A.M.; Shapiro, A.A.; Suh, J.O.; *A study of solder alloy ductility for cryogenic applications*. Proceedings - International Symposium on Advanced Packaging Materials, 82-88, 2013.

164. Macaskill, J.A.; Madzunkov, S.M.; Chutjian, A.; *Dipole field effects on ion ejections from A paul ion trap*. Journal of Physics: Conference Series, 388: (PART 14) 142029, 2012.

165. Madzunkov, Stojan M.; Simcic, Jurij; Darrach, Murray et al.; *Recent developments in gas chromatographs and mass spectrometers for crewed and robotic space missions*. 43rd International Conference on Environmental Systems, 2013.

166. Maestrini, Alain; Mehdi, Imran; Lin, Robert; Lee, Choonsup; Chattopadhyay, Goutam; Pearson, John; Siegel, Peter et al.; *Frequency tunable electronic sources working at room temperature in the 1 to3THz band*. Proceedings of SPIE - The International Society for Optical Engineering, 8496: 84960E, 2012.

167. Malbet, Fabien; Goullioud, Renaud et al.; *NEAT: A space born astrometric mission for the detection and characterization of nearby habitable planetary systems*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84420J, 2012.

168. Manning, Evan M.; Jiang, Yibo; Aumann, Hartmut H.; Elliott, Denis A.; Hannon, Scott; *Level-1C product from AIRS: Principal component filtering*. Proceedings of SPIE - The International Society for Optical Engineering, 8510: 85100V, 2012.

169. Marsili, F.; Stern, Jeffrey; Shaw, Matthew et al.; *Detecting single infrared photons with 93% system efficiency*. Nature Photonics, 7: (3) 210-214, 2013.

170. Maruyama, Yuki; Charbon, Edoardo; Blacksberg, Jordana; *A 1024×8 700ps time-gated SPAD line sensor for laser raman spectroscopy and LIBS in space and rover-based planetary exploration*. Digest of Technical Papers - IEEE International Solid-State Circuits Conference, 56: 110-111, 2013.

171. Mattmann, Chris A.; *A vision for data science*. NATURE, 493: (7433) 473-475, 2013.

172. Mattmann, Chris A.; Ramirez, Paul M.; Goodale, Cameron; Hart, Andrew F.; Downs, Robert R.; *Developing an open source strategy for NASA earth science data systems*. Proceedings of the 2012 IEEE 13th International Conference on

Information Reuse and Integration, IRI 2012, 687-693, 2012.

173. Mawet, Dimitri; Lawson, Peter; Wallace, James et al.; *Review of small-angle coronagraphic techniques in the wake of ground-based second-generation adaptive optics systems*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 844204, 2012.

174. Mazin, Ben; McHugh, Sean; Meeker, Seth; Marsden, Danica; Bumble, Bruce; *ARCONS: A 1024 pixel superconducting integral field spectrograph*. Proceedings of SPIE - The International Society for Optical Engineering, 8446: 84460F, 2012.

175. McKenney, Christopher M.; Leduc, Henry; Day, Peter et al.; *Design considerations for a background limited 350 micron pixel array using lumped element superconducting microresonators*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84520S, 2012.

176. McKinney, Colin M.; Yager, Jeremy; Mojarradi, Mohammad et al.; *Distributed Motor Controller (DMC) for operation in extreme environments*. IEEE Aerospace Conference Proceedings, 6187248, 2012.

177. McKitterick, Christopher B.; Prober, Daniel E.; Karasik, Boris S.; *Performance of graphene thermal photon detectors*. Journal of Applied Physics, 113: (4) 44512, 2013.

178. Mehdi, Imran; Lee, Choonsup; Schlecht, Erich; Chattopadhyay, Goutam et al.; *Local oscillator sub-systems for array receivers in the 1-3 THz range*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 845212, 2012.

179. Mendillo, Christopher B.; Rao, Shanti et al.; *PICTURE: A sounding rocket experiment for direct imaging of an extrasolar planetary environment*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84420E, 2012.

180. Mennesson, B.; Colavita, M et al.; *An Interferometric Study of the Fomalhaut Inner Debris Disk. II. Keck Nuller Mid-Infrared Observations*. Astrophysical Journal, 763: (2) 119, 2013.

181. Menzies, Robert T.; Spiers, Gary D.; Jacob, Joseph; (2014), *Airborne Laser Absorption Spectrometer Measurements of Atmospheric CO2 Column Mole Fractions: Source and Sink Detection and Environmental Impacts on Retrievals*, J. Atmos , and Oceanic Tech, in press

182. Mercury, M.; Green, Robert et al.; *Global cloud cover for assessment of optical satellite observation opportunities: A HyspIRI case study*. Remote Sensing of Environment, 126: 62-71, 2012.

183. Michel, R.; Redding, David et al.; *A geostationary optical seismometer, proof of concept*. IEEE Transactions on Geoscience and Remote Sensing, 51: (1) 695-703, 2013.

184. Miller, Charles E.; Dinardo, Steven J.; *CARVE: The Carbon in Arctic Reservoirs Vulnerability Experiment*. IEEE Aerospace Conference Proceedings, 6187026, 2012.

185. Miller, Jennifer R.; Liu, Yuanming et al.; *Leak mitigation in mechanically pumped fluid loops for long duration space missions*. 43rd International Conference on Environmental Systems, 2013.

186. Misra, Sidharth; De Roo, Roger D.; Ruf, Christopher S.; Ruf, Christopher S.; *An Improved Radio Frequency Interference Model: Reevaluation of the Kurtosis Detection Algorithm Performance Under Central-Limit Conditions*. IEEE Transactions on Geoscience and Remote Sensing, 50: (11) 4565-4574, 2012.

187. Misra, Sidharth; Ruf, Christopher S.; *Analysis of radio frequency interference detection algorithms in the angular domain for SMOS*. IEEE Transactions on Geoscience and Remote Sensing, 50: (5 PART 1) 1448-1457, 2012.

188. Mora, Maria F.; Stockton, Amanda M.; Willis, Peter A.; *Analysis of thiols by microchip capillary electrophoresis for in situ planetary investigations*. ELECTROPHORESIS, 34: (2) 309-316, 2013.

189. Moretto, P.; Zan, Jason et al.; *A Round Robin Test exercise on hydrogen absorption/desorption properties of a magnesium hydride based material*. International Journal of Hydrogen Energy, 38: (16) 6704-6717, 2013.

190. Morrissey, Patrick; Bartos, Randall et al.; *The Keck Cosmic Web Imager: A capable new integral field spectrograph for the W. M. Keck Observatory*. Proceedings of SPIE - The International Society for Optical Engineering, 8446: 844613, 2012.

191. Morse, A.D.; Lee, Seungwon et al.; *The Rosetta campaign to detect an exosphere at Lutetia*. Planetary and Space Science, 66: (1) 165-172, 2012.

192. Mouroulis, Pantazis; Green, Robert; Eastwood, Michael; Richardson, Brandon; Rodriguez, Jose; Franklin, Brian et al.; *Portable remote imaging spectrometer (PRISM): Laboratory and field calibration*. Proceedings of SPIE - The International Society for Optical Engineering, 8515: 85150F, 2012.

193. Mukhanov, Oleg A.; Kleinsasser, Alan; Johnson, Mark W.; *Preface*. 2013 IEEE 14th InternationalSuperconductive Electronics Conference, ISEC 2013, 6604253, 2013.

194. Muller, Inigo A.; Brunner, Benjamin; Coleman, Max; *Isotopic evidence of the pivotal role of sulfite oxidation in shaping the oxygen isotope signature of sulfate*. Chemical Geology, 354: 186-202, 2013.

195. Murakami, Naoshi; Kern, Brian et al.; *Coronagraph focal-plane phase masks based on photonic crystal technology: Recent progress and observational strategy*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 844205, 2012.

196. Nativi, Stefano; Craglia, Max; Jackson, Mike; Khalsa, Siri Jodha Singh; Geller, Gary; *Foreword to the special issue on interoperability architectures and arrangements for multi-disciplinary earth observation systems and applications*. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 5: (6) 1591-1593, 2012.

197. Nativi, Stefano; Mazzetti, Paolo; Geller, Gary N.; *Environmental model access and interoperability: The GEO Model Web initiative*. Environmental Modelling and Software, 39: 214-228, 2013.

198. Nguyen, Jean; Gill, John; Rafol, Sir; Soibel, Alexander; Ting, David; Keo, Sam; Fisher, Anita; Luong, Edward; Liu, John; Mumolo, Jason; Gunapala, Sarath et al.; *Inductively coupled plasma etching for delineation of InAs/GaSb pixels*. Proceedings of SPIE - The International Society for Optical Engineering, 8511: 851103, 2012.

199. Noroozian, Omid; Day, Peter K.; LeDuc, Henry G.; Zmuidzinas, Jonas; Eom, Byeong Ho; *Crosstalk reduction for superconducting microwave resonator arrays*. IEEE Transactions on Microwave Theory and Techniques, 60: (5) 1235-1243, 2012.

200. Novak, Keith S.; Kempenaar, Joshua E.; Bhandari, Pradeep; Liu, Yuanming; Lee, Chern-Jiin; *Thermal performance of the mars science laboratory rover during mars surface operations*. 43rd International Conference on Environmental Systems, 2013.

201. Ogburn IV, R.W.; Turner, Anthony et al.; *BICEP2 and Keck Array operational overview and status of observations*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84521A, 2012.

202. Ohtake, M.; Green, Robert et al.; *One Moon, Many Measurements 3: Spectral reflectance*. ICARUS, 226: (1) 364-374, 2013.

203. Oppenheimer, B. R.; Burruss, Rick; Cady, Eric; Roberts, Jenny; Roberts, Lewis; Wallace, James et al.; *Reconnaissance of the HR 8799 Exosolar System. I. Near-Infrared Spectroscopy*. Astrophysical Journal, 768: (1) 24, 2013.

204. Oppenheimer, Ben R.; Burruss, Rick; Cady, Eric; Lockhart, Thomas; Roberts, Jenny; Zhai, Chengxing et al.; *Project 1640: The world's first ExAO coronagraphic hyperspectral imager for comparative planetary science*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 844720, 2012.

205. Pagano, Thomas S.; Olsen, Edward T.; Nguyen,

Hai; *Global and regional seasonal variability of mid-tropospheric CO2 as measured by the atmospheric infrared sounder (AIRS)*. Proceedings of SPIE - The International Society for Optical Engineering, 8515: 851507, 2012.

206. Paige, David A.; Siegler, Nicholas et al.; *Thermal Stability of Volatiles in the North Polar Region of Mercury*. SCIENCE, 339: (6117) 300-303, 2013.

207. Parness, Aaron; White, Victor et al.; *Controllable ON-OFF adhesion for Earth orbit grappling applications*. IEEE Aerospace Conference Proceedings, 6497364, 2013.

208. Pearson, John C.; Yu, Shanshan; Drouin, Brian J.; *The ground state torsion rotation spectrum of CH2DOH*. Journal Of Molecular Spectroscopy, 280: 119-133, 2012.

209. Pereira, H. M.; Geller, Gary et al.; *Essential Biodiversity Variables*. SCIENCE, 339: (6117) 277-278, 2013.

210. Pierce, R.; Spero, Robert; Thompson, Becky et al.; *Stabilized lasers for space applications: A high TRL optical cavity reference system*. 2012 Conference on Lasers and Electro-Optics, CLEO 2012, 6326587, 2012.

211. Pieters, C. M.; Green, Robert et al.; *One Moon, many measurements 1: Radiance values*. ICARUS, 226: (1) 951-963, 2013.

212. Postman, Marc; Green, Joseph; Goullioud, Renaud et al.; *Using the ISS as a testbed to prepare for the next generation of space-based telescopes*. Proceedings of SPIE - The International Society for Optical Engineering, 8442: 84421T, 2012.

213. Pueyo, Laurent; Roberts, Lewis; Burruss, Rick et al.; *Application of a Damped Locally Optimized Combination of Images Method to the Spectral Characterization of Faint Companions Using an Integral Field Spectrograph*. Astrophysical Journal Supplement Series, 199: (1) 6, 2012.

214. Rafol, S.B.; Gunapala, Sarath; Ting, David; Soibel, Alexander; Khoshakhlagh, Arezou; Hoeglund, Linda; Liu, John; Mumolo, Jason; Keo, Sam; Luong, Edward et al.; *Characterization of Type II SLS n-CBIRD focal plane array*. Proceedings of SPIE - The International Society for Optical Engineering, 8511: 851107, 2012.

215. Rafol, S. B.; Soibel, Alexander; Khoshakhlagh, Arezou; Liu, John; Mumolo, Jason; Keo, Sam; Ting, David; Gunapala, Sarath et al.; *Performance of a 1/4 VGA format long-wavelength infrared antimonides-based superlattice focal plane array*. IEEE Journal of Quantum Electronics, 48: (7) 878-884, 2012.

216. Ragland, S.; Colavita, M et al.; *First Keck Nulling Observations of a Young Stellar Object: Probing the Circumstellar Environment of the Herbig Ae Star MWC 325*. Astrophysical Journal, 746: (2) 126, 2012.

217. Reck, Theodore; Jung-Kubiak, Cecile; Lee, Choonsup; Chattopadhyay, Goutam; Mehdi, Imran et al.; *Terahertz antenna for arrays of hundreds of pixels*. IEEE Antennas and Propagation Society, AP-S International Symposium (Digest), 6349001, 2012.

218. Reising, S.C.; Brown, Shannon et al.; *A three-frequency feed for millimeter wave radiometry*. Microwave and Optical Technology Letters, 54: (11) 2483-2487, 2012.

219. Rhodes, Jason; Paine, Christopher et al.; *Space-quality data from balloon-borne telescopes: The High Altitude Lensing Observatory (HALO)*. Astroparticle Physics, 38: (1) 31-40, 2012.

220. Riechers, Dominik A.; Naylor, Bret et al.; *A dust-obscured massive maximum-starburst galaxy at a redshift of 6.34*. NATURE, 496: (7445) 329-333, 2013.

221. Roberts Jr., Lewis C.; Page, Norman; Burruss, Rick; Truong, Tuan; Dew, Sharon; Troy, Mitchell et al.; *Conceptual design of the adaptive optics system for the laser communication relay demonstration ground station at Table Mountain*. Proceedings of SPIE - The International Society for Optical Engineering, 8610: 86100N, 2013.

222. Rothman, L.S.; Cohen, David et al.; *The HITRAN2012 molecular spectroscopic database*. Journal of Quantitative Spectroscopy and Radiative Transfer, 130: 4-50, 2013.

223. Schlecht, Erich; Jamnejad, Vahraz; *Dual-band optical bench for terahertz radiometer for outer planet atmospheres (TROPA)*. IEEE Antennas and Propagation Society, AP-S International Symposium (Digest), 6348812, 2012.

224. Schlecht, Erich T.; Jarnot, Robert; Lin, Robert et al.; *Dual band 550/1200 GHz wideband spectrometer for planetary observation*. Proceedings of SPIE - The International Society for Optical Engineering, 8496: 84960U, 2012.

225. Scott Howe, A.; Barmatz, Martin et al.; *Faxing structures to the moon: Freeform Additive Construction System (FACS)*. AIAA SPACE 2013 Conference and Exposition, 2013.

226. Scott, Valerie J.; Siegel, Peter H.; Amashukeli, Xenia; *Hydrolysis of lysozyme with an RF-powered micro-reactor*. Analytical Methods, 5: (11) 2860-2865, 2013.

227. Segato, Thiago P.; Willis, Peter et al.; *Microfabless microfluidic capillary electrophoresis devices*. Analytical Methods, 5: (7) 1652-1657, 2013.

228. Seo, Byoung-Joon; Nissly, Carl; Troy, Mitchell et al.; *Approximation of normalized point source sensitivity using power spectral density and slopes of wavefront aberration*. Applied Optics, 52: (17) 3910-3922, 2013.

229. Seo, Byoung-Joon; Nissly, Carl; Troy, Mitchell et al.; *Estimation of normalized point-source sensitivity of segment surface specifications for extremely large telescopes*. Applied Optics, 52: (18) 4111-4122, 2013.

230. Seroussi, H.; Schiermeier, John et al.; *Sensitivity Analysis of Pine Island Glacier ice flow using ISSM and DAKOTA*. Journal of Geophysical Research-Earth Surface, 117: F02009, 2012.

231. Seshadri, Suresh; Shapiro, Charles; Goodsall, Timothy et al.; *Initial Results from a Laboratory Emulation of Weak Gravitational Lensing Measurements*. Publications of the Astronomical Society of the Pacific, 125: (931) 1065-1086, 2013.

232. Shapiro, Mikhail G.; Priest, Michael F.; Bezanilla, Francisco; Siegel, Peter H.; Siegel, Peter H.; *Temperature-Mediated Effects of Millimeter Wave Stimulation on Membrane Protein Function*. Biophysical Journal, 104: (2) 679A-679A, 2013.

233. Shen, Janice T.; Perun, Vincent et al.; *Diagnosis of regime-dependent cloud simulation errors in CMIP5 models using A-Train satellite observations and reanalysis data*. Journal of Geophysical Research-Atmospheres, 118: (7) 2762-2780, 2013.

234. Shirokoff, E.; Chattopadhyay, Goutam; Day, Peter; Leduc, Henry et al.; *MKID development for SuperSpec: An on-chip, mm-wave, filter-bank spectrometer*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84520R, 2012.

235. Sidick, Erkin; *Extended scene Shack-Hartmann wavefront sensor algorithm: minimization of scene content dependent shift estimation errors*. Applied Optics, 52: (26) 6487-6496, 2013.

236. Sidick, Erkin; Shaklan, Stuart; Balasubramanian, Kunjithapatham; *HCIT broadband contrast performance sensitivity studies*. Proceedings of SPIE - The International Society for Optical Engineering, 8520: 85200M, 2012.

237. Sidick, Erkin; *Extended scene SH wavefront sensor algorithm: Minimization of scene content dependent shift estimation errors*. IEEE Aerospace Conference Proceedings, 6187169, 2012.

238. Siegel, Peter H.; *Special Issue on Terahertz Spectroscopy*. IEEE Transactions on Terahertz Science and Technology, 3: (3) 225-227, 2013.

239. Siegel, Peter H.; *Terahertz Pioneers: Manfred Winnewisser and Brenda Pruden Winnewisser Equating Hamiltonians to Nature*. IEEE Transactions on Terahertz Science and Technology, 3: (3) 229-236, 2013.

240. Siegel, Peter H.; *Untitled*. IEEE Transactions on Terahertz Science and Technology, 3: (2) 125-128, 2013.

241. Siegel, Peter H.; *Terahertz Pioneer: Koji Mizuno*

50 Years in Submillimeter-Waves: From Otaku to Sensei. IEEE Transactions on Terahertz Science and Technology, 3: (2) 130-133, 2013.

242. Siegel, Peter H.; *Terahertz Pioneer: Federico Capasso Physics by Design: Engineering Our Way Out of the THz Gap*. IEEE Transactions on Terahertz Science and Technology, 3: (1) 6-13, 2013.

243. Siegel, Peter H.; *Terahertz Pioneer: Frank C. De Lucia The Numbers Count*. IEEE Transactions on Terahertz Science and Technology, 2: (6) 578-583, 2012.

244. Siegel, Peter H.; *Terahertz Pioneer: Thomas G. Phillips The Sky Above, the Mountain Below*. IEEE Transactions on Terahertz Science and Technology, 2: (5) 478-484, 2012.

245. Siegel, Peter H.; *Terahertz Pioneer: Maurice F. Kimmitt A Person Who Makes Things Work*. IEEE Transactions on Terahertz Science and Technology, 2: (1) 6-9, 2012.

246. Siegel, Peter H.; *Electro-Thermal Model for Multi-Anode Schottky Diode Multipliers*. IEEE Transactions on Terahertz Science and Technology, 2: (3) 261-264, 2012.

247. Siegel, Peter H.; *Terahertz Pioneer: Richard J. Saykally Water, Water Everywhere....* IEEE Transactions on Terahertz Science and Technology, 2: (3) 266-270, 2012.

248. Siegel, Peter H.; *Terahertz Pioneer: Robert W. Wilson*. IEEE Transactions on Terahertz Science and Technology, 2: (2) 162-166, 2012.

249. Siegel, Peter H.; *Terahertz Pioneer: Philippe Goy If You Agree With the Majority, You Might be Wrong*. IEEE Transactions on Terahertz Science and Technology, 3: (4) 348-353, 2013.

250. Siegel, Peter H.; *Terahertz Pioneer: Fritz Keilmann RF Biophysics: From Strong Field to Near Field*. IEEE Transactions on Terahertz Science and Technology, 3: (5) 506-514, 2013.

251. Siegel, Peter H.; *Terahertz Pioneers: A series of interviews with significant contributors to terahertz science and technology*. IEEE Transactions on Terahertz Science and Technology, 2: (4) 377, 2012.

252. Siegel, Peter H.; *Terahertz pioneers a series of interviews with significant contributors to terahertz science and technology*. IEEE Transactions on Terahertz Science and Technology, 3: (1) 5, 2013.

253. Siegler, Matthew; Hudson, Troy et al.; *Measurements of thermal properties of icy Mars regolith analogs*. Journal of Geophysical Research-Planets, 117: E03001, 2012.

254. Siles, J.V.; Chattopadhyay, Goutam; Schlecht, Erich; Lin, Robert; Gill, John; Mehdi, Imran; Siegel, Peter et al.; *Next generation solid-state broadband frequency-multiplied terahertz sources*. IEEE Antennas and Propagation Society, AP-S International Symposium (Digest), 6348819, 2012.

255. Siles, Jose V.; Cooper, Ken; Reck, Theodore; Jung-Kubiak, Cecile; Lee, Choonsup; Lin, Robert; Peralta, Alejandro; Schlecht, Erich; Chattopadhyay, Goutam; Mehdi, Imran et al.; *Transceiver array development for submillimeter-wave imaging radars*. Proceedings of SPIE - The International Society for Optical Engineering, 8715: 87150A, 2013.

256. Soibel, A.; Rafol, Sir; Khoshakhlagh, Arezou; Hoeglund, Linda; Keo, Sam; Mumolo, Jason; Liu, John; Ting, David; Gunapala, Sarath et al.; *Long wavelength infrared superlattice detectors and FPAs based on CBIRD design*. IEEE Photonics Technology Letters, 25: (9) 875-878, 2013.

257. Spak, Kaitlin; Agnes, Gregory; Inman, Daniel; *Cable modeling and internal damping developments*. Applied Mechanics Reviews, 65: (1) 10801, 2013.

258. Spak, Kaitlin S.; Agnes, Gregory S.; Inman, Daniel J.; *Toward modeling of cable-harnessed structures: Cable damping experiments*. 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2013.

259. Stachnik, R. A.; Jarnot, Robert; Monroe, Ryan et al.; *Stratospheric BrO abundance measured by a balloon-borne submillimeterwave radiometer*. Atmospheric Chemistry and Physics, 13: (6) 3307-3319, 2013.

260. Staehle, Robert L.; Mouroulis, Pantazis; Pingree, Paula J.; et al.; *Interplanetary CubeSats: Opening the Solar System to a Broad Community at Lower Cost*, Journal of Small Satellites, Vol. 2, No. 1, pp. 161-186, 2013

261. Staniszewski, Z.; Turner, Anthony et al.; *The Keck Array: A Multi Camera CMB Polarimeter at the South Pole*. Journal of Low Temperature Physics, 167: (41400) 827-833, 2012.

262. Stockton, Amanda M.; Willis, Peter et al.; *Hydrolysis of 3-carboxy-6,8-difluoro-7-hydroxycoumarin (Pacific Blue) succinimidyl ester under acidic and basic conditions*. Dyes and Pigments, 96: (1) 148-151, 2013.

263. Stockton, Amanda M.; Mora, Maria F.; Cable, Morgan L.; Willis, Peter A.; *Design rules and operational optimization for rapid, contamination-free microfluidic transfer using monolithic membrane valves*. Sensors and Actuators, B: Chemical, 177: 668-675, 2013.

264. Sugai, Hajime; Braun, David; Fisher, Charles et al.; *Prime Focus Spectrograph - Subaru's future*. Proceedings of SPIE - The International Society for Optical Engineering, 8446: 84460Y, 2012.

265. Suh, J.; Shaw, M.D.; Weinstein, A.J.; Schwab, K.C.; Leduc, H.G.; *Thermally induced parametric instability in a back-action evading measurement of a micromechanical quadrature near the zero-point level*. Nano Letters, 12: (12) 6260-6265, 2012.

266. Sutton, Andrew J.; Ware, Brent; Spero, Robert et al.; *Improved optical ranging for space based gravitational wave detection*. Classical and Quantum Gravity, 30: (7) 75008, 2013.

267. Suvarna, Puneet; Nikzad, Shouleh et al.; *Design and growth of visible-blind and solar-blind III-N APDs on sapphire substrates*. Journal of Electronic Materials, 42: (5) 854-858, 2013.

268. Swartzlander, Grover; Quadrelli, Marco B.; Basinger, Scott; *Dynamics and control of a disordered system in space*. AIAA SPACE 2013 Conference and Exposition, 2013.

269. Swenson, L.J.; Day, Peter; Leduc, Henry et al.; *Operation of a titanium nitride superconducting microresonator detector in the nonlinear regime*. Journal of Applied Physics, 113: (10) 104501, 2013.

270. Swenson, Loren J.; Day, Peter; Jarnot, Robert; Leduc, Henry; Monroe, Ryan et al.; *MAKO: A pathfinder instrument for on-sky demonstration of low-cost 350 micron imaging arrays*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 84520P, 2012.

271. Tang, Adrian; Chang, Mau-Chung Frank; *A 294 GHz 0.47mW caterpillar amplifier based transmitter in 65nm CMOS for THz data-links*. 2013 IEEE 13th Topical Meeting on Silicon Monolithic Integrated Circuits in RF Systems, SiRF 2013 - RWW 2013, 27-29, 2013.

272. Tang, Aik Yean; Schlecht, Erich; Lin, Robert; Chattopadhyay, Goutam; Lee, Choonsup; Gill, John; Mehdi, Imran et al.; *Electro-thermal model for multi-anode schottky diode multipliers*. IEEE Transactions on Terahertz Science and Technology, 2: (3) 290-298, 2012.

273. Tecza, Matthias; Roberts, Jenny et al.; *15x optical zoom and extreme optical image stabilisation: Diffraction limited integral field spectroscopy with the SWIFT spectrograph*. Proceedings of SPIE - The International Society for Optical Engineering, 8446: 844622, 2012.

274. Tesch, Jonathan; Gibson, Steve; Verhaegen, Michel; *Receding-horizon adaptive control of aero-optical wavefronts*. Optical Engineering, 52: (7) 71406, 2013.

275. Thomas, P.; Klaasen, Kenneth et al.; *The nucleus of Comet 9P/Tempel 1: Shape and geology from two flybys*. ICARUS, 222: (2) 453-466, 2013.

276. Thomas, P.; Klaasen, Kenneth et al.; *Shape, density, and geology of the nucleus of Comet 103P/Hartley 2*. ICARUS, 222: (2) 550-558, 2013.

277. Thompson, David R.; Jiang, Yibo; Oyafuso, Fabiano; Castano, Rebecca et al.; *Atmospheric validation of high accuracy CO2 absorption coefficients for the OCO-2 mission*. Journal of Quantitative Spectroscopy and Radiative Transfer, 113: (17) 2265-2276, 2012.

278. Thompson, David R.; Mandrake, Lukas; Green, Robert O.; Chien, Steve A.; *A case study of spectral signature detection in multimodal and outlier-contaminated scenes*. IEEE Geoscience and Remote Sensing Letters, 10: (5) 1021-1025, 2013.

279. Thompson, David R.; Noell, Aaron et al.; *Autonomous spectral discovery and mapping onboard the EO-1 spacecraft*. IEEE Transactions on Geoscience and Remote Sensing, 51: (6) 3567-3579, 2013.

280. Thompson, David R.; Lundeen, Sarah et al.; *Airborne imaging spectroscopy to monitor urban mosquito microhabitats*. Remote Sensing of Environment, 137: 226-233, 2013.

281. Ting, David Z.; Keo, Sam; Liu, John; Mumolo, Jason; Khoshakhlagh, Arezou; Soibel, Alexander; Rafol, Sir; Hill, Cory; Gunapala, Sarath et al.; *Barrier infrared detector research at the Jet Propulsion Laboratory*. Proceedings of SPIE - The International Society for Optical Engineering, 8511: 851104, 2012.

282. Ting, David Z.; Soibel, Alexander; Khoshakhlagh, Arezou; Keo, Sam; Mumolo, Jason; Liu, John; Rafol, Sir; Hill, Cory; Gunapala, Sarath et al.; *Complementary barrier infrared detector (CBIRD) with double tunnel junction contact and quantum dot barrier infrared detector (QD-BIRD)*. Infrared Physics and Technology, 59: 146-151, 2013.

283. Ting, David Z.; Soibel, Alexander; Khoshakhlagh, Arezou; Keo, Sam; Mumolo, Jason; Gunapala, Sarath et al.; *Exclusion, extraction, and junction placement effects in the complementary barrier infrared detector*. Applied Physics Letters, 102: (12) 121109, 2013.

284. Trebi-Ollennu, Ashitey; Deen, Robert; Alexander, Douglass; Toda, Risaku; Manohara, Harish; Mojarradi, Mohammad; Wright, John; Hartman, Frank et al.; *Lunar Surface Operation Testbed (LSOT)*. IEEE Aerospace Conference Proceedings, 6187057, 2012.

285. Truong, Tuan N.; Burruss, Rick; Roberts, Jenny; Shelton, Chris; Troy, Mitchell et al.; *Design and implementation of the PALM-3000 real-time control system*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 84472F, 2012.

286. Tsikata, Edem; Darrach, Murray; Madzunkov, Stojan; Chutjian, Ara; *Dissociative Electron Attachment to NO, CO and N2O in a 0.5 T Magnetic Field*. Journal of Physics: Conference Series, 388: (PART 5) 52014, 2012.

287. Vacchione, Joseph D.; Kruid, Ronald C.; Amaro, Luis R.; Mittskus, Anthony P.; Prata Jr., Aluizio; *Telecommunications antennas for the Juno Mission to Jupiter*. IEEE Aerospace Conference Proceedings, 6187091, 2012.

288. Van Gorp, Byron; Mouroulis, Pantazis; Green, Robert; Rodriguez, Jose; Wilson, Daniel; Richardson, Brandon et al.; *Ultra-compact imaging spectrometer (UCIS) for in-situ planetary mineralogy: Laboratory and field calibration*. Proceedings of SPIE - The International Society for Optical Engineering, 8515: 85150G, 2012.

289. Varonen, M.; Samoska, Lorene; Kangaslahti, Pekka; Gaier, Todd et al.; *160-270-GHz InP HEMT MMIC low-noise amplifiers*. Technical Digest - IEEE Compound Semiconductor Integrated Circuit Symposium, CSIC, 6340058, 2012.

290. Vazquez-Cuervo, Jorge; Armstrong, Edward et al.; *An analysis of SST gradients off the Peruvian Coast: The impact of going to higher resolution*. Remote Sensing of Environment, 131: 76-84, 2013.

291. Veach, Todd J.; Scowen, Paul A.; Beasley, Matthew; Nikzad, Shouleh; *Modified modular imaging system designed for a sounding rocket experiment*. Proceedings of SPIE - The International Society for Optical Engineering, 8446: 84467F, 2012.

292. Verma, V.B.; Stern, Jeffrey et al.; *55% System detection efficiency with self-aligned WSi superconducting nanowire single-photon detectors*. 2012 Conference on Lasers and Electro-Optics, CLEO 2012, 6327052, 2012.

293. Veverka, J.; Klaasen, Kenneth et al.; *Return to Comet Tempel 1: Overview of Stardust-NExT results*. ICARUS, 222: (2) 424-435, 2013.

294. Vieregg, A.G.; Turner, Anthony et al.; *Optical characterization of the keck array polarimeter at the south pole*. Proceedings of SPIE - The International Society for Optical Engineering, 8452: 845226, 2012.

295. Wagner, Dave; Dekens, Frank et al.; *Model based systems engineering on the Europa mission concept study*. IEEE Aerospace Conference Proceedings, 6187337, 2012.

296. Wallace, J. Kent; Crawford, Sam; Loya, Frank; Moore, James; *A phase-shifting Zernike wavefront sensor for the palomar P3K adaptive optics system*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 84472K, 2012.

297. Wardlow, Julie L.; Nguyen, Haley et al.; *HerMES: Candidate Gravitationally Lensed Galaxies and Lensing Statistics at Submillimeter Wavelengths*. Astrophysical Journal, 762: (1) 59, 2013.

298. Weisbin, Charles R.; Lincoln, William; Papanastassiou, Dimitri A.; Coleman, Max L.; *Mars biosignature-detection capabilities: A method for objective comparison of in situ measurements and sample return*. AIAA SPACE 2013 Conference and Exposition, 2013.

299. Welch, Richard; Limonadi, Daniel; Samuels, Jessica; Warner, Noah; Morantz, Chaz; *Verification and validation of Mars Science Laboratory surface system*. Proceedings of 2013 8th International Conference on System of Systems Engineering: SoSE in Cloud Computing and Emerging Information Technology Applications, SoSE 2013, 64-69, 2013.

300. Williams, R. Brett; Fisher, Charles D.; Gallon, John C.; *Practical considerations for using constant force springs in space-based mechanisms*. 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2013.

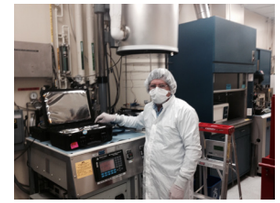
301. Worden, J.; Lee, Michael et al.; *CH4 and CO distributions over tropical fires during October 2006 as observed by the Aura TES satellite instrument and modeled by GEOS-Chem*. Atmospheric Chemistry and Physics, 13: (7) 3679-3692, 2013.

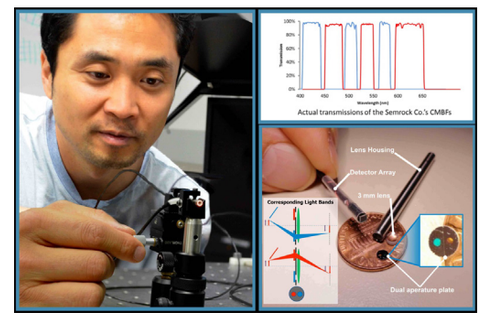
302. Xu, F.; Geier, Sven; Hancock, Bruce et al.; *The Airborne Multiangle SpectroPolarimetric Imager (AirMSPI): a new tool for aerosol and cloud remote sensing*. Atmospheric Measurement Techniques, 6: (8) 2007-2025, 2013.

303. Yu, Shanshan; Pearson, John C.; Drouin, Brian J.; *Terahertz spectroscopy of water in its second triad*. Journal of Molecular Spectroscopy, 288: (1) 7-10, 2013.

304. Zhai, Chengxing; Lockhart, Thomas; Cady, Eric; Burruss, Rick et al.; *A first order wavefront estimation algorithm for P1640 calibrator*. Proceedings of SPIE - The International Society for Optical Engineering, 8447: 84476W, 2012.

305. Zimmerman, Wayne et al.; *MSL Chemistry and Mineralogy X-ray Diffraction X-ray Fluorescence (CheMin) Instrument*. IEEE Aerospace Conference Proceedings, 6496835, 2013.





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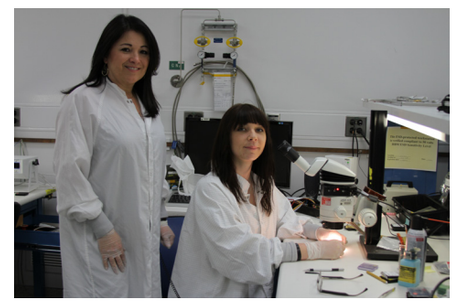

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