National Aeronautics and Space Administration

the earth observer

The Earth Observer. May - June 2013. Volume 25, Issue 3.

Editor's Corner

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Every Earth-observing mission that has ever flown began as an inspiring vision of what might be possible, followed by a long and challenging journey as the vision confronted reality—both technical and financial. As those who have been involved in developing missions and instruments can attest, it is a journey of many years. Of course some visions never make it to space, but the ones that do are typically based on demonstrated and mature technology.

In 1998, as the first missions of the Earth Observing System (EOS) began to launch, NASA established the Earth Science Technology Office (ESTO) as a testbed to develop technology that could be used for future missions and instruments. ESTO uses an end-to-end approach for demonstrating advanced and cost-effective technologies that help NASA fulfill its science objectives. To date, more than 37% of ESTO-funded technologies have been infused into Earth-observing spaceborne and airborne missions. Please turn to page 22 to read more about recent ESTO projects.

continued on page 2

These images of Paluweh volcano, in the Flores Sea, Indonesia, were obtained on April 29, 2013 by the Landsat Data Continuity Mission's (LDCM) Operational Land Imager (OLI) [*top*] and Thermal Infrared Sensor (TIRS) [*bottom*]. The image pair illustrates the value of having both OLI and TIRS on LDCM. Indeed, "the whole is greater than the sum of its parts." The OLI captures a high-resolution visible image of the plume showing the white cloud of ash drifting northwest over the darker forests and water. Adding the TIRS image allows us to "see" into the infrared and reveals a bright white "hot spot" over the volcano, surrounded by cooler ash clouds, and highlighting TIRS ability to detect very small changes in temperature over small distances—down to about 0.10 °C (0.18 °F). **Credit:** Robert Simmon, NASA's Earth Observatory, using data from the U.S. Geological Survey and NASA.

NASA Intensifies Hurricane Studies with CYGNSS

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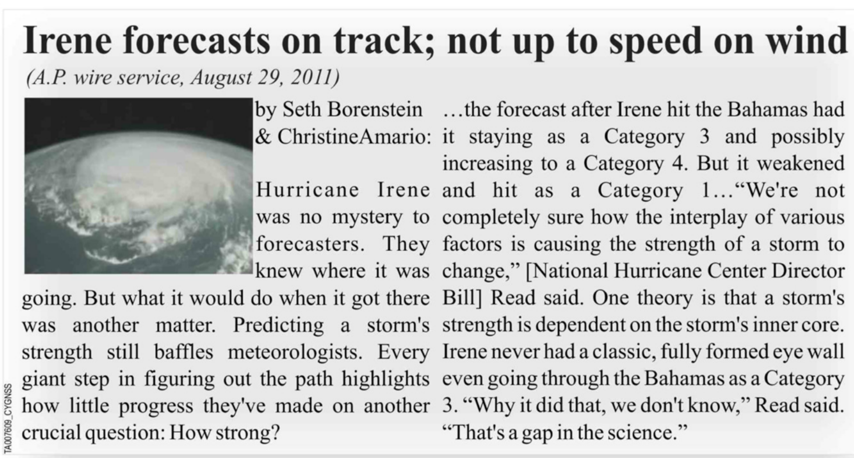
Historically, it has been difficult to obtain space-based measurements of ocean surface vector winds in regions with heavy precipitation.

Rationale for CYGNSS

Hurricane track forecasts have improved in accuracy by about 50% since 1990, largely as a result of improved mesoscale and synoptic modeling and data assimilation. On the other hand, in that same period there has been essentially no improvement in the accuracy of intensity forecasts—an observation that is widely recognized not only by national research institutions[1], but also by the popular press—see **Figure 1**.

A hurricane intensity forecast is critically dependent on accurate wind measurements in the core of the developing tropical cyclone. Current hurricane intensity forecasts are limited by two factors: inaccuracy of current ocean surface wind measurements and inadequate sampling of the rapidly evolving core environment. Historically, it has been difficult to obtain space-based measurements of ocean surface vector winds[2] in regions with heavy precipitation. While supplementing satellite observations with aircraft-based observations has helped improve accuracy in some instances, wind-speed estimates in the inner core of a hurricane continue to be a challenge.



Irene forecasts on track; not up to speed on wind

(A.P. wire service, August 29, 2011)

by Seth Borenstein & ChristineAmario:

Hurricane Irene was no mystery to forecasters. They knew where it was going. But what it would do when it got there was another matter. Predicting a storm's strength still baffles meteorologists. Every giant step in figuring out the path highlights how little progress they've made on another crucial question: How strong?

…the forecast after Irene hit the Bahamas had it staying as a Category 3 and possibly increasing to a Category 4. But it weakened and hit as a Category 1…"We're not completely sure how the interplay of various factors is causing the strength of a storm to change," [National Hurricane Center Director Bill] Read said. One theory is that a storm's strength is dependent on the storm's inner core. Irene never had a classic, fully formed eye wall even going through the Bahamas as a Category 3. "Why it did that, we don't know," Read said. "That's a gap in the science."

Figure 1: Excerpt from article on the Associated Press Wire Service, August 29, 2011.

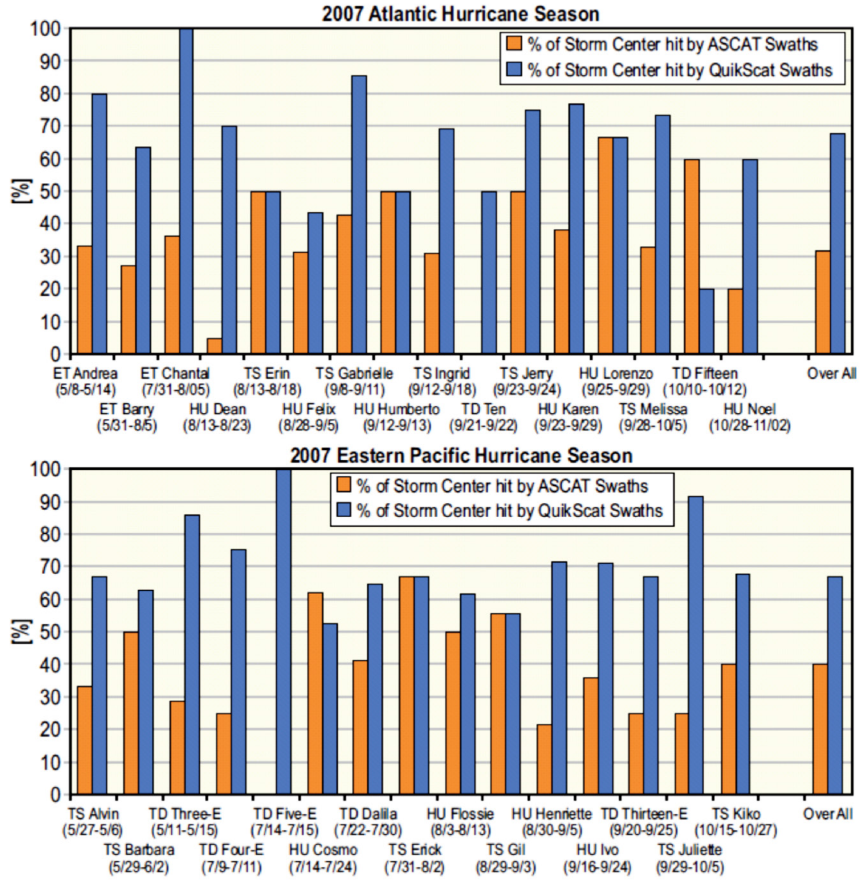
Tropical cyclones form from *mesoscale convective systems* (MCSs[3]). In the tropics, MCSs account for more than half of the total rainfall, and their development is critically dependent on complex interactions between ocean surface properties, moist-atmosphere thermodynamics, radiation, and convective dynamics. Unfortunately, most current space-based active and passive microwave instruments are in polar low-Earth orbits (LEOs) that maximize global coverage but leave significant "data gaps" over the tropics. Further, a single, broad-swath, high-resolution scatterometer system cannot resolve synoptic-scale spatial detail everywhere on the globe, and in particular not over the tropics. The revisit times of current on-orbit instruments range between 12 hours and several days, and are similarly not sufficient to capture the rapidly changing environment at the core of a tropical cyclone.

As a striking example, **Figure 2** (next page) shows the percentage of times that the core of every tropical depression, storm, and cyclone from the 2007 Atlantic and Pacific storm seasons was successfully imaged by the Quick Scatterometer (QuikSCAT) or Advanced Scatterometer (ASCAT). Sometimes, the core is missed when an organized system passes through an imager's coverage gap; other times, it is because the storm's motion is appropriately offset from the motion of the imager's swath. The figure highlights the fact that, in many cases, tropical cyclones are observed

[1] *Hurricane Warning: The Critical Need for a National Hurricane Research Initiative*, National Science Foundation, NSB-06-115, 2007; Hurricane Forecast Improvement Project, NOAA, 2008

[2] These include NASA's Quick Scatterometer (QuikSCAT), which flew on the SeaWinds mission, the Advanced Scatterometer (ASCAT) on the European Organization for the Exploitation of Meteorological Satellites' (EUMETSAT) METOP series of satellites, and the Oceansat-2.

[3] Tropical cyclones, mesoscale convective complexes, squall lines, lake effect snow, and polar lows are all weather phenomena that form from MCSs.



ET = Extratropical HU = Hurricane TD = Tropical Depression TS = Tropical Storm

Figure 2. These graphs show the percentage of times the center of named tropical cyclones were observed by either the QuikSCAT (blue) or ASCAT (orange) polar-orbiting scatterometers during the 2007 Atlantic [*top graph*] and Pacific [*bottom graph*] hurricane season. Poor performance results from the coverage gaps and infrequent revisit times are characteristic of polar-orbiting wide-swath imagers.

less than half the time. One particularly egregious case is Hurricane Dean, for which ASCAT was able to observe it during less than 5% of its life cycle.

The goal of NASA's Cyclone Global Navigation Satellite System (CYGNSS) is to resolve these two principal deficiencies with current tropical cyclone intensity forecasts. Selected as a Venture Class mission[4], CYGNSS–with a tentative launch date of 2016–uses an innovative design that employs eight small satellites carried into orbit on a single launch vehicle. The eight satellites will comprise a *constellation* that will allow the observatories to fly in close proximity to each other to measure the ocean surface wind field with unprecedented temporal resolution and spatial coverage, under all precipitating conditions, and over the full dynamic range of wind speeds experienced in a tropical cyclone. (The constellation concept is described in greater detail below.) It will do so by combining the all-weather performance of Global Positioning System (GPS)-based *bistatic scatterometry* with the sampling properties of a dense microsatellite (microsat) constellation—see *CYGNSS Heritage: Using GPS Reflectometry for Geophysical Measurements* on page 17. In orbit, the observatories will receive both direct and reflected signals from GPS satellites. The direct signals pinpoint CYGNSS observatory positions, while the reflected signals respond to ocean surface roughness, from which wind speed is retrieved. **Figure 3** illustrates the improvements that

> *The system will allow us to probe the inner core of hurricanes for the first time from space to better understand their rapid intensification.*
>
> —***Christopher Ruf*** *[University of Michigan—CYGNSS Principal Investigator]*

[4] *Venture Class* missions are intended to be principal-investigator-led, rapidly developed, cost-constrained missions/instruments for NASA's Earth Science Division. The September–October 2010 issue of *The Earth Observer* [**Volume 22**, **Issue 5**, pp. 13-18] described the program. CYGNSS was selected in June 2012 from among several proposals submitted for the EV-2 Announcement of Opportunity.

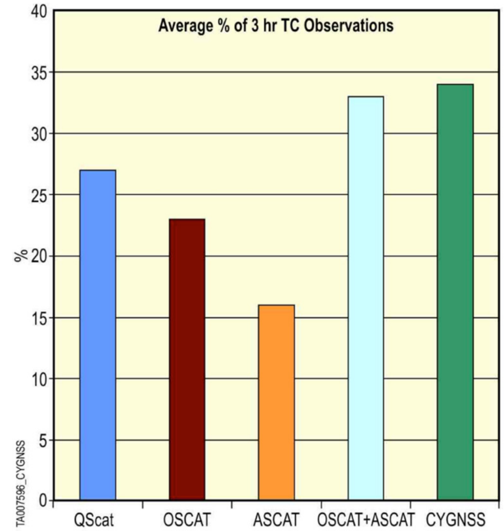


Figure 3. This graph shows the percentage of three-hour intervals during the 2005 Atlantic hurricane season in which each of three ocean wind scatterometers [QuikSCAT (QScat), OSCAT, and ASCAT] would have sampled the inner core region of every tropical cyclone that occurred that year. Also included is the percentage sampled by the combined OSCAT+ASCAT constellation (since these two scatterometers are currently operational) and the percentage that would have been sampled by CYGNSS, had it been in orbit at the time. CYGNSS will have a substantially higher sampling capability of tropical storm inner core regions than any one scatterometer—and will be comparable to the combined capabilities of ASCAT and OSCAT.

CYGNSS observations are expected to achieve over those from current scatterometers, using the 2005 Atlantic hurricane season as an example.

CYGNSS Measurement Concept: Constellation Flying Provides More Coverage

CYGNSS relies on an innovative design that will deploy eight observatories flying together in a constellation—an approach that has a heritage in Earth science observations. For example, the A-Train[5] constellation consists of several satellite missions flying within precise distances of one another. NASA and its partners have also deployed multiple satellites from a single launch vehicle. The Gravity Recovery and Climate Experiment (GRACE[6]) satellites, for example, were launched by the same vehicle and fly in precision formation—a key feature of the mission concept. Similarly, the CloudSat and the Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite missions were comanifested. However, as one might expect, launching eight satellites from a single launch vehicle presents new engineering challenges that must be carefully planned and executed.

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As described earlier, sampling by a single observatory results in both poor spatial coverage and temporal resolution of tropical cyclone evolution. The constellation approach overcomes these limitations—see *Coverage Comparison: CYGNSS Constellation versus ASCAT* on the next page. The constellation will sample the ocean more frequently than a single satellite would, resulting in a more highly resolved view of the ocean's surface. Each observatory simultaneously tracks scattered signals from up to four independent transmitters in the operational GPS network. The number of observatories and orbital inclination are chosen to optimize the tropical cyclone sampling properties. The result is a dense cross-hatch of sample points on the ground that cover the critical latitude band between ±35° with an average revisit time of 4.0 hours. The spatial coverage possible with CYGNSS is illustrated in **Figure 4** on the next page.

The CYGNSS Observatories: Eight Self-contained Digital Doppler Mappers

The CYGNSS observatory design accommodates the solar power arrays, the GNSS antennas required by the Delay Doppler Mapping Imager (DDMI), and other launch

[5] "A-Train" is the popular nickname for the Afternoon Constellation of satellites that includes NASA's Aqua, Aura, CloudSat, and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) missions, as well as the Japan Aerospace Exploration Agency's (JAXA) Global Change Observation Mission-Water (GCOM-W1). The second Orbiting Carbon Observatory (OCO-2) is expected to join them in 2014. For more information, visit: *atrain.nasa.gov*.

[6] A description of the GRACE mission and its accomplishments during its first ten years in orbit appears in the March–April 2012 issue of *The Earth Observer* [**Volume 24**, **Issue 2**, pp. 4-13].

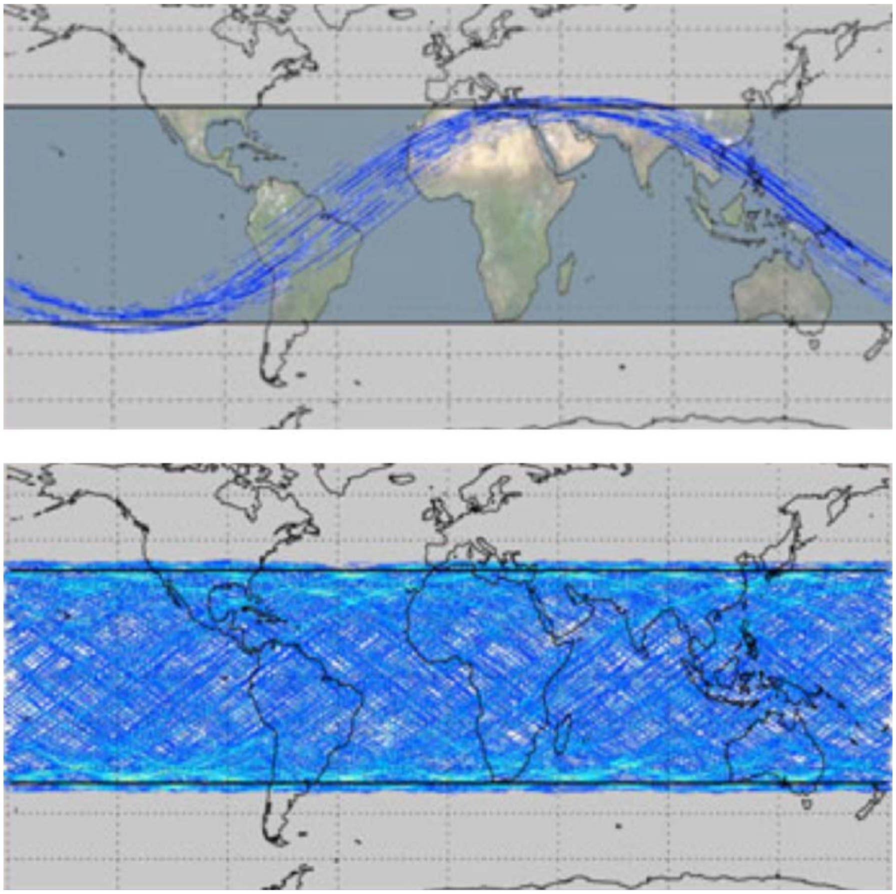
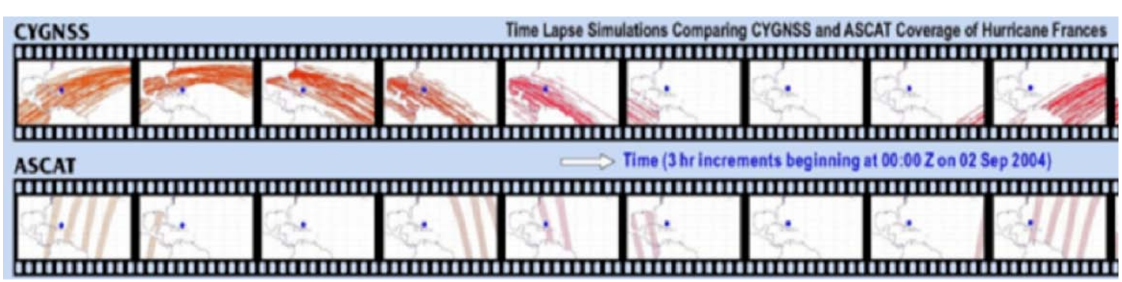


Figure 4: Each low-Earth-orbiting CYGNSS observatory will orbit at an inclination of 35° and be capable of measuring 4 simultaneous reflections, resulting in 32 wind measurements per second across the globe. The orbit inclination was selected to maximize the dwell time over latitudes at which hurricanes are most likely to occur. The result will be high-temporal-resolution wind-field imagery of tropical cyclone genesis, intensification, and decay. Shown here are planned CYGNSS ground tracks for 90 minutes [*top*] and a full 24-hour period [*bottom*].

constraints—see **Figure 5** on the next page. The design also incorporates functional and selective redundancy for critical systems. Observatory attitude is three-axis stabilized using horizon sensors, a magnetometer, pitch momentum wheels, and torque rods. Observatory mass and power are estimated to be ~18 kg (~40 lbs) and ~49 W, respectively.

Coverage Comparison: CYGNSS Constellation versus ASCAT

This figure depicts a time-lapse simulation comparing the spatial and temporal sampling properties of CYGNSS [*top row*] and ASCAT [*bottom row*], assuming they had both been in orbit on September 2, 2004, when Hurricane Frances made U.S. landfall. Data from satellite coverage models for both ASCAT and CYGNSS were projected onto archival storm track records for Frances to create the maps. Each frame represents all samples taken within a three-hour interval. The inner core of Frances is shown as a large blue dot in each frame. ASCAT, with its relatively narrow swath width, does not sample the inner core very frequently, whereas the much wider and more dispersed effective swath of the CYGNSS constellation would have allowed for much more-frequent sampling. The average revisit time for inner-core sampling for CYGNSS is predicted to be 4.0 hours, with a median revisit time of 1.5 hours.



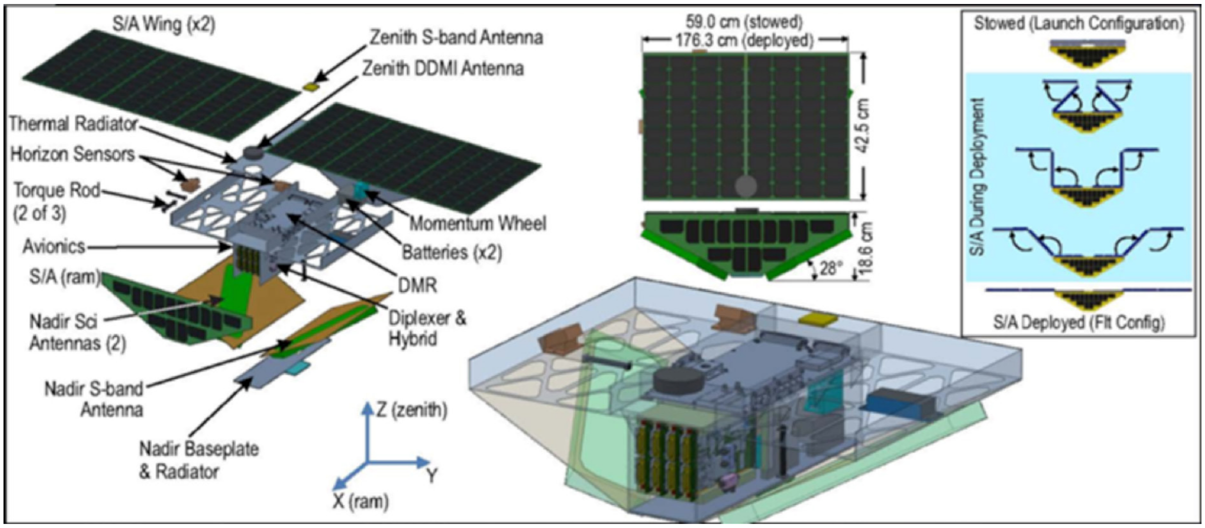


Figure 5. This figure shows a CYGNSS observatory. The exploded view shows individual subsystems, including the science payload's Delay Doppler Mapping Imager (DDMI) antennas and receiver electronics [DMR]. Solar array deployment, performed after ejection from the launch deployment module, is also illustrated.

Each observatory is deployed from the launch vehicle with solar arrays stowed, and can remain in this configuration indefinitely. After deployment from the launch vehicle, each observatory transitions automatically through three initial states before reaching *Standby Mode,* where it will remain until all eight satellites are ready for use. Upon completion of commissioning activities, the observatories will transition into the *Science Mode* of operation. At this point, aside from the brief engineering verification test modes described below, the DDMI is set to Science Mode for the duration of the mission[7]. In Science Mode, subsampled Delay Doppler Maps (DDMs) are generated onboard and downlinked with a 100% duty cycle.

In developing the design concepts for the CYGNSS observatories, the systems engineering team sought to ensure the safety of the observatories without ground intervention. The onboard systems have been designed to minimize the need for ground-based, time-tagged command sequences for each observatory for routine operations. This helps to enable a simplified and automated sequence of science observations and engineering calibration procedures that can operate unattended during normal Science Mode. With the DDMI in its Science Mode, the observatory is set to maintain all nominal operations without additional commands. The primary "routine" activity performed on a regular basis is communication with the ground network to downlink the accumulated science and engineering data.

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Launch/Commissioning Activities

CYGNSS is currently scheduled for launch in 2016; details (e.g., location and launch vehicle) are still to be determined. After launch, the mission begins with *engineering commissioning* of the observatories and science instruments. Additional *science commissioning* activities for the observatories will begin once the solar arrays are deployed on every observatory in the constellation and will continue for a period of two-to-four weeks.

Engineering Commissioning

Since each observatory functions independently, *engineering commissioning* activities for satellites and instruments may progress in an interleaved manner: Within a single communications pass, activities will be performed on a single observatory; however, it is not necessary to complete all commissioning tasks on one observatory before progressing to the next observatory in the constellation. Similarly, it is also unnecessary to ensure that each observatory is at the same "step" in a commissioning sequence. This independence allows a flexible scheduling approach to be used in setting up commissioning passes and does not delay commissioning activities for all observatories if a single satellite requires extra time while an off-nominal issue is being addressed.

[7] The only other interruption to Science Mode will be brief returns to *Calibration/Validation Mode* performed biannually—see **Data Products** section for details.

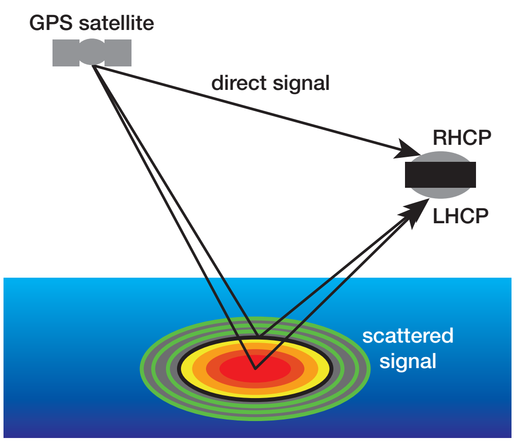
CYGNSS Heritage: Using GPS Reflectometry for Geophysical Measurements

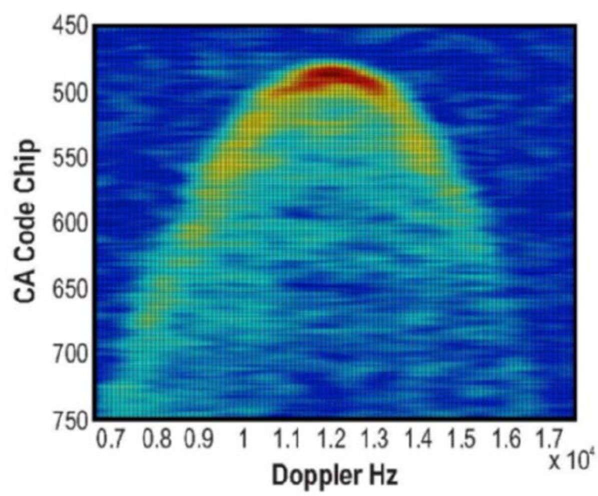
For some years, GPS receivers have been used to provide position, velocity, and time measurements to satellite platforms in low Earth orbit. In a similar way, they are also used for ground-based navigation. Beyond navigation however, GPS signals have been increasingly used for remote sensing. Signals at *L-band*[1] —with a bandwidth between 2 and 20 MHz—are broadcast globally from an altitude of ~20,000 km (~12,427 mi) and are used to measure, amongst other things, tectonic plate motion and ionospheric and tropospheric parameters. Furthermore, signals from other Global Navigation Satellite Systems (GNSS[2]) are becoming available: There will soon be more than 120 such signal sources in space.

The United Kingdom Disaster Monitoring Constellation (UK-DMC-1[3]) space-based demonstration mission showed that a microsatellite-compatible passive instrument potentially could make valuable geophysical measurements using *GPS reflectometry.* The left side of the figure below diagrams how the process works. The direct GPS signal is transmitted from the orbiting GPS satellite and received by a right-hand circular polarization (RHCP) receive antenna on the *zenith* (i.e., top) side of the spacecraft that provides a coherent reference for the coded GPS transmit signal. The quasispecular, forward-scattered signal that returns from the ocean surface is received by a *nadir-* (i.e., downward-) looking left-hand circular polarization (LHCP) antenna on the nadir side of the spacecraft. The scattered signal contains detailed information about its roughness statistics, from which local wind speed can be derived.

The image on the right below shows *scattering cross section* as measured by UK-DMC-1 and demonstrates its ability to resolve the spatial distribution of ocean surface roughness. This type of scattering image is referred to as a *Delay Dopplar Map* (DDM).

There are two different ways to estimate ocean surface roughness and near-surface wind speed from a DDM. The *maximum scattering cross-section* (the darkest shades in the graph) can be related to roughness and wind speed.





[*Left.*] GPS signal propagation and scattering geometries for *ocean surface bistatic quasispecular scatterometry*. The position of the spacecraft is determined from the direct GPS signal; the surface winds are determined by the indirect signal (scattered off the ocean surface). Combining the position and scattering information allows for the creation of Delay Doppler Maps (DDM), from which ocean surface vector wind speeds can be inferred. [*Right.*] An example DDM showing the spatial distribution of the ocean surface scattering measured by the UK-DMC-1. Scattering cross section is plotted as a function of Doppler Shift (x-axis) and propagation time of flight (y-axis), which is measured in units of Coarse Acquisition GPS Code or "Chips." See text for further details.

[1] The L-band portion of the electromagnetic spectrum covers the range from 1 to 2 GHz, and is commonly used for satellite communications.
[2] The current Global Navigation Satellite System (GNSS) currently includes two fully operational networks: the U.S. Global Positing Satellite (GPS) system and the Russian Globalnaya Navigatsionnaya Sputnikovaya Sistema (GLONASS). By 2020 the European Union [Galileo] and China [COMPASS] should have fully functional GNSS systems. Other nations are also working on their own systems, that may eventually become part of the network.
[3] The Disaster Monitoring Constellation (DMC) was deployed in 2003. It was constructed by a U.K.-based company called Surrey Satellite Technology Ltd. (SSTL) and the University of Surrey (Guildford, U.K.), and is comprised of several remote sensing satellites operated for the Algerian, Nigerian, British, and Chinese governments by DMC International Imaging.

This, however, requires *absolute calibration* of the DDM, which is not always available. Wind speed can also be estimated from a *relatively calibrated* DDM, using the *shape of the scattering arc* (the lighter shades in the graph). The arc represents the departure of the actual *bistatic scattering* from the theoretical *purely specular case*—i.e., scattering from a perfectly flat ocean surface—which appears in the DDM as a single-point scatterer. The latter approach imposes more-relaxed requirements on instrument calibration and stability than does the former. However, it derives its wind speed estimate from a wider region of the ocean surface, and thus has lower spatial resolution.

After UK-DMC-1, development of wind-speed retrieval algorithms from DDMs became an active area of research and resulted in the design of a new instrument called the Space GNSS Receiver – Remote Sensing Instrument (SGR-ReSI[4]). Like its predecessor, the instrument can make valuable scattering measurements using GPS, but it has greater onboard data storage capacity and can process the raw data into DDMs in real time. It also has been designed with flexibility so it can be programmed while in orbit for different purposes—e.g., tracking new GNSS signals when needed, or applying spectral analysis to received signals.

In effect, the SGR-ReSI fulfils in one module what has historically been handled by three separate units on earlier spacecraft. Specifically,

- it performs all the core functions of a space GNSS receiver, with front-ends supporting up to eight single or four dual-frequency antenna ports;
- it is able to store a quantity of raw sampled data from multiple front ends, or processed data in its one-gigabyte solid-state data recorder; and
- it has a dedicated reprogrammable field-programmable gate array (FPGA) coprocessor (a Xilinx *Virtex 4*).

Each CYGNSS observatory will be equipped with a Digital Doppler Mapping Instrument (DDMI), based on the SGR-ReSI design. The DDMI will generate DDMs continuously at a low data rate, which will provide a source for ocean roughness measurements across the ocean. In special situations, such as when passing over an active tropical cyclone, the instrument can be operated in *Raw Data Mode*, where 60 seconds of raw sampled data is accumulated. This allows researchers to fully analyze and re-analyze the acquired data using different processing schemes to ensure that the nominal DDM mode of operation is not losing important geophysical data.

[4] SSTL and the University of Surrey teamed with the National Oceanographic Centre in Southampton, U.K., University of Bath, and Polar Imaging Ltd. to develop SGR-ReSI.

A large wind field intercomparison database will be assembled from a variety of sources including buoys, other satellite-based instruments, and global meteorological and oceanographic model assimilations.

Science Commissioning

Science commissioning takes place after engineering commissioning activities are completed. At this time, the observatory will be operated in its nominal Science Mode, and preliminary Level-2 (L2) wind speed data products[8] will be produced. A large wind field intercomparison database will be assembled from a variety of sources including buoys, other satellite-based instruments, and global meteorological and oceanographic model assimilations. During science commissioning the ground-processing algorithms used to produce L2 data will be refined. The data assimilation tools, which ingest L2 data into numerical weather prediction forecast models, are also tested.

Ground System Overview

The CYGNSS ground system—shown in **Figure 6**, next page—consists of: a Mission Operations Center (MOC), located at the Southwest Research Institute's (SwRI) Planetary Science Directorate in Boulder, CO; a Science Operations Center (SOC), located at the University of Michigan's Space Physics Research Laboratory in Ann Arbor, MI; and a Ground Data Network, operated by Universal Space Network (USN) and

[8] A list of planned CYGNSS data products appears at *aoss-research.engin.umich.edu/missions/cygnss/data-products.php*. Data are expected to be publicly available about a year after launch.

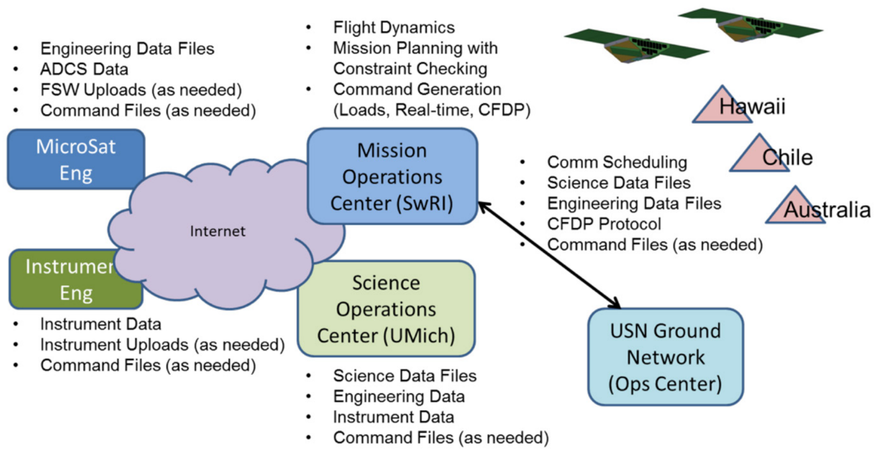


Figure 6. Diagram showing an overview of the components of the CYGNSS ground system.

consisting of existing *Prioranet*[9] ground stations in South Point, HI, in Santiago, Chile, and in Western Australia, some 400 km (~248.5 mi) south of Perth, and at the MOC facility. Additional interfaces between the MOC and the microsat engineering team and the DDMI instrument engineering teams are also supported. The MOC coordinates operational requests from all facilities and develops long-term operations plans. Each of these components is described in more detail below.

Mission Operations Center (MOC)

During the mission the CYGNSS MOC is responsible for mission planning, flight dynamics, and command and control tasks for each of the observatories in the constellation. These primary MOC tasks include:

- Coordinating activity requests;
- scheduling ground network passes;
- maintaining the Consultative Committee for Space Data Systems (CCSDS) File Delivery Protocol (CFDP) ground processing engine;
- collecting and distributing engineering and science data;
- tracking and adjusting the orbit location of each observatory in the constellation;
- trending microsat data;
- creating real-time command procedures or command loads required to perform maintenance and calibration activities; and
- maintaining configuration of onboard and ground parameters for each observatory.

Science Operations Center (SOC)

The CYGNSS SOC will be responsible for the following items related to calibration/validation activities, routine science data acquisition and special requests, and data processing and storage:

- Supporting DDMI testing and validation both prelaunch and on-orbit;
- providing science operations planning tools;
- generating instrument command requests for the MOC;
- processing Levels 0 through 3 science data; and

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[9] *Prioranet* was specifically designed for comprehensive communications and ground support to Earth-orbiting satellite. For more information, visit: *www.sscspace.com/ground-network-prioranet-1*.

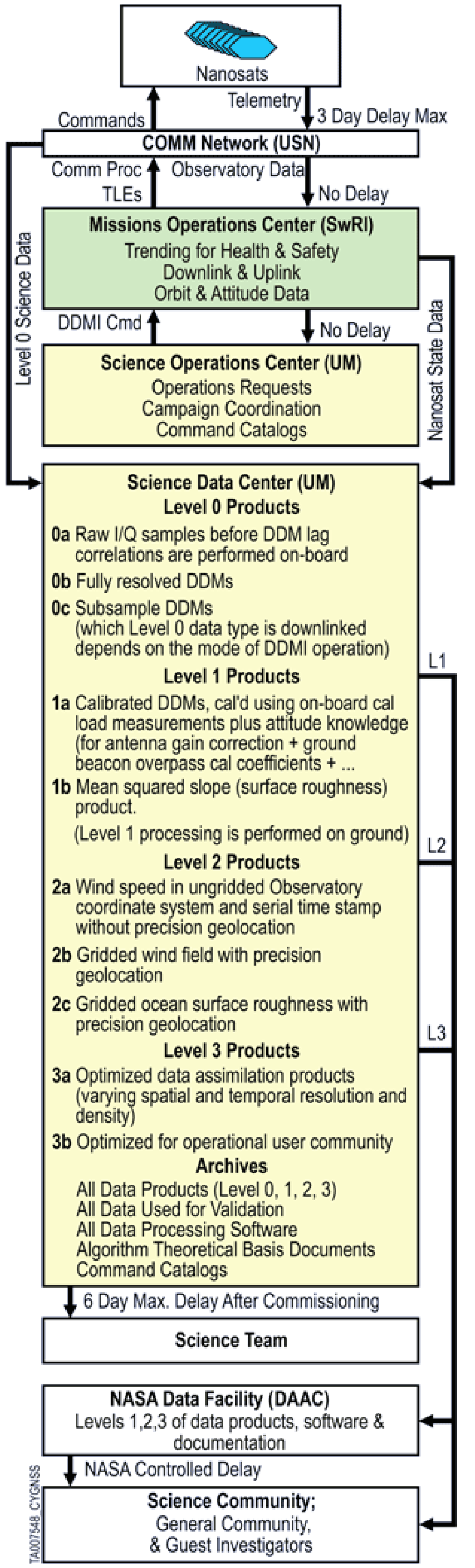

Figure 7. *CYGNSS Data Flowchart.* This figure illustrates how the data flows from the CYGNSS observatories to the various elements of the ground system for processing, to the DAAC for archiving, to the science team for analysis, and ultimately to the broader user community for application. The planned CYGNSS data products are also listed.

- archiving Level 0-3 data products, DDMI commands, code, algorithms, and ancillary data at a NASA Distributed Active Archive Center.

Ground Data Network

CYGNSS selected USN to handle ground communications because of their extensive previous experience with missions similar to CYGNSS. Collocation of a back-up CYGNSS MOC server at the USN Network Management Center (NMC) can also be supported.

Each of the observatories in the CYGNSS constellation will be visible to the three ground stations within the USN for periods that average between 470 and 500 seconds of visibility per pass. Each observatory will pass over each of the three ground stations six-to-seven times each day, thus providing a large pool of scheduling opportunities for communications passes. MOC personnel will schedule passes as necessary to support commissioning and operational activities. High-priority passes will be scheduled to support the solar array deployment for each observatory.

For all subsequent stages, the MOC schedules nominal passes for the USN stations for each observatory in the constellation per the USN scheduling process. Each observatory can accommodate gaps in contacts with storage capacity for greater than 10 days' worth of data with no interruption of science activities.

Data Products

The data returned from CYGNSS are expected to expand our knowledge of the rapidly changing environment in the core of a developing tropical cyclone—see **Figure 7** for details on data flow and a list of planned CYGNSS data products. The SOC is responsible for data product development and dissemination. After science commissioning is complete and the mission enters its nominal science operations stage, the L2 data will be made available for public release. The CYGNSS science team members will use the fully calibrated L2 data for their own research and make it available to the external user science community and eventually to operational users. Calibration/validation assessment of L2 data quality continues for the life of the mission using an updated version of the same wind field intercomparison database used during science commissioning. Twice a year, nominally at the beginning and end of the Atlantic hurricane season, engineering performance will be verified by a brief (approximately two-week) repeat of the instrument calibration activities performed during engineering commissioning.

Application of CYGNSS to Hurricane Forecasting

As stated above, the primary goals of CYGNSS are to measure ocean surface wind speeds in all weather conditions—including those inside the eyewall—and measuring wind speed with sufficient frequency to resolve genesis and rapid intensification in the inner core of a tropical cyclone. In addition to success with these two primary objectives, there is likely to be a secondary benefit with direct societal relevance: The CYGNSS team will produce and provide ocean surface wind speed data products to the operational hurricane forecast community and help them assess the value of these products for use in their retrospective studies of potential new data sources. In time, this information will be incorporated into models used to predict the evolution of hurricanes.

While improved hurricane forecasting is not the CYGNSS mission's primary objective, it is hoped that hurricane prediction—in particular, hurricane intensity forecasts—will improve as a result of the data that the CYGNSS mission returns.

*While improved hurricane forecasting is **not** the CYGNSS mission's primary objective, it is hoped that hurricane prediction—in particular, hurricane intensity forecasts—will improve as a result of the data that the CYGNSS mission returns.*

Acknowledgment

Parts of this article have been extracted from some proceedings papers of a recent technical conference focusing on CYGNSS. The citations for those papers can be found at *aoss-research.engin.umich.edu/missions/cygnss/reference-material.php*.

For More Information

Some of the text and graphics that appear in this article have been extracted from these sources and adapted for use in *The Earth Observer*:

General information about the CYGNSS mission (e.g., science, technology, data products)
CYGNSS-Michigan.org.

List of references on topics mentioned herein (e.g., GNSS, ocean surface scattering, aircraft observations, spaceborne observations)
aoss-research.engin.umich.edu/missions/cygnss/reference-material.php. ■

Aqua AIRS Version 6 Level 3 Data Release

The Atmospheric Infrared Sounder (AIRS) Project and NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC) are pleased to announce the availability of *Aqua AIRS Version 6 Level 3* data. The AIRS Version 6 processing code has a number of improvements in addition to the Level 2 improvements from which it is built.

Significant changes include:

- Level 3 support products, which contain profile data at 100 vertical levels;
- a "TqJoint" grid, which contains gridded data for a common set of temperature and water vapor observations; and
- water vapor and trace gas products that are now reported both as layer and level quantities.

For additional information and to access to these data, visit:

disc.sci.gsfc.nasa.gov/datareleases/aqua-airs-version-6-level-3.