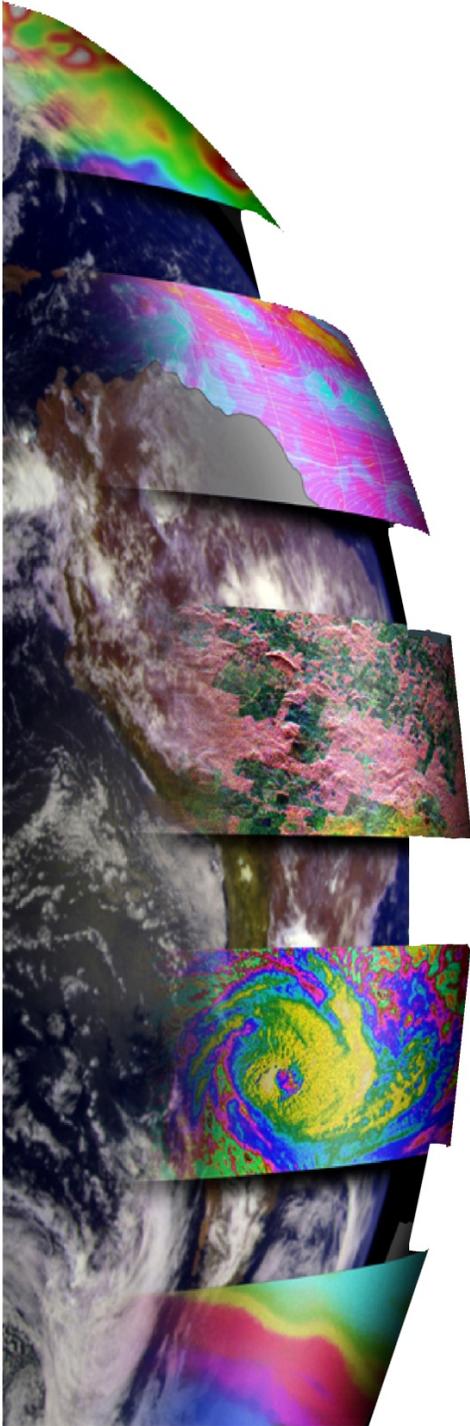
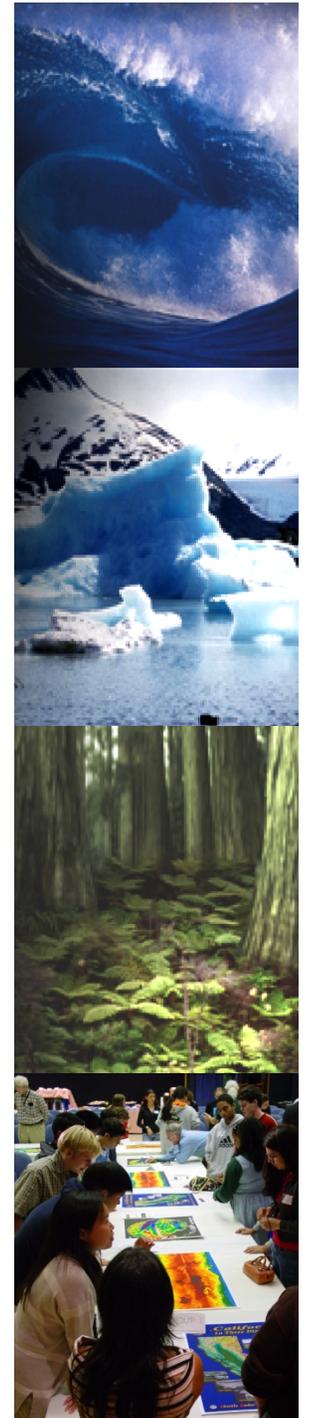


# Scientific Discovery and Technology Innovation Through Partnerships

A presentation to the Earth Science Technology Forum  
21 June 2011

**Charles Elachi, Director**  
NASA Jet Propulsion Laboratory  
California Institute of Technology



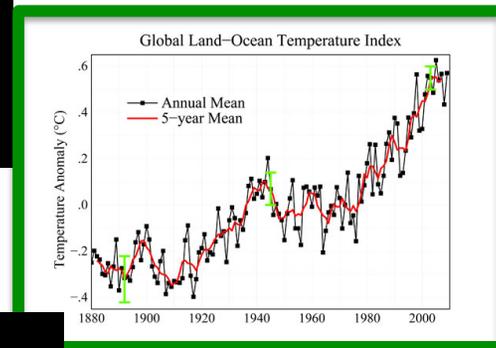
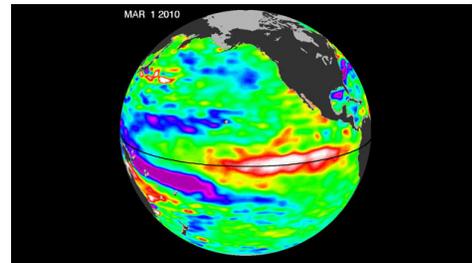
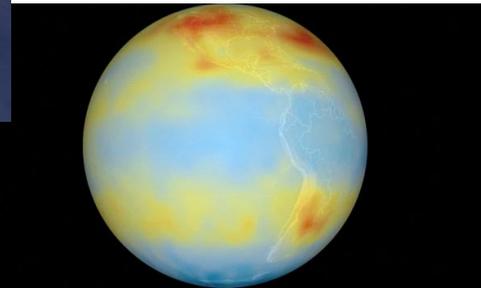
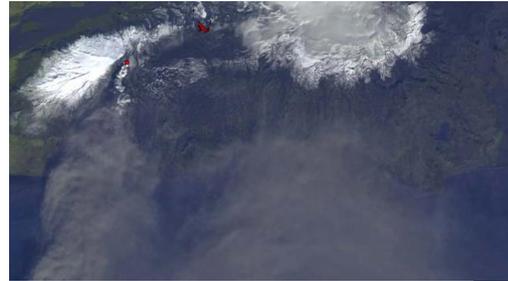


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## Some Recent Successes



- JPL's AIRS, MISR, and ASTER spacecraft monitor Iceland volcano
- AIRS maps CO<sub>2</sub> around Earth.
- Jasons see end of 2009 El Niño.
- NASA and JPL launch "Eyes on the Earth" tracking climate change.
- ASTER monitors landslides from Haiti earthquake.



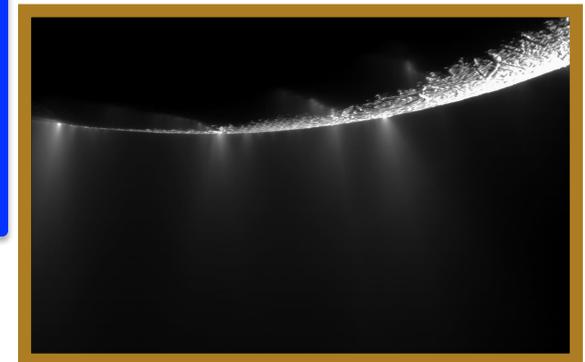
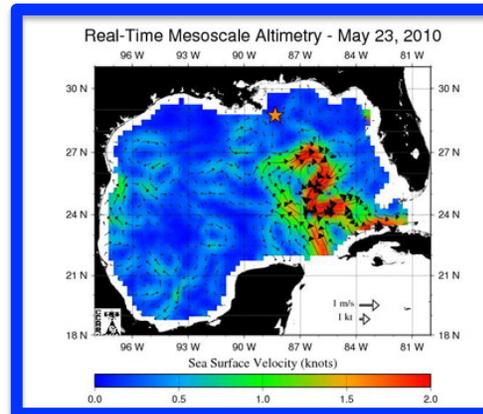
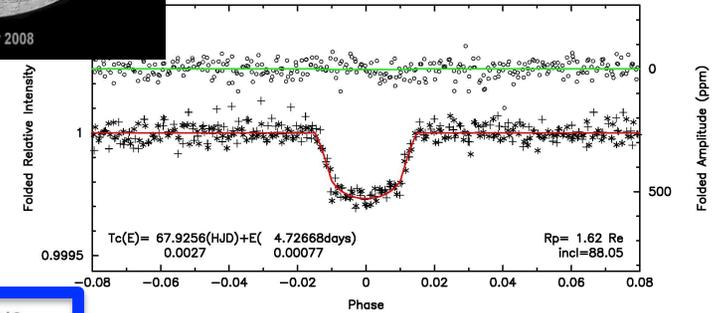
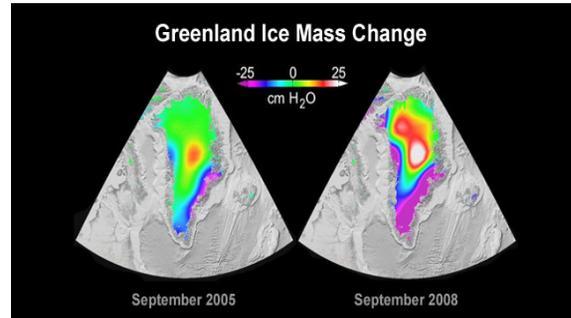


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## Some Recent Successes (cont'd)



- GRACE monitors Greenland and Antarctic ice loss
- Kepler releases preliminary data on transiting exoplanets
- JPL's AVIRIS monitored oil spill in the Gulf
- Cassini images ice particles and water vapor from Saturn's moon Enceladus





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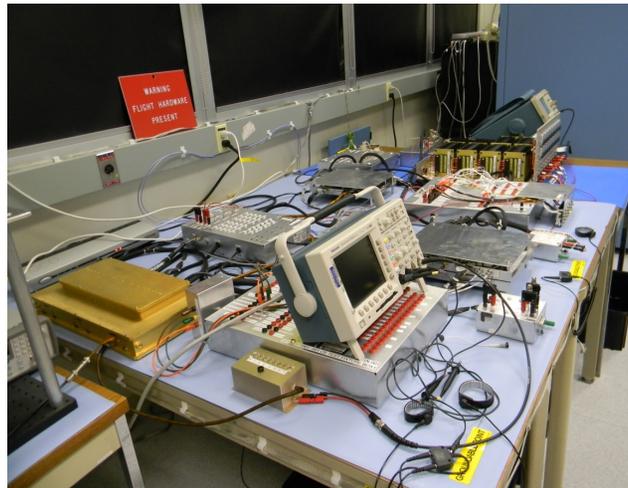
## Earth Science Activities: Aquarius, SMAP, OCO-2



- Aquarius/SAC-D  
launched June 9,  
2011



- SMAP radar  
breadboard  
development  
underway



- OCO-2 in  
development

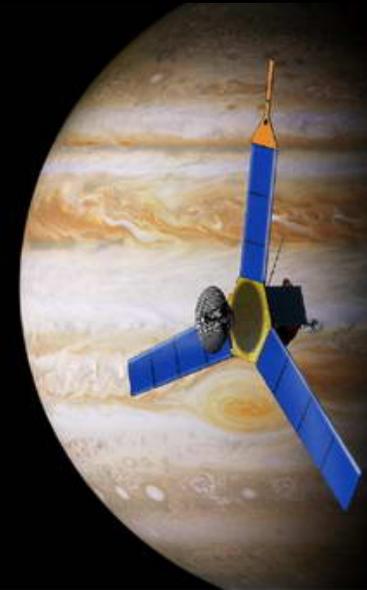


- Jason 3, Grace F.O., DESDynI, SWOT...

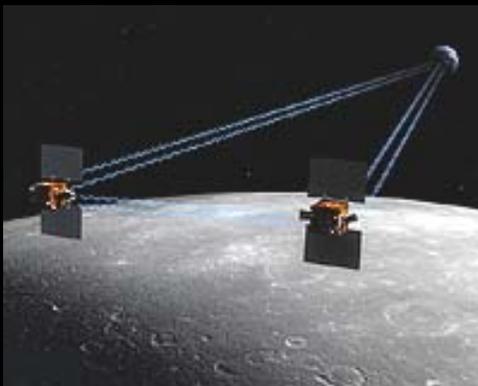
# Upcoming Mars & Solar System Exploration Events



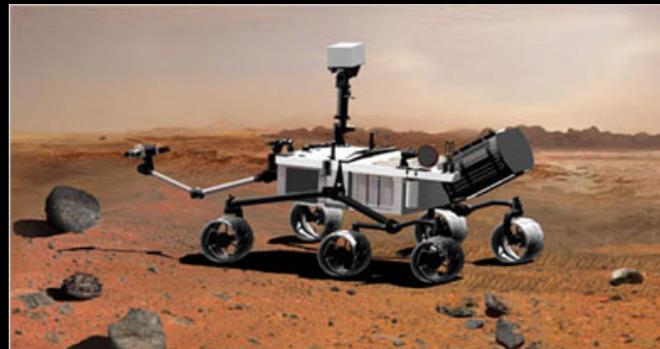
Dawn  
Vesta Arrival  
July 16, 2011  
(Ceres, February 2015)



Juno  
August 5, 2011



GRAIL  
September 8, 2011



Mars Science Laboratory  
November 25, 2011



NuSTAR  
February 3, 2012

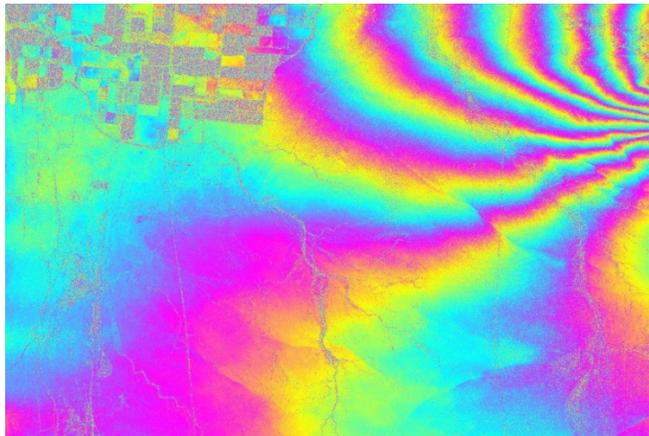


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# UAVSAR- Unmanned Airborne Vehicle Heritage and Innovation



**L-band repeat-pass interferometry**



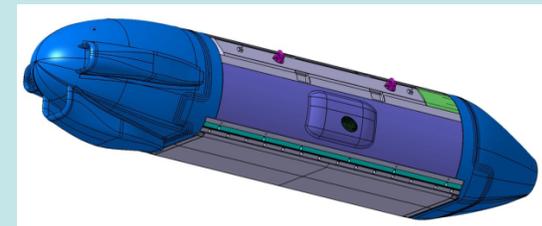
Mexicali earthquake deformation captured by UAVSAR using data acquired on October 21, 2009 and April 13, 2010. Major deformation (multiple color wraps) and subtle faulting are visible in the interferogram

**Ka-band single-pass InSAR for observing glacier and land ice topography**



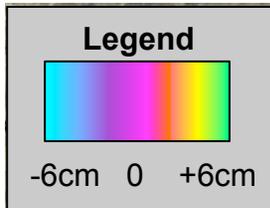
**L-band single-pass PolInSAR**

**P-band POLSAR (AirMOSS) for measuring subsurface and subcanopy soil moisture**

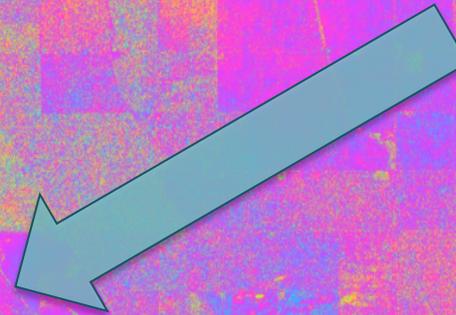


**Ongoing Instrument Development**

# UAVSAR Central California Subsidence Study



Interferogram showing subsidence (ground sinking) due to oil pumping



Missouri Triangle

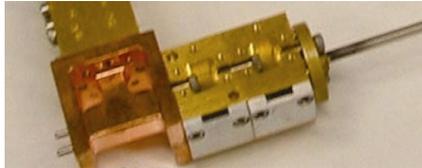
2010-09: Central California

UAVSAR



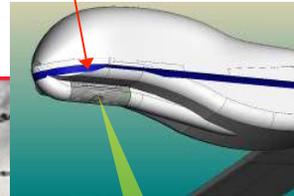
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# JPL and Northrop Grumman collaboration on GeoSTAR InP MMIC LNAs

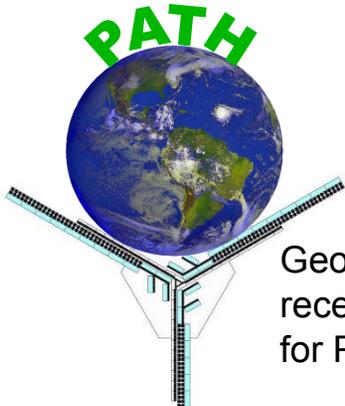


89 GHz CloudSat LNA

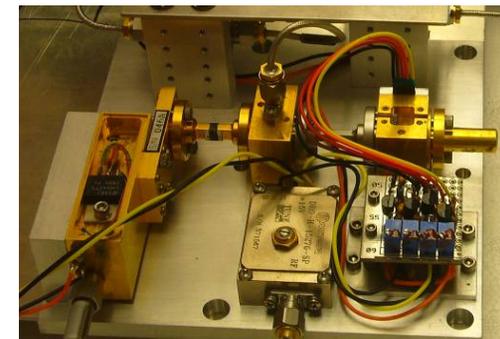
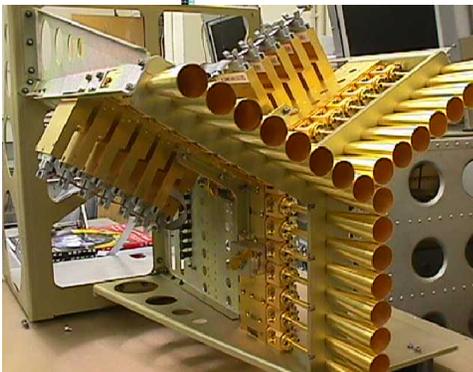
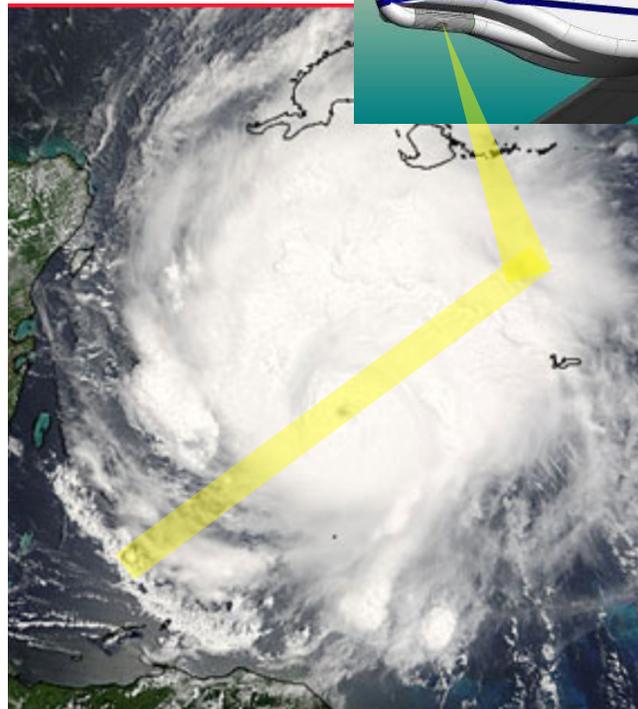
HAMSR on  
Global Hawk



50-60 GHz GeoSTAR/IMAS/  
HAMSR Receivers



GeoSTAR  
receiver arrays  
for PATH



165-183 GHz HAMSR  
Receiver



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# ESTO CubeSat Flight Validation for Multiangle Spectropolarimetric Imager (MSPI) Processing for ACE



David Diner, Paula Pingree et al., JPL

## MSPI Ground-based measurements



470, 660, 865 nm Intensity



470, 660, 865 nm DOLP

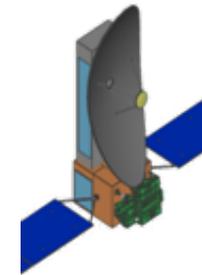
## MSPI Airborne engineering flight testing



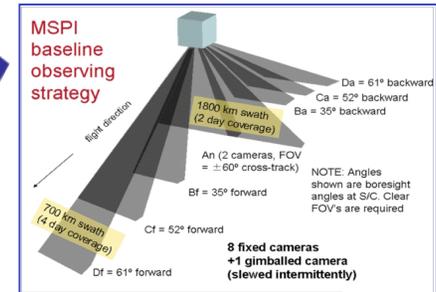
## MSPI algorithms/FPGA on CubeSat operating in space environment



## Multiangle polarimetric spectroscopy



## MSPI on ACE



2011 **Flight Validated** MSPI instrument processor and algorithms

On-board instrument processing enables downlink by reducing data rate by 2-orders of magnitude in real time with no science data lost



IIP-07 and AIST-08 Ground Testbed Development and Demonstration



AIST-08 AirMSPI board with algorithms on Xilinx Virtex-5 FPGA

ATI-10 COVE CubeSat board with algorithms on Xilinx SIFR FPGA





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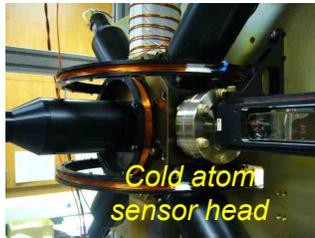
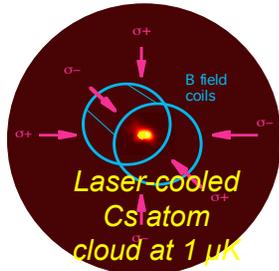
# Atomic Interferometer Inertial Sensors in Space



*For advanced gravity measurements for Earth and planetary sciences*

Technology:

- Atomic freefall test masses
- Quantum atom-wave interferometry



- Gravity gradiometer for higher resolution
- Simpler mission architecture (single spacecraft)
- More flexible orbits and satellite constellation (more comprehensive data for data analyses)

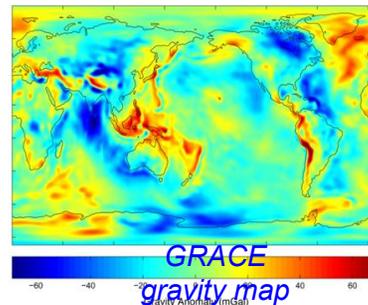
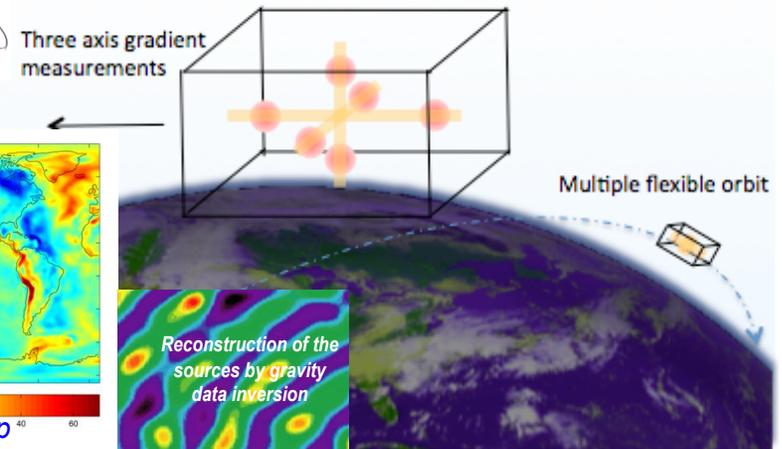
## Geodesy

### Earth and Planetary Interiors

- Lithospheric thickness, composition
- Lateral mantle density heterogeneity
- Deep interior studies
- Translational oscillation between core/mantle

### Earth and Planetary Climate Effects

- Oceanic circulation
- Tectonic and glacial movements
- Tidal variations
- Surface and ground water storage
- Polar ice sheets
- Earthquake monitoring





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# Infrared Imaging with JPL's HOT BIRDS



Below: IRPTG's newest invention is the High Operating Temperature (HOT) mid-infrared VGA format BIRD camera. The focal plane array operates at 150 K with NEDT of 27 mk at 300 K background with f/2 aperture.

Right: Infrared image of Dr. David Ting, who designed the HOT MWIR device.

Left: Thermal image of Dr. Ting taken with the HOT MWIR camera.



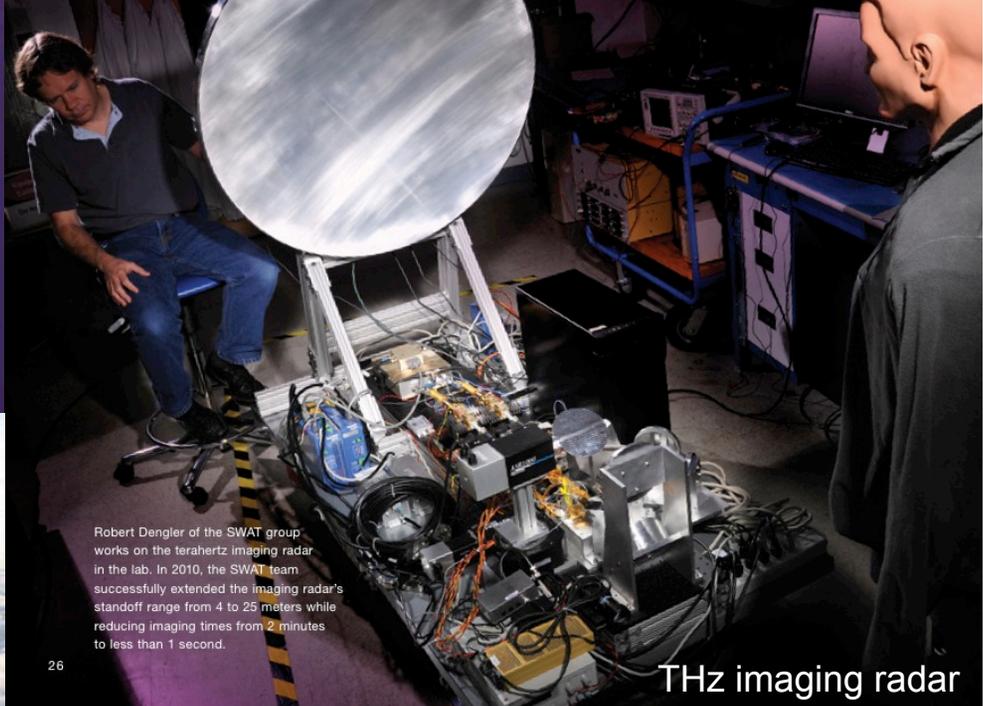
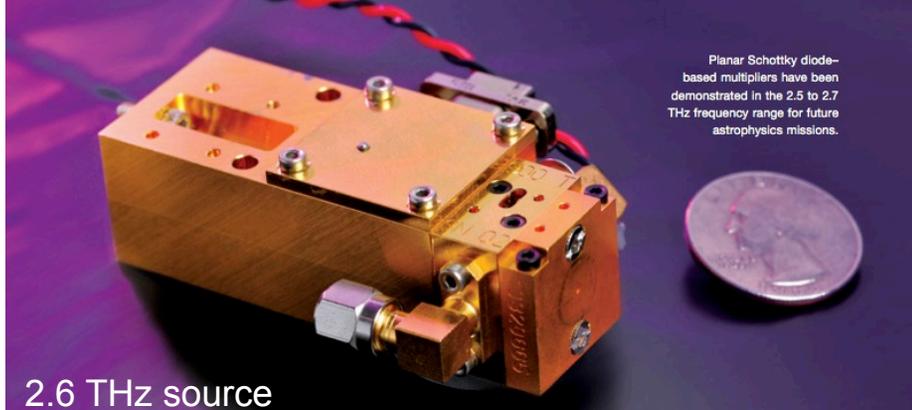
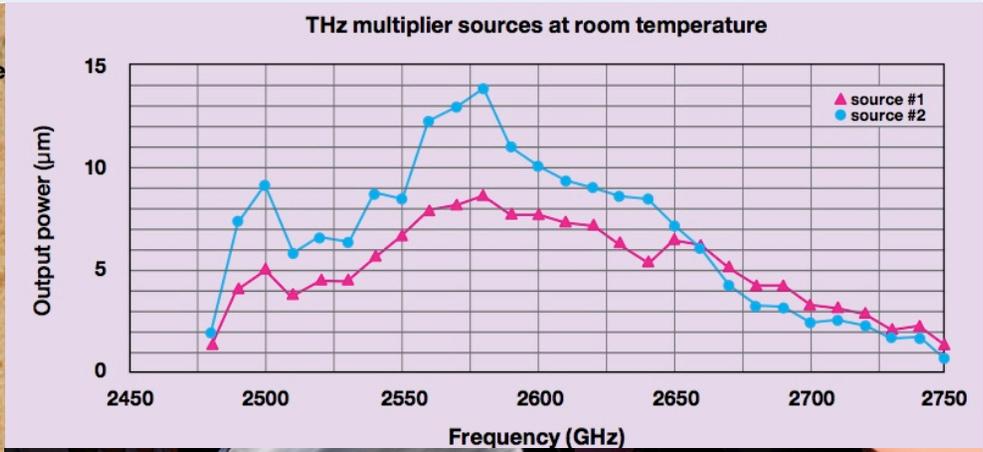
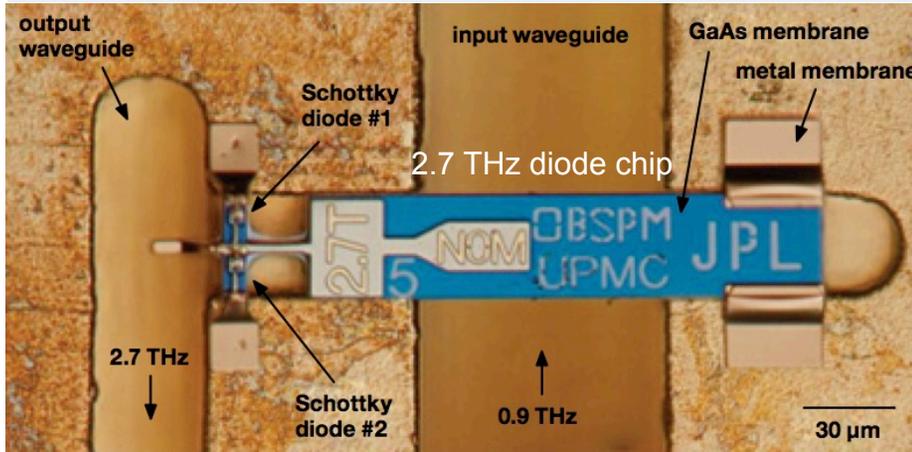
MDLs John Liu and Jason Mumolo at the SET FC-300 flip-chip bonder.

Credit: Sarath Gunapala, David Ting & JPL's IR Photonics Group



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# THz Electronics





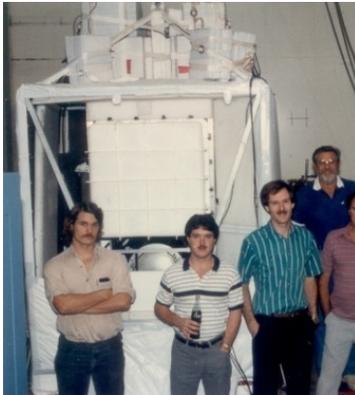
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# Infrared Lasers at 3- $\mu$ m for Earth and Planetary Science



*JPL's Micro Devices Lab (MDL) developed 3 micron tunable lasers to measure methane on Earth and on Mars*

## Stratospheric Balloons



## High-altitude aircraft



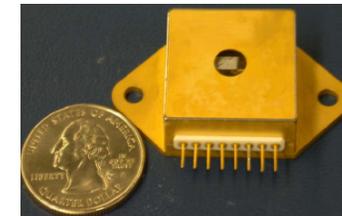
## Planetary Missions



**5 ft tall, 70 kg laser source**  
 (LHe) inside 1,600 kg (!) balloon instrument



**2 kg laser source** (liquid N<sub>2</sub>)  
 in 80 kg instrument



**MSL-TLS 100 g laser source** with internal TEC





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## Space-based Networking



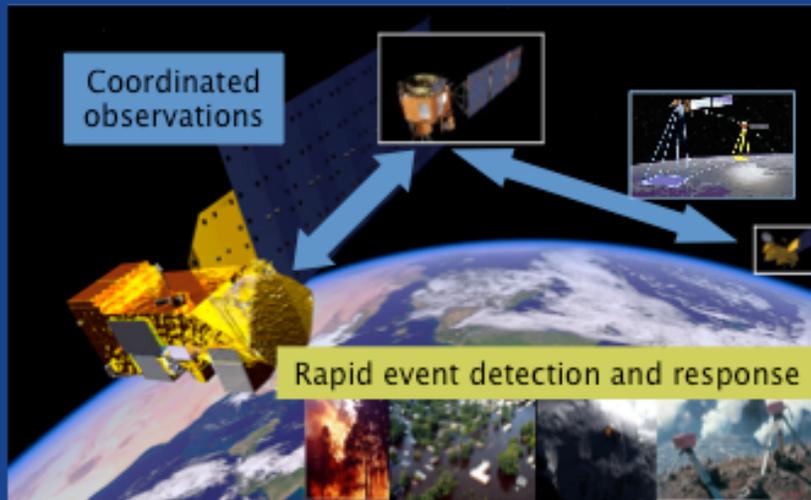
- Technology developed through partnerships:
  - 5 NASA field centers (JSC, GRC, GSFC, JPL, MSFC), JHU-APL, MITRE, and U. Colorado; and
  - International collaboration involving ESA, JAXA, CSA, and Roscosmos
- The first instance of Space-based Networking, including the core communication protocol DTN (Disruption Tolerant Networking), was flight validated on EPOXI
- Wide range of benefits for science return, mission risk, and cost

**Earth**

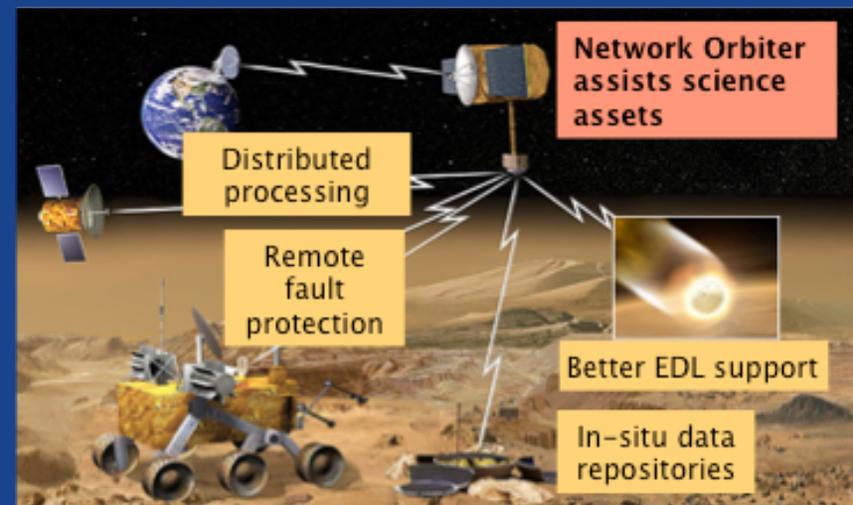


**Mars**

### Coordinated Science Observations



### Orbiter Assisted Operations





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# Operational Deployment of Sensorwebs



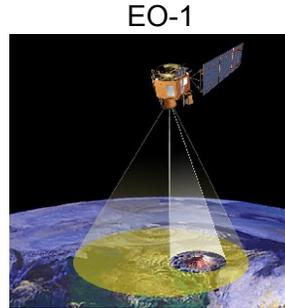
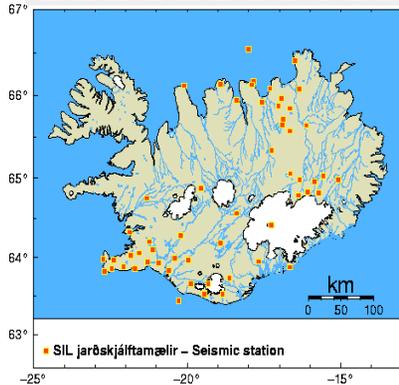
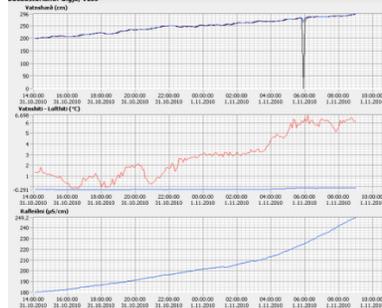
Steve Chien et al., JPL

## Iceland: Volcanoes

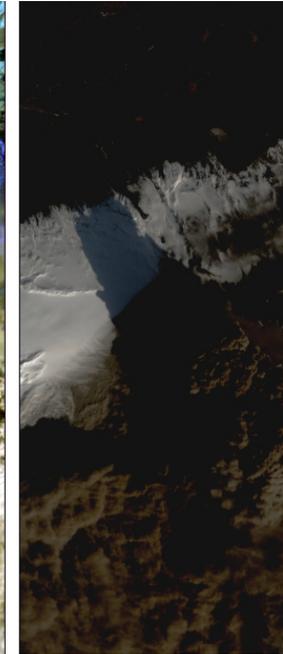
MODVOLC  
 (Terra, Aqua)

In-situ  
 sensors

Detection



→  
Response



Eyafallajökull 2010  
 1.9-3.3B USD Economic Damage [EU]

Left – thermal false color  
 Right – True color  
 17 April 2010  
 NASA/JPL/GSFC/EO-1 Mission

*“the Sensor Web has clearly demonstrated its value to the volcanological community...products were often delivered within a few hours of data acquisition”*

*S. Jakobsdottir, Manager, Earth Hazards, Iceland Meteorological Office*



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# QuakeSim: Japan GPS Time Series Analysis Points to Interesting Geophysics

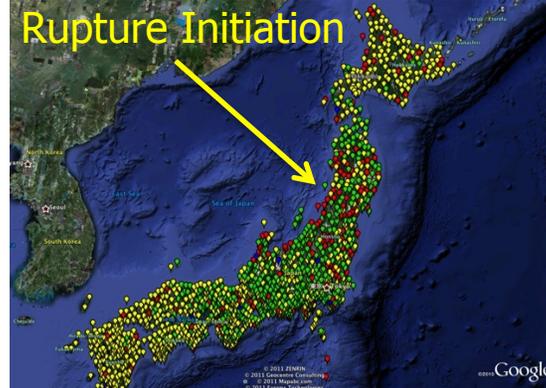


Robert Granat, Andrea Donnellan et al., JPL  
 March 11, 2011 0600 UTC

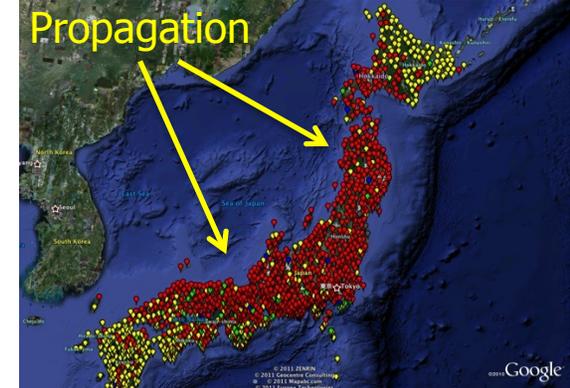
March 11, 2011 0500 UTC



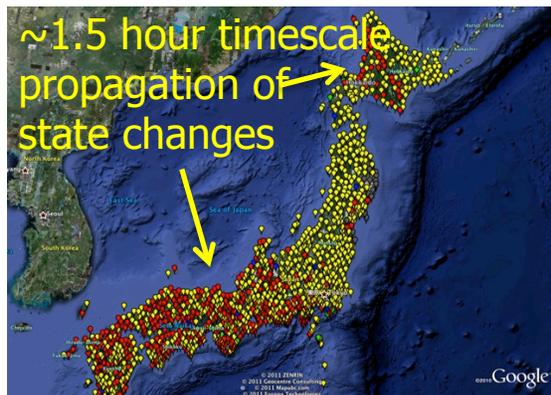
March 11, 2011 0530 UTC



March 11, 2011 0600 UTC



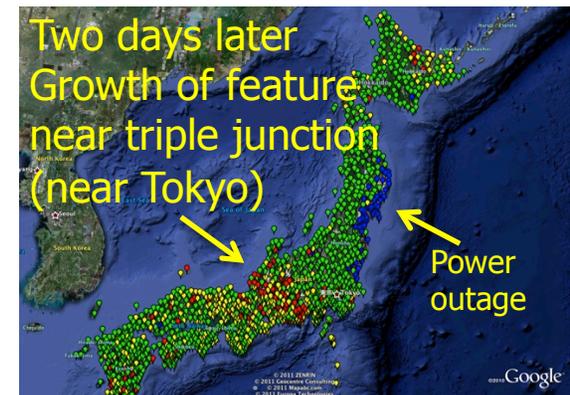
March 11, 2011 0630 UTC



March 11, 2011 0700 UTC



March 13, 2011 1300 UTC



Partners: Scripps Orbit and Analysis Center,  
 Indiana University, Computer Science  
 Application: Joint DHS/NPS project on earthquakes

Green – no state change  
 Red – state changes in last hour  
 Yellow – state changes in last day  
 Blue – no data



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## Advanced Rapid Imaging Analysis (ARIA) Recent Result from M9.0 Tohoku-Oki earthquake

Ground displacements from the March 11, 2011, magnitude 9.0 Tohoku earthquake in Japan, overlaid on a map of recent earthquake activity from the U.S. Geological Survey. The total surface displacement in the line of sight measured by this Envisat ASAR interferogram is about 2.5 meters.

Partnering with USGS and Caltech

