Next Generation
GNSS Bistatic Radar Receiver

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Overview of NGRx Project

- Develop a next generation GNSS bistatic radar receiver capable of processing signals transmitted by both GPS and Galileo satellites, including both low (L1/E1) and high (L5/E5) bandwidth signals

- Raise technology readiness from TRL-4 to TRL-6
First Gen GNSS-R is CYGNSS Payload

- Limited to GPS L1 C/A signal reception (co-pol only)
- Limited to 4 parallel receive channels by digital processor capacity
- Limited to static coherent/incoherent real time digital signal processing
- Navigation and reflection processing not optimized due to legacy code development
CYGNSS Mission Timeline

• Jun 2012 CYGNSS Earth Venture Mission Selected
• Jan 2014 Preliminary Design Review
• Jan 2015 Critical Design Review
• 15 Dec 2016 LAUNCH
• Mar 2017 Post Launch Commissioning Completed
• Mar 2019 End of Prime Mission/Beginning of Extended Mission
Wind Speed Retrieval Uncertainty Below 20 m/s

- Mar 2017 – Aug 2018 Matchups with 76 tropical moored buoys (12,164 samples)
- 1.7 m/s RMS difference between CYGNSS and buoys
Tropical Cyclone Overpass Examples

- Hurricane Maria overpasses centered on: 16 Sep @ 14:00, 17 Sep @ 00:00, 17 Sep @ 23:45, 20 Sep @ 14:45, 24 Sep @ 18:15, 25 Sep @ 18:30 UTC
- National Hurricane Center best track storm center in middle of black circle
# CYGNSS Mission Science Requirements

## CYGNSS Level 1 Mission Science Performance

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>CBE</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wind speed dynamic range at 5 km x 5 km resolution</td>
<td>1-54 m/s</td>
<td>Exceeds 40 m/s threshold</td>
</tr>
<tr>
<td>2</td>
<td>Operation in presence of rain</td>
<td>Yes</td>
<td>Meets baseline</td>
</tr>
<tr>
<td>3a</td>
<td>Retrieval uncertainty for winds &gt; 20 m/s</td>
<td>11.3%</td>
<td>10% requirement</td>
</tr>
<tr>
<td>3b</td>
<td>Retrieval uncertainty for winds &lt; 20 m/s</td>
<td>1.7 m/s</td>
<td>Exceeds 2 m/s baseline</td>
</tr>
<tr>
<td>3c</td>
<td>Spatial Resolution</td>
<td>25.4 km</td>
<td>Exceeds 50 km threshold</td>
</tr>
<tr>
<td>4a</td>
<td>100% duty cycle during science operations</td>
<td>Yes</td>
<td>Meets baseline</td>
</tr>
<tr>
<td>4b</td>
<td>Mean temporal resolution</td>
<td>9.1 hr</td>
<td>Exceeds 12 hr baseline</td>
</tr>
<tr>
<td>4c</td>
<td>Spatial sampling coverage of cyclone historical tracks in 24 hours</td>
<td>50-74%</td>
<td>Exceeds 50% threshold</td>
</tr>
<tr>
<td>5</td>
<td>Calibrate and validate CYGNSS data in individual wind speed bins above and below 20 m/s</td>
<td>Yes</td>
<td>Meets baseline</td>
</tr>
</tbody>
</table>
CYGNSS SNR Images of Southeast Texas Before & After Hurricane Harvey Landfall on Aug 25, 2017

- (right) Time lapse SNR images in Houston metro region
  - Large increases in SNR indicate flooding inundation
- (below) Aug 29 SNR image with coastal flooding circled

(courtesy Mary Morris, NASA/JPL)
CYGNSS-Derived Soil Moisture Time Series (C. Chew, UCAR)

west of Dallas, Texas

r = 0.90  ubRMSD = 0.026 cm$^3$ cm$^{-3}$

SM (cm$^3$ cm$^{-3}$)

Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep 2017 2018

Grid cell with good quality SMAP data
CYGNSS Spatial Resolution Over Land

• High res land imaging from coherent forward scatter
  – First Fresnel zone for CYGNSS is ~500 m
• Images of the same section of the Amazon River by:
  – SMAP passive microwave
    ~30 km res
  – SMAP active radar
    ~3 km res
  – CYGNSS GNSS-R
    <500 m res
IIP NGRx Enhancements

- **Engineering Design**
  - GPS L1&L5, Galileo E1&E5
  - 20 simultaneous receive channels
  - Co- and X-pol antenna

- **Science data products**
  - 2 hr mean revisit (8 s/c constellation)
  - Co- and X-pol scattering cross section
IIP NGRx Subsystem Development

Antenna testing in anechoic chamber with spacecraft mock-up

Receiver testing on vibe table
Status and Next Steps

- TRL-5 functional testing completed for antennas and receiver (analog) front end
- TRL-5 functional testing underway for receiver (digital) back end
- TRL-6 environmental testing later in 2019
- Possible airborne flights for demo in scientifically relevant environment
- Possible cubesat flight for demo of signal processing in relevant flight environment
- Possible inclusion in upcoming NASA DO mission