Fraser River at Vancouver outlet Landsat 5 Sept. 7, 2011

Arising from headwaters around Mount Robson in the Rocky Mountains, the Fraser River starts as a fast-moving stream. The river angles northward around the Columbia Mountains, picking up so much sediment that it appears brown by the time it reaches Quesnel. Near the coast, the river flows over flatter terrain, so it slows down and spreads out. On the final leg of its journey, the Fraser travels along the southern fringe of Vancouver.

The Thematic Mapper on the Landsat 5 satellite captured this image of Vancouver on September 7, 2011. Flowing through braided channels, the Fraser River meanders toward the sea, emptying through multiple outlets.

The river's abundant sediment forms a distinct plume west of Vancouver, extending across the Strait of Georgia to the eastern shore of Valdes Island. In fact, the Fraser River carries an estimated 20 million metric tons of sediment to the Pacific Ocean each year. Some of it drops out of the water before reaching the ocean, and this steady delivery has contributed to the landscape of Vancouver.

The muddy surface of the river often hides the complex, turbulent activity below. The mouth of the Fraser River is an estuary—a place where freshwater from rivers mixes with salt water from the ocean. But this estuary differs from some others in North America. In the San Francisco Bay, the Chesapeake Bay, and the mouth of the Hudson River, the mixing of salt and fresh water extends over miles. Near Vancouver, the mixing occurs along an abrupt front spanning just tens of meters. Although the swirling water and thick sediment can confuse salmon, the mixing also expels stagnant water and pollution and draws in oxygen.

A salmon-rich river draining into a seafood-rich ocean likely played a role in human settlement along the Fraser. Artifacts in this region suggest that human occupation may have started as long as 16,000 years ago. Unlike many other rivers, the Fraser has not been dammed. But it faces an indirect threat from pine beetle infestation;the subsequent removal of trees may warm the river water, making it inhospitable to the fish.

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Geyer, R. (2004, December 16). Where the rivers meet the sea. *Oceanus* Accessed February 23, 2012.

Linder, C. (2012, February 18). Fraser River: Running Free. Woods Hole Oceanographic Institution. Accessed February 23, 2012.

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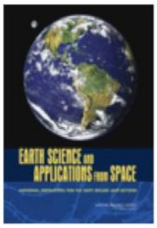
NASA Earth Observatory image created by Robert Simmon and Jesse Allen, using Landsat data provided by theUnited States Geological Survey. Caption by Michon Scott.

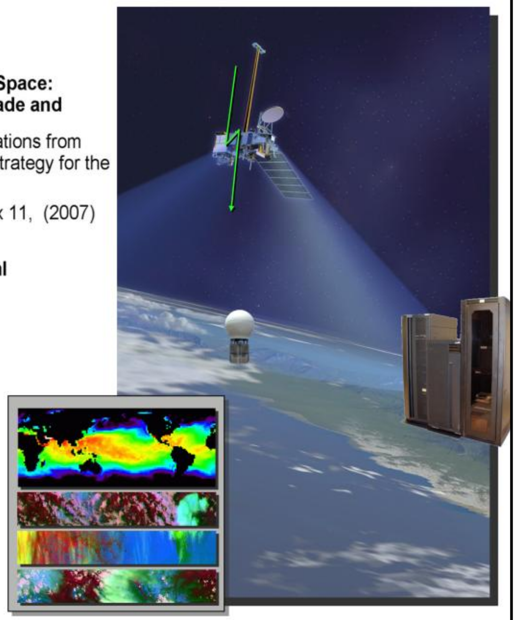
Lecture 20: Planned and Proposed Satellites in the Next Decade
March 15, 2012

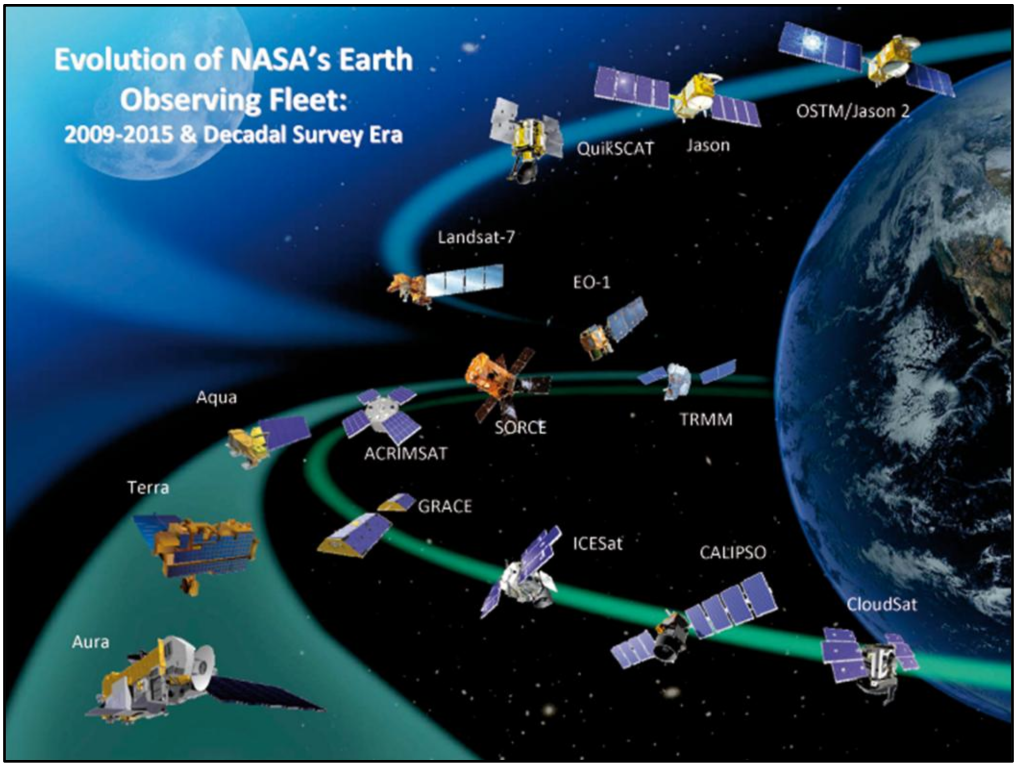


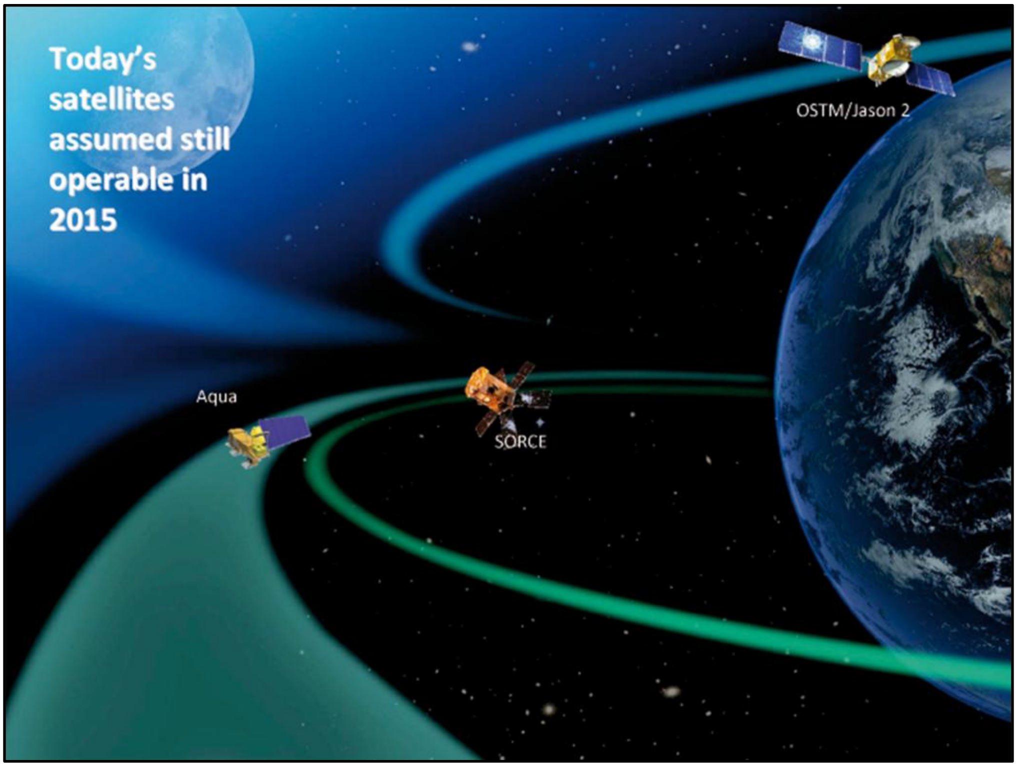
Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond

Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, National Research Council

ISBN: 0-309-66714-3, 456 pages, 8 1/2 x 11, (2007)




Evolution of NASA's Earth Observing Fleet:
2009-2015 & Decadal Survey Era
QuikSCAT
Jason
OSTM/Jason 2
Landsat-7
EO-1
Aqua
ACRIMSAT
SORCE
TRMM
Terra
GRACE
ICESat
CALIPSO
CloudSat
Aura


Today's
satellites
assumed still
operable in
2015
OSTM/Jason 2
Aqua
SORCE

U.S. Earth Observing Satellites

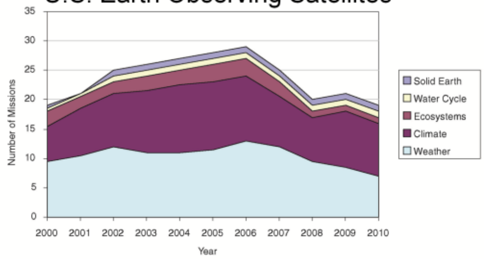


FIGURE ES.1 Number of U.S. space-based Earth observation missions in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of missions near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years past their nominal lifetimes. Most of the missions were deemed to contribute at least slightly to human health issues, and so health is not presented as a separate category. SOURCE: Information from NASA and NOAA Web sites for mission durations.

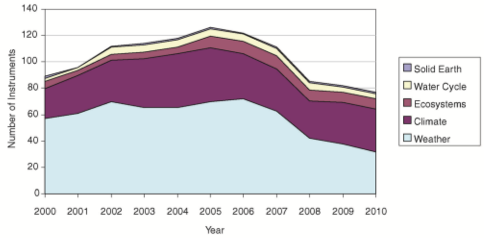
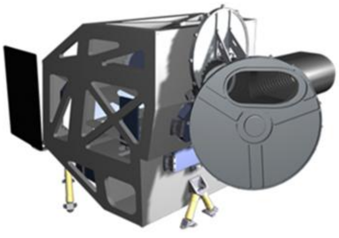


FIGURE ES.2 Number of U.S. space-based Earth observation instruments in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of instruments near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years past their nominal lifetimes. Most of the missions were deemed to contribute at least slightly to human health issues, and so health is not presented as a separate category. SOURCE: Information from NASA and NOAA Web sites for mission durations.

The Landsat Data Continuity Mission: Extending the Longest Legacy of Global Land Observation

306 Days to Launch: January 14

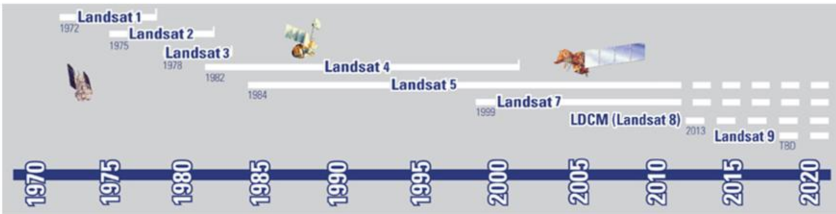
Design concept of LDCM's Operational Land Imager instrument. Image credit: Ball Aerospace & Technology Corp.



Band Number	Band Name	Min. Lower Band Edge (nm)	Max. Upper Band Edge (nm)	Ground Sampling Distance (m)
1	Coastal/Aerosol	433	453	28–30
2	Blue	450	515	28–30
3	Green	525	600	28–30
4	Red	630	680	28–30
5	NIR	845	885	28–30
6	SWIR 1	1560	1660	28–30
7	SWIR 2	2100	2300	28–30
8	Panchromatic	500	680	14–15
9	Cirrus	1360	1390	28–30

185-km cross-track swath width at the equator
ground sampling distance of between 28 and 30 m for spectral bands
14-15m for panchromatic band
TIR band

Current Launch Date is Dec. 2012


Landsat 1
1972
Landsat 2
1975
Landsat 3
1978
Landsat 4
1982
Landsat 5
1984
Landsat 7
1999
LDCM (Landsat 8)
2013
Landsat 9
TBD
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

CLARREO Cancelled 3/2011
SMAP in construction 2014
IceSat II scheduled 2016
DESDynI Cancelled 3/2011
HyspIRI delayed to 2021-2023

NRC, 2007 "Decadal Survey" Report

EXECUTIVE SUMMARY 9

TABLE ES.2 Launch, Orbit, and Instrument Specifications for Missions Recommended to NASA

Decadal Survey Mission	Mission Description	Orbit[a]	Instruments	Rough Cost Estimate (FY 06 $million)
2010-2013				
CLARREO (NASA portion)	Solar and Earth radiation; spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally resolved interferometer	200
SMAP	Soil moisture and freeze-thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	300
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	300
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	700
2013-2016				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	300
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	400
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka- or Ku-band radar Ku-band altimeter Microwave radiometer	450
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High-spatial-resolution hyperspectral spectrometer Low-spatial-resolution imaging spectrometer IR correlation radiometer	550
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	800
2016-2020				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	300
PATH	High-frequency, all-weather temperature and humidity soundings for weather forecasting and sea-surface temperature[b]	GEO	Microwave array spectrometer	450
GRACE-II	High-temporal-resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	450
SCLP	Snow accumulation for freshwater availability	LEO, SSO	Ku- and X-band radars K- and Ka-band radiometers	500
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	600
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	650

NOTE: Missions are listed by cost. Colors denote mission cost categories as estimated by the committee. Pink, green, and blue shading indicates large-cost ($600 million to $900 million), medium-cost ($300 million to $600 million), and small-cost (<$300 million) missions, respectively. Detailed descriptions of the missions are given in Part II, and Part III provides the foundation for their selection.

[a]LEO, low Earth orbit; SSO, Sun-synchronous orbit; GEO, geostationary Earth orbit.
[b]Cloud-independent, high-temporal-resolution, lower-accuracy sea-surface temperature measurement to complement, not replace, global operational high-accuracy sea-surface temperature measurement.

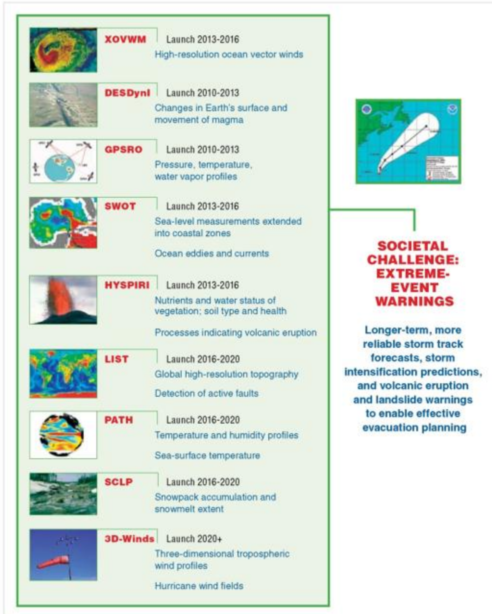
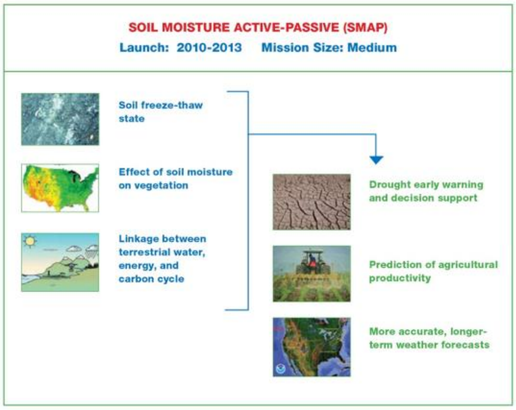
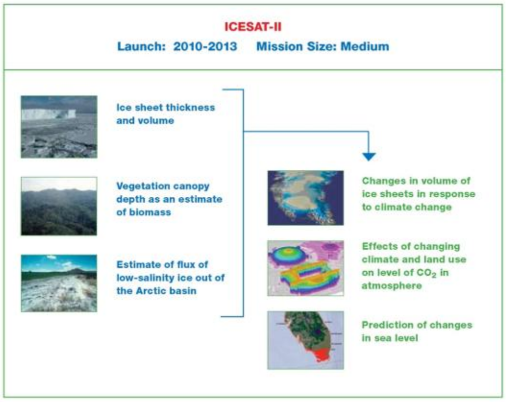


FIGURE 2.14 Recommended missions supporting extreme-event warnings.



SOIL MOISTURE ACTIVE-PASSIVE (SMAP) MISSION

Soil moisture is a key control on evaporation and transpiration at the land-atmosphere boundary. Large amounts of energy are required to vaporize water, and so soil control on evaporation and transpiration also influences surface energy fluxes. Hence, variations in soil moisture affect the evolution of weather and climate over continental regions. Initialization of numerical weather prediction (NWP) models and seasonal climate models with correct information on soil moisture enhances their prediction skill and extends their lead times. Soil moisture strongly affects plant growth and therefore agricultural productivity, especially during conditions of water shortage, the most severe of which is drought. There is no global in situ network for measuring soil moisture, and global estimates of soil moisture, and, in turn, plant water stress, must be derived from models. The model predictions (and hence drought monitoring) could be greatly enhanced through assimilation of soil-moisture observations. Soil moisture and its freeze-thaw state are also key determinants of the global carbon cycle. Carbon uptake and release in boreal landscapes are a major source of uncertainty in assessing the carbon budget of the Earth system (the so-called missing carbon sink). Soil moisture also is a key variable in water-related natural hazards, such as floods and landslides. High-



ICESat-II MISSION

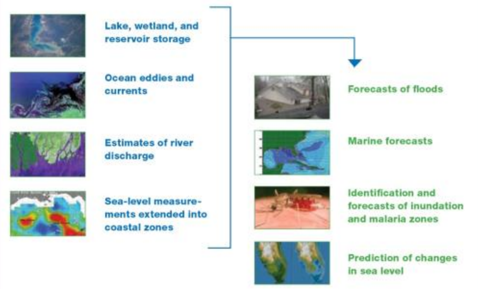
Sea-level rise is governed by three factors: melting of permanent snow cover and mountain glaciers, the thermal expansion component of sea level, and decreases in the size of permanent ice sheets, the last of which is the least well constrained. The measurements proposed for ICESat-II directly address the contribution of changing terrestrial ice cover to global sea level. Thus, they are key to projecting the effects of sea-level change on growing populations and infrastructure along almost all coastal regions.

Canopy-depth measurements made from ICESat-II will address changes in terrestrial biomass, which stores a substantial amount of carbon. Many factors influence the character of the vegetation, including climate, land-use, and fertilization by increased CO_2. Measurement of the vegetation-canopy depth will contribute to the ability to assess those influences and therefore better understand the carbon balance and future climate change.

Background: Space-borne lidar is a demonstrated technology for obtaining highly accurate topographic measurements of glaciers, ice sheets, and sea ice. Repeated observations of the polar ice caps by NASA's

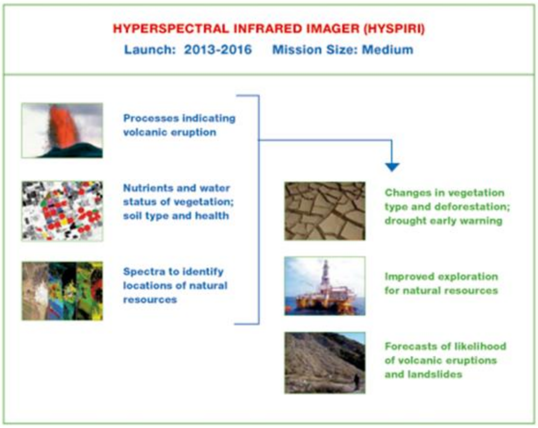
SURFACE WATER AND OCEAN TOPOGRAPHY (SWOT)

Launch: 2013-2016 Mission Size: Medium



SURFACE WATER AND OCEAN TOPOGRAPHY (SWOT) MISSION

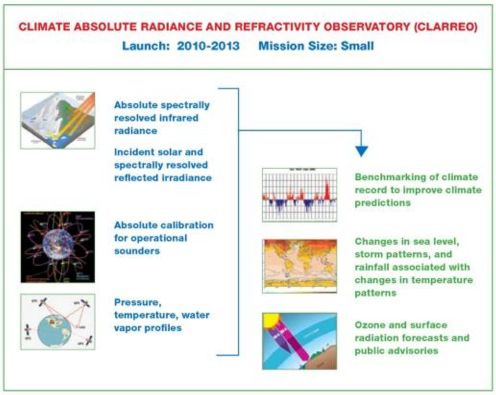
More than 75 percent of the world's population depends on surface water as its primary source of drinking water, but there is no coordinated global observing system for surface water. Furthermore, in the case of transboundary rivers, information is often not freely available about water storage, discharge, and diversions in one country that affect the availability of water in its downstream neighbors. For rivers, the surface stage, or water level, is the most critical observation that allows estimation of river discharge, but the global network of in situ river discharge observations is extremely nonuniform; generally, the observation density is much higher in the densely populated portions of developed countries than in the developing world. The SWOT mission would produce swath (image) altimetry of water surfaces over both the lands and oceans globally at much higher spatial resolution than is now available. That information would extend the successes of ocean altimeters to inland and coastal waters and would provide a basis for directly measuring the storage of water in lakes, reservoirs, and wetlands globally. River discharge would be estimated as a derived variable. River discharge is a key variable not only for water management but also for flood forecasting, which is the main tool for mitigation of property damage and loss of life related



HYPERSPECTRAL INFRARED IMAGER (HyspIRI) MISSION

Ecosystems respond to changes in land management and climate through altered nutrient and water status in vegetation and changes in species composition. A capability to detect such changes provides possibilities for early warning of detrimental ecosystem changes, such as drought, reduced agricultural yields, invasive species, reduced biodiversity, fire susceptibility, altered habitats of disease vectors, and changes in the health and extent of coral reefs. Through timely, spatially explicit information, the observing capability can provide input into decisions about management of agriculture and other ecosystems to mitigate negative effects. The observations would also underpin improved scientific understanding of ecosystem responses to climate change and management, which ultimately supports modeling and forecasting capabilities for ecosystems. Those, in turn, feed back into the understanding, prediction, and mitigation of factors that drive climate change.

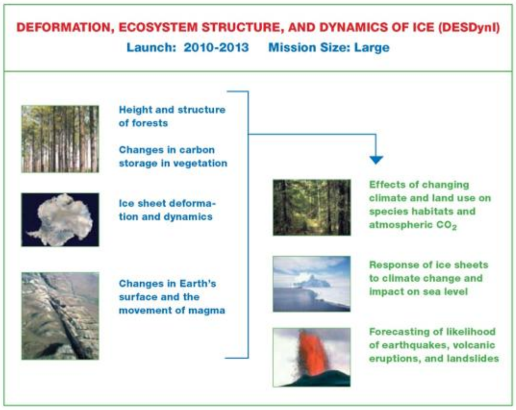
Volcanos are a growing hazard to large populations. Key to an ability to make sensible decisions about preparation and evacuation is detection of the volcanic unrest that may precede eruptions, which is marked by noticeable changes in the visible and IR centered on craters. Assessment of soil type is an



CLIMATE ABSOLUTE RADIANCE AND REFRACTIVITY OBSERVATORY (CLARREO) MISSION

Decision support for vital choices regarding water resources, human health, natural resources, energy management, ozone depletion, civilian and military communication, insurance infrastructure, fisheries, and international negotiations is necessarily linked to an understanding of climate. Effectively addressing each of these societal concerns depends on accurate climate records and credible long-term climate forecasts. Development of climate forecasts that are tested and trusted requires a chain of strategic decisions to establish fundamentally improved climate observations that are suitable for the direct testing and systematic improvement of long-term forecasts. That strategy sets the foundation of CLARREO.

CLARREO addresses three key societal objectives: (1) provision of a benchmark climate record that is global, accurate in perpetuity, tested against independent strategies that reveal systematic errors, and pinned to international standards; (2) development of a trusted, tested operational climate forecast through a disciplined strategy using state-of-the-art observations with mathematically rigorous techniques to establish credibility; and (3) disciplined decision structures that assimilate accurate data and forecasts into intelligible and specific products that promote international commerce and societal stability and security.

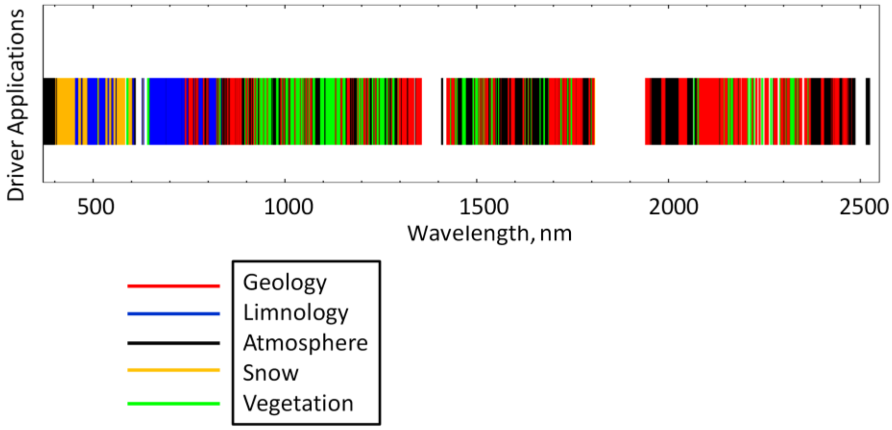


DEFORMATION, ECOSYSTEM STRUCTURE, AND DYNAMICS OF ICE (DESDynI) MISSION

Surface deformation is linked directly to earthquakes, volcanic eruptions, and landslides. Observations of surface deformation are used to forecast the likelihood of earthquakes as a function of location and to predict the places and times of volcanic eruptions and landslides. Advances in earthquake science leading to improved time-dependent probabilities would be facilitated by global observations of surface deformation and could result in increases in the health and safety of the public because of decreased exposure to tectonic hazards. Monitoring surface deformation is also important for improving the safety and efficiency of extraction of hydrocarbons, for managing groundwater resources, and, in the future, for providing information for managing CO_2 sequestration.

Radar and lidar measurements will probably help to understand responses of terrestrial biomass, which stores a large pool of carbon, to changing climate and land management. Benefits would include the potential for development of more effective land-use management, especially as climate-driven effects become more pronounced.

Wavelength Locations of Significant Information Identified by Different Disciplines

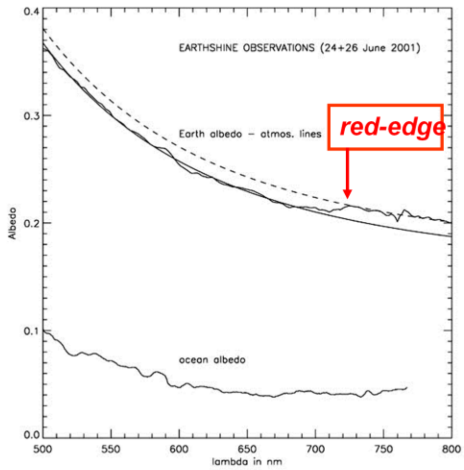


Schläpfer, D., & Schaepman, M.E. (2002). Modeling the noise equivalent radiance requirements of imaging spectrometers based on scientific applications. *Applied Optics, 41, 5691-5701*

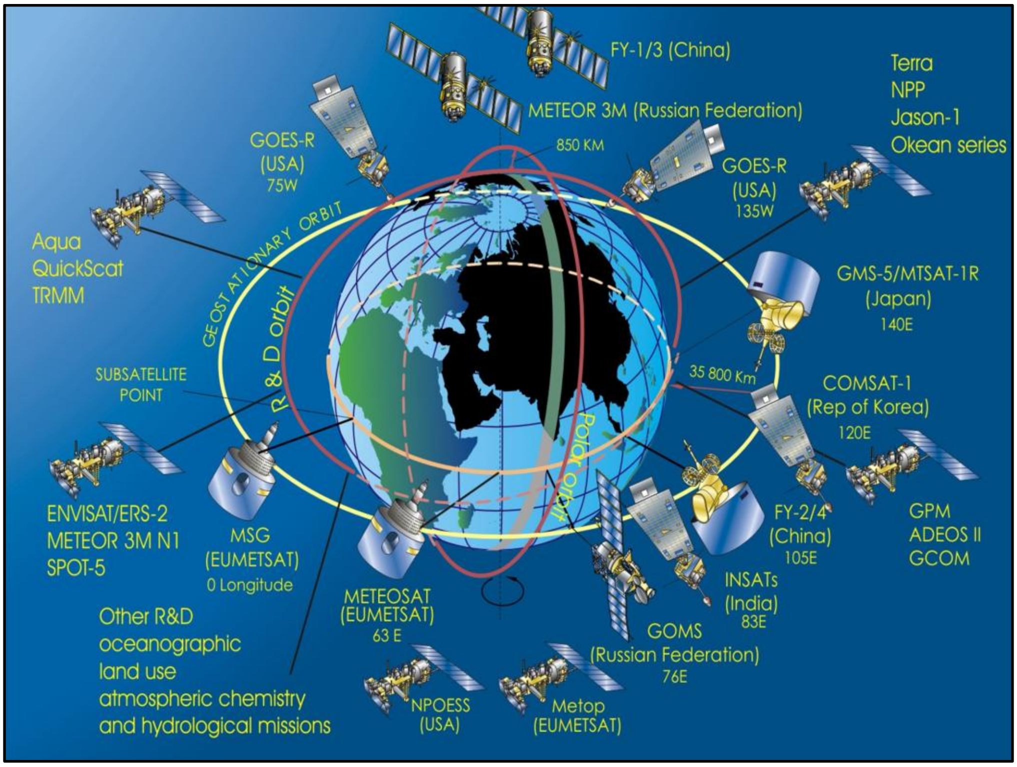
Image of Earth from the Moon

Image of Earth from the Moon acquired by the NASA Moon Mineralogy Mapper (M3) onboard the ISRO Chandrayaan-1 Mission to the Moon. Australia is visible in the lower center of the image. The false color composite shows the oceans as dark blue, clouds white, and vegetation enhanced green. The data were acquired on the 22nd of July 2009.

LUCAS (LUmière Cendrée en Antarctique par Spectroscopie)



L. Arnold, S. Gillet, O. Lardiere, P. Riaud & J. Schneider, 2002, A test for the search for life on extrasolar planets, *Astronomy & Astrophysics*, 392:231-237.



International Coordinated Weather Satellite Programs

The Environmental Observation Satellite network includes five operational near-polar-orbiting satellites and six operational geostationary environmental observation satellites as well as several Research and Development satellites (See WMO's Space Programme for current information). Polar orbiting and geostationary satellites are normally equipped with visible and infra-red imagers and sounders, from which many meteorological parameters are derived. Several of the polar-orbiting satellites are equipped with sounders instruments that can provide vertical profiles of temperature and humidity in cloud free areas. Geostationary satellites are used to measure wind velocity in the tropics by tracking clouds and water vapor.

Satellite sensors, communications and data assimilation techniques are evolving steadily so that better use is being made of the vast amount of satellite data. Improvements in numerical modeling in particular, have made it possible to develop increasingly sophisticated methods of deriving the temperature and humidity information directly from the satellite radiances. Research and Development (R&D) satellites comprise the newest constellation in the space-based component of the Global Observational System (GOS). R&D missions provide valuable data for operational use as well as for many WMO supported programmes. Instruments on R&D missions either provide data not normally observed from operational meteorological satellites or improvements to current operational systems.

International Program Cooperation

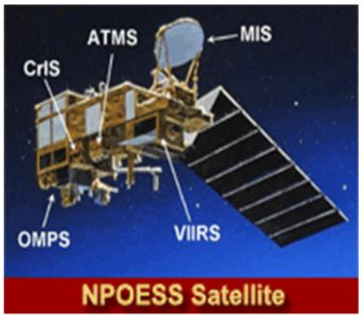
In the 1980s, NOAA needed to balance the high cost of space systems and the growing need to provide a complete and accurate description of the atmosphere at regular intervals as inputs to numerical weather prediction and climate monitoring support systems. This led NOAA to enter into discussions and agreements at the international level with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The goal of this cooperation is to provide continuity of measurements from polar orbits, cost sharing, and improved forecast and monitoring capabilities through the introduction of new technologies.

Building upon the POES program, an agreement is in place between NOAA and EUMETSAT on the Initial Joint Polar-orbiting Operational Satellite System (IJPS). This program will include two series of independent but fully coordinated NOAA and EUMETSAT satellites, exchange of instruments and global data, cooperation in algorithm development, and plans for real-time direct broadcast. Under terms of the IJPS agreement, NOAA will provide NOAA-N and NOAA-N' satellites for flights in the afternoon orbit while EUMETSAT makes available METOP-1 and METOP-2 satellites for flights in the mid-morning orbit. The first METOP satellite is was launched Oct. 19, 2006.

Primary NPOESS Instruments

CrIS: The Cross-track Infrared Sounder (CrIS), with ATMS, collects atmospheric data to calculate emperature and moisture profiles at high(~ daily) temporal resolution.

ATMS: The Advanced Technology Microwave Sounder (ATMS) with CrIS, will profile atmospheric temperature and moisture.



MIS: Microwave Imaging Sounder (MIS) will collect global microwave radiometery and sounding data.

OMPS: The Ozone Mapping and Profiler Suite (OMPS) monitors ozone from space.

VIIRS: The Visible/Infrared Imager/Radiometer Suite collects visible/infrared imagery and radiometric data.

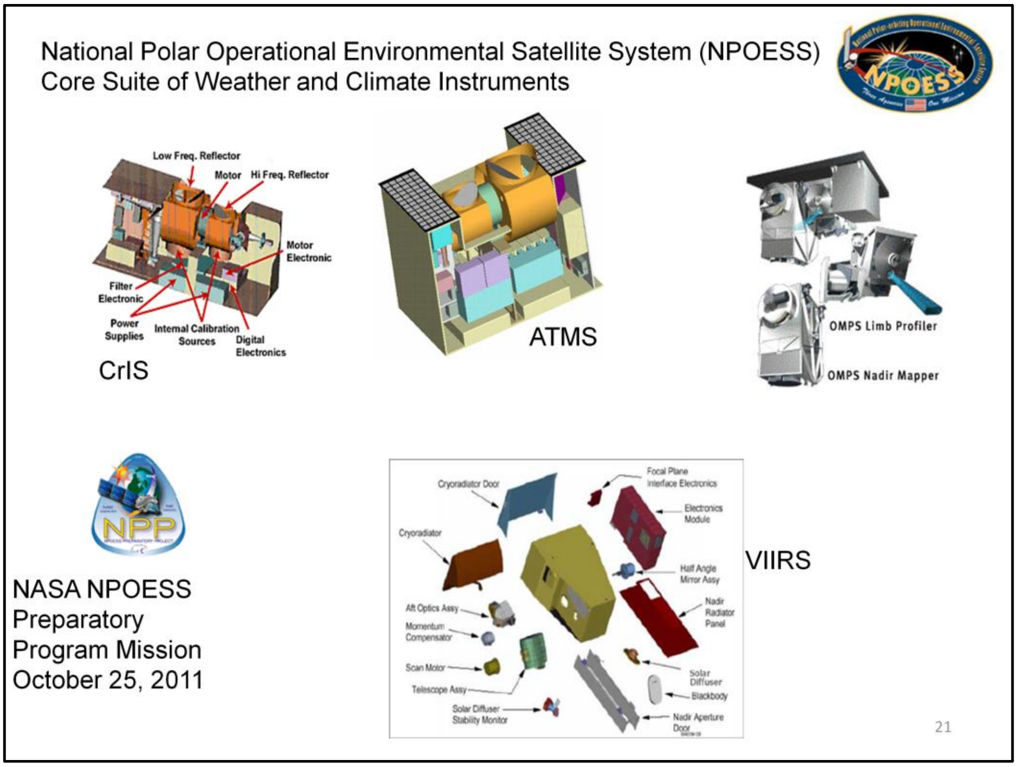
What is NPOESS?

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is the next generation of low earth orbiting environmental satellites. The NPOESS will circle the Earth approximately once every 100 minutes. During these rotations, the NPOESS will be providing global coverage, monitoring environmental conditions, and collecting and disseminating data about the Earth's weather, atmosphere, oceans, land, and near-space environment.

The NPOESS system will be able to monitor the entire planet and provide data for long-range weather and climate forecasts. The data gathered by the NPOESS will aid in reducing the potential loss of human life and property by allowing more efficient disaster planning and response to severe weather conditions such as tornadoes and floods.

Citizens will benefit from the satellite's data in the areas of general aviation, agriculture, and maritime activities. Military users will benefit from NPOESS as well, tactically and strategically. NPOESS will permit the military to capitalize on favorable weather conditions or avoid harsh weather conditions that could hinder maneuverability.

The NPOESS will collect a massive amount of very precise earth surface, atmospheric and space environmental measurements from a variety of on-board sensors. This volume of data will allow scientists and forecasters to monitor and predict weather patterns with greater speed and accuracy.



On Feb. 1, 2010, the White House restructured the National Polar-orbiting Operational Environmental Satellite System, or NPOESS, tri-agency effort among NOAA, NASA and the Department of Defense. Through the NOAA-NASA partnership, another polar-orbiting satellite called the NPOESS Preparatory Project is scheduled to launch in late 2011. It will demonstrate the capabilities of next-generation sensors and provide continuity with NASA's Earth Observing System satellites. The NOAA-NASA team also will build, launch and operate two more polar satellites under the Joint Polar Satellite System. The satellites are planned to be ready for launch in 2015 and 2018.

The Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) will collect atmospheric data to permit the calculation of temperature and moisture profiles at high (~ daily) temporal resolution.

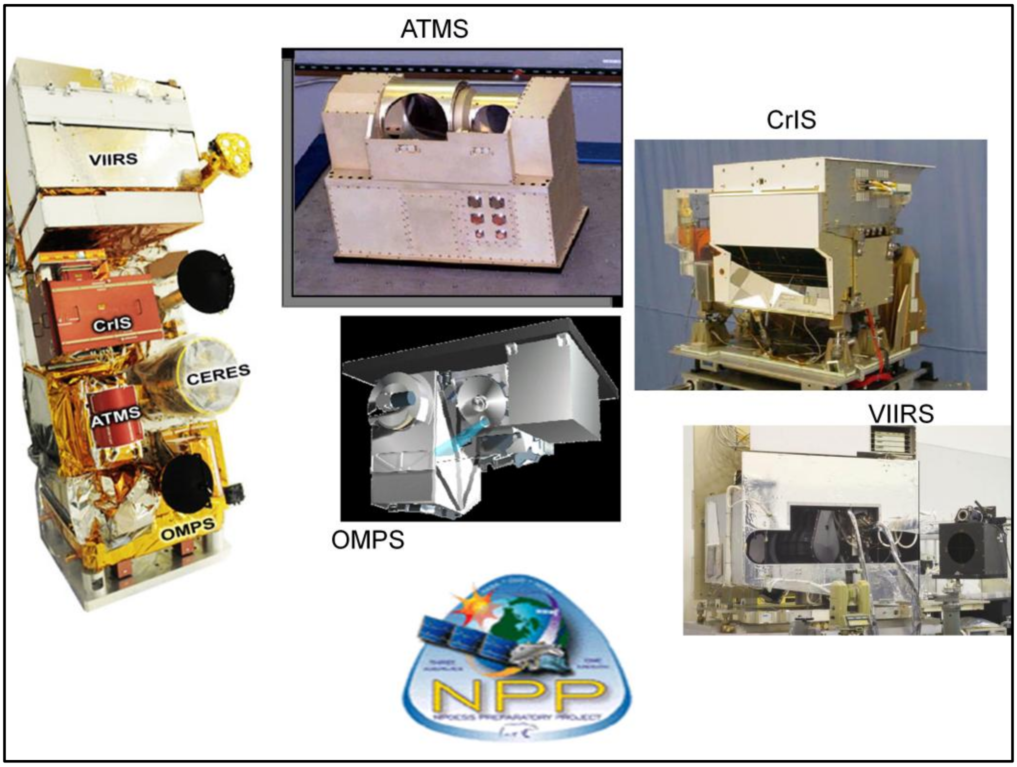
The Ozone Mapping and Profiler Suite (OMPS) monitors ozone from space. OMPS will collect total column and vertical profile ozone data and continue the daily global data produced by the current ozone monitoring systems, the Solar Backscatter Ultraviolet radiometer (SBUV)/2 and Total Ozone Mapping Spectrometer (TOMS), but with higher fidelity. The collection of this data contributes to fulfilling the U.S. treaty obligation to monitor the ozone depletion for the Montreal Protocol to ensure no gaps on ozone coverage.

The Visible/Infrared Imager/Radiometer Suite (VIIRS) visible/infrared imagery and radiometric data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery. VIIRS contributes to 23 Environmental Data Records (EDRs) and is the primary instrument for 18 EDRs.

The Visible Infrared Imager / Radiometer Suite (VIIRS) will combine the radiometric accuracy of the Advanced Very High Resolution Radiometer (AVHRR) currently flown on the NOAA polar orbiters with the high (0.65 kilometer) spatial resolution of the Operational Linescan System (OLS) flown on DMSP. The VIIRS will provide imagery of clouds under sunlit conditions in about a dozen visible channels (or frequency bands), as well as provide coverage in a number of infrared channels for night and day cloud imaging applications.VIIRS will have multichannel imaging capabilities to support the acquisition of high resolution atmospheric imagery and generation of a variety of applied products including: visible and infrared imaging of hurricanes and detection of fires, smoke, and atmospheric aerosols. VIIRS will also provide capabilities to produce higher resolution and more accurate measurements of sea surface temperature than currently available from the heritage AVHRR instrument on POES, as well as an operational capability for ocean color observations and a variety of derived ocean color products.

The NPOESS Preparatory Project (NPP) is a joint mission to extend key measurements in support of long-term monitoring of climate trends and of global biological productivity. It extends the measurement series being initiated with EOS Terra and AQUA by providing a bridge between NASA's EOS missions and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) of the Integrated Program Office (IPO). The NPP mission will provide operational agencies early access to the next generation of operational sensors, thereby greatly reducing the risks incurred during the transition. This will permit testing of the advanced ground operations facilities and validation of sensors and algorithms while the current operational systems are still in place. This new system will provide nearly an order of magnitude more data than the current operational system.

NPOESS will provide long-term systematic measurements of key environmental variables beginning about 2009. In preparation for this system, NPP will provide risk reduction for this future operational system and it will maintain continuity of certain environmental data sets that were initiated with NASA's Terra and Aqua satellites. These measurements will be taken by three different sensors; Visible Infrared Imaging spectroRadiometer Suite (VIIRS), Crosstrack Infrared Sounder (CrIS), and Advanced Technology Microwave Sounder (ATMS). These sensors will collect data on atmospheric and sea surface temperatures, humidity soundings, land and ocean biological productivity, and cloud and aerosol properties. This data will be used for long-term climate and global change studies.



The Cross-track Infrared Sounder (CrIS) combined with the Advanced Technology Microwave Sounder (ATMS) globally produces atmospheric temperature, moisture and pressure profiles from space. CrIS and ATMS (CrIMSS) are the next generation operational sensor suite selected to fly on the National Polar orbiting Operational Environmental Satellite System (NPOESS) spacecraft.

ATMS provides high spatial resolution microwave data to support temperature and humidity sounding generation in cloud covered conditions. In addition, ATMS provides advances in technology that allow the current operational temperature and moisture microwave sounder elements to be packaged in one sensor with less total weight, power, and volume.

The Ozone Mapping and Profiler Suite (OMPS) monitors ozone from space. OMPS will collect total column and vertical profile ozone data and continue the daily global data produced by the current ozone monitoring systems, the Solar Backscatter Ultraviolet radiometer (SBUV)/2 and Total Ozone Mapping Spectrometer (TOMS), but with higher fidelity. The collection of this data contributes to fulfilling the U.S. treaty obligation to monitor the ozone depletion for the Montreal Protocol to ensure no gaps on ozone coverage.

The Visible/Infrared Imager/Radiometer Suite (VIIRS) collects visible/infrared imagery and radiometric data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery. Primary instrument for satisfying 22 environmental data records (EDRs).

The Cloud and Earth Radiant Energy System (CERES) measures the reflected shortwave and Earth emitted radiances. The CERES measurements seek to develop

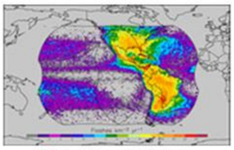
and improve weather forecast and climate models prediction, to provide measurements of the space and time distribution of the Earth's Radiation Budget (ERB) components, and to develop a quantitative understanding of the links between the ERB and the properties of the atmosphere and surface that define that budget. CERES consists of three broadband radiometers that scan the earth from limb to limb. The three spectral channels cover the spectral regions of 0.3 to > 50 µm (total radiation channel), 8 µm to 12 µm (atmospheric window channel) and 0.3 µm to 5 µm (shortwave channel).

Earth Pointing | **In-Situ** | **Sun Pointing**

Visual & IR Imagery

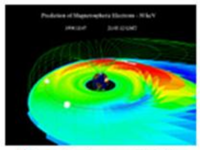
* Advanced Baseline Imager (ABI)

Lightning Mapping



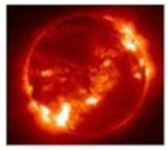
* Geostationary Lightinng Mapper (GLM)

Space Weather Monitoring



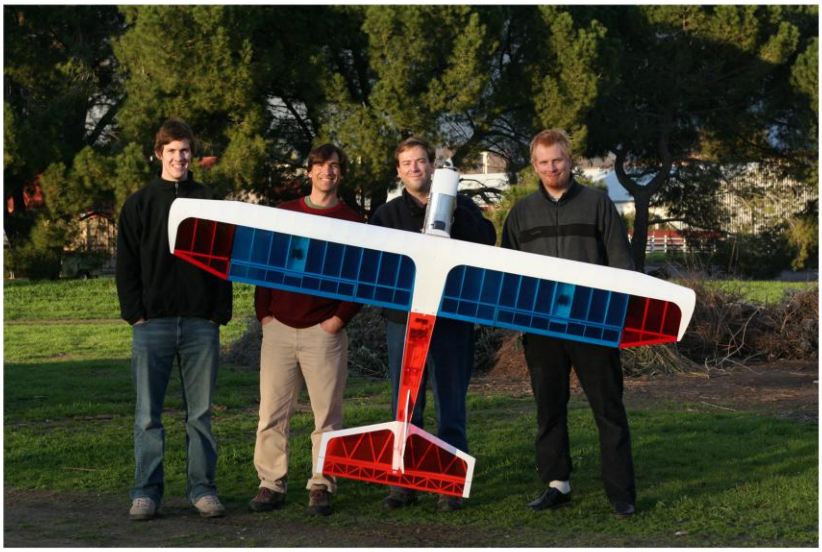
* Space Environment In-Situ Sensor Suite (SEISS)
* Magnetometer

Solar Imaging



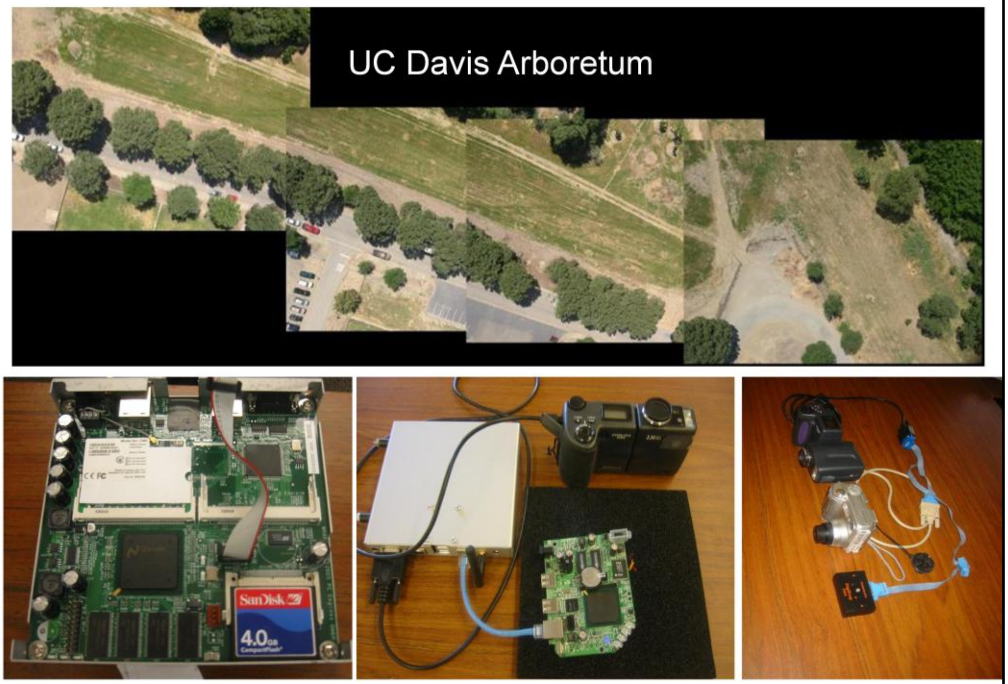
* Solar Ultra-Violet Imager (SUVI)
* Extreme UV / X-Ray Irradiance Sensors (EXIS)

CSTARS Unpiloted Airborne Vehicle



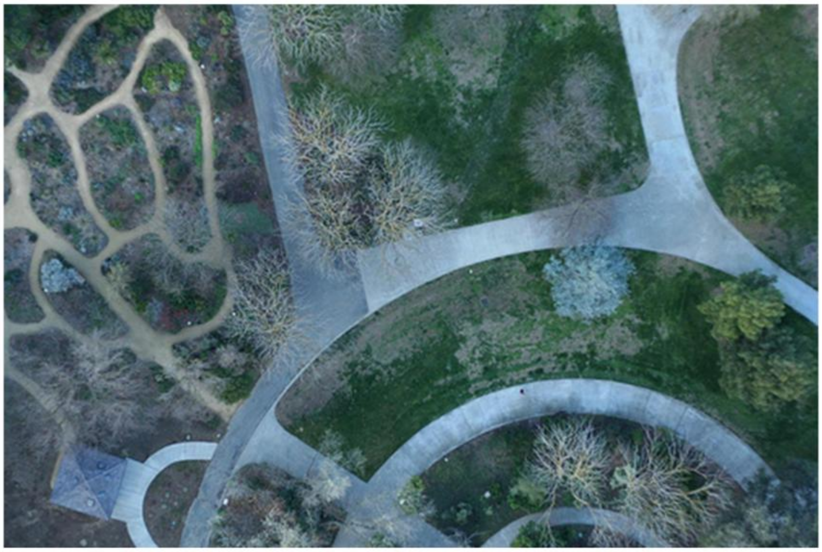
~8 kg Payload, Electric motor, Pointing & GPS

SYMP 9 - Ecological Analysis in the 21st Century:
Advances in Space-based Observations for local to global ecological studies



Computer Sensors: IRGA CIR Imagers

A new generation of miniaturized instruments




UC Davis Arboretum