NASA CYGNSS Satellite Constellation for Tropical Cyclone Observations

Chris Ruf\textsuperscript{1}, Scott Gleason\textsuperscript{2}, Aaron Ridley\textsuperscript{1}, Randy Rose\textsuperscript{2}, John Scherrer\textsuperscript{2}

1. University of Michigan, Ann Arbor, MI
2. Southwest Research Institute, Boulder, CO
The NASA Cyclone Global Navigation Satellite System (CYGNSS) Mission consists of 8 microsatellites, each with a 4-channel GPS bi-static radar receiver

- Mission lead/Science Ops (University of Michigan)
- Spacecraft/Integration/Mission Ops (Southwest Research Institute)

The driving science objective is rapid sampling of ocean surface winds in the inner core of tropical cyclones

CYGNSS uses a new measurement technique and a new satellite mission architecture

- Measure the distortion of GPS signals scattered from the ocean surface to determine ocean surface roughness and wind speed
- Use small satellites so many can be flown to improve sampling
Spaceborne Empirical Demonstration of Ocean Wind Speed Retrievals by GNSS-R

GNSS-R instrument (early version of CYGNSS science payload) deployed on UK-DMC-1 mission, launch 2003

- Winds ~ 2 m/s
- Winds 7 m/s
- Winds 10 m/s
# Level 1 Baseline Mission Science Requirement

<table>
<thead>
<tr>
<th>Sci Rqmt #</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 m/s to 70 m/s at 5 km x 5 km resolution</td>
</tr>
<tr>
<td>2</td>
<td>Operation in presence of rain</td>
</tr>
<tr>
<td>3a</td>
<td>10% retrieval uncertainty for winds &gt; 20 m/s</td>
</tr>
<tr>
<td>3b</td>
<td>2 m/s retrieval uncertainty for winds &lt; 20 m/s</td>
</tr>
<tr>
<td>3c</td>
<td>Spatial Resolution of 25 km x 25 km or better</td>
</tr>
<tr>
<td>4a</td>
<td>100% duty cycle during science operations</td>
</tr>
<tr>
<td>4b</td>
<td>Mean temporal resolution less than 12 hours</td>
</tr>
<tr>
<td>4c</td>
<td>24 hour spatial sampling covering 70% or more of the cyclone historical track</td>
</tr>
<tr>
<td>5</td>
<td>Calibrate and validate CYGNSS data in individual wind speed bins above and below 20 m/s</td>
</tr>
<tr>
<td>6</td>
<td>Support operational hurricane forecast community</td>
</tr>
</tbody>
</table>
CYGNSS Spatial Sampling Over 24 Hours

- Revisit time: 2.8 hr (median), 7.2 hr (mean)
Observatory Fabrication and Testing
Pegasus Installed on L-1011 Aircraft
Observatory Separation
(simulation)
• The first CYGNSS science instrument was turned on while spacecraft FM03 was crossing the eastern coastline of Brazil on 4 January 2017.

• First Light Delay Doppler Maps (DDMs) measured during 4 Jan 2017 coastal crossing. CH1-3 are ocean reflections. CH4 is land reflection.
First Ground Truth Matchup (1) (FM06 on 21 Jan 2017)

- Location of specular point shown
- Color coded by coincident GDAS wind speed
- Dynamic range of wind speed over the interval is 4-12 m/s
First Ground Truth Matchup (2)
(FM06 on 21 Jan 2017)

- Sequence of DDMs of Bistatic Radar Cross Section (BRCS)
- Matchup with coincident GDAS winds shown below (in black)
- Decreasing wind speed (from left to right) coincides with increase in BRCS, as expected
CYGNSS Mission Status and Plans

PAST
• Launch 15 Dec 2016 at 08:37 EST
  – Observatories in “safe mode”, sun-pointed with only essential systems powered on
• Transition to nadir-point and turn on science instruments

FUTURE
• Mar 2017: complete engineering commissioning
• Apr – May 2017: Initial validation of Level 1 DDM calibration and Level 2 wind speed retrieval algorithm
• Mid May 2017: First public release of DDM and wind speed data products to NASA PO.DAAC
• Dec 2017 – Feb 2018: Cal/Val with 2017 Atlantic hurricane season ground truth
Thank You

for more information visit http://cygnss-michigan.org

or contact Chris Ruf, cruf@umich.edu