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Dr. Chris Ruf (PI – UM), Randy Rose (SwRI), Aaron Ridley (UM), Buddy Walls (SwRI)
Hurricane Katrina’s Storm Surge was 30 Feet Over What was Expected
Irene forecasts on track; not up to speed on wind

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

by Seth Borenstein & Christine Amario:

...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.”
CYGNSS Science Goals & Objectives

• CYGNSS Science Goal
  – Understand the coupling between ocean surface properties, moist atmospheric thermodynamics, radiation, and convective dynamics in the inner core of a tropical cyclone (TC)

• CYGNSS Objectives
  – Measure ocean surface wind speed in all precipitating conditions, including those experienced in the TC eyewall
  – Measure ocean surface wind speed in the TC inner core with sufficient frequency to resolve genesis and rapid intensification

• Questions Answered by CYGNSS
  – How do the dynamics within TCs determine their intensity at landfall?
    • CYGNSS measures surface winds in the TC inner core with a 4 hr average revisit time, enabling the dynamics of the TC to be investigated
  – How do moist atmospheric thermodynamics, radiation and convection interact to control the development of TCs?
    • CYGNSS measures wind speed through intense rain fall, enabling researchers to better understand the complex feedback between mass and energy interchange processes
Instrument: Bi-Static Quasi-Specular Ocean Surface Scatterometry

- Bi-static scattering geometry with GPS direct signal proving reference and quasi-specular forward scattered signal containing ocean surface roughness information
- Scattering cross-section image measured by UK-DMC-1 demonstration spaceborne mission with variable lag correlation and Doppler shift enabling resolution
Analogy: Reflection of the Moon

Moderate wind speed

Low wind speed
Performance in Intense Precipitation

- One-way transmissivity through typical tropical storm (5 km freezing level) for: GPS (1.575 GHz), ASCAT (5.255 GHz), QSCAT (13.4 GHz)

- Airborne GNSS wind speed retrieval during overpass of Hurricane Bill on 19 Aug 2009. Strong rain bands (black) do not noticeably affect the GNSS retrieved wind (red)
CYGNSS Constellation
CYGNSS Earth Coverage

- 90 min (one orbit) coverage showing all specular reflection contacts by each of 8 s/c
- 24 hr coverage provides nearly gap free spatial sampling within +/- 35 deg orbit inclination
CYGNSS Historical Storm Track Overlay

CYGNSS coverage map overlaid on historical record of all named (wind speed >30 kt) storm tracks during 2000-2009. Red indicates Cat 1 or higher TC.
Links to CubeSats

• CYGNSS began as a CubeSat concept
• CubeSats offer unique science capabilities
  – Distributed sensing
  – Improved revisit time
• CubeSats are a new way of looking at reliability
  – Observatory-level redundancy
  – If the costs are low, it is okay if you loose 1 or more
• NASA is embracing the CubeSat movement
  – The perfect answer to the sequestor
Microsat Characteristics

- Configuration: Accommodate DDMI antennas and 100% DDMI duty cycle
- Power: 48.8 W (Available: 70.1 W EOL, Margin: 30.3%)
- Attitude: 3-axis stabilized, pitch momentum-biased nadir-pointed, 2.1° (3σ) knowledge and 2.3° (3σ) control (horizon sensors, magnetometer, pitch momentum wheel, torque rods)
- Communication: 1.25 Mbps S-band with 6.7 dB margin provides 31% Science data downlink margin
- Mass (ea): 17.6 kg
- Orbit: 500 km, i=35°
- Launch: 10-Sept-2016
- Bus: SwRI
- Instrument: Surrey
- Avionics: SwRI
- Deployment Module: NASA Ames
- Contract: NASA Langley
μSat Block Diagram – Avionics Highlighted

- **Centaur**
  - SBC (SPARC 8)
  - Nanosat Data Storage
  - C&T IF
  - Lvl 0 C&T
  - Payload IF
  - Sci data compression
  - Sci Data Storage
  - Temp Sensor IF
  - ADCS IF

- **CDS**
  - S-band XCVR
    - Tx BRF
    - Rx BRF
  - Diplexer
  - Hybrid Coupler

- **SMT**
  - Temperature Sensors
  - Heaters (includes instrument survival heaters)
  - Surface Finishes
  - MLI
  - Radiators
  - Structure

- **ADCS**
  - Horizon Sensors
  - Magnetometer (3-axis)
  - Momentum Wheel
  - Torquerods (3)

- **EPS**
  - Battery 3 Ah Li-ion
  - Solar Array Panels
  - Deploy Actuators

- **DDMI**
  - Oo Ant
  - LNA

- **DMR**
  - Pri Pwr
  - RS422
  - LV Pwr

- **LVPS+**
  - Low Voltage Power Generation
  - LV Pwr Dist

- **PPT**
  - Batt Chg Ctrl
  - Pri Pwr Dist
  - EPS Safe Hold
  - SPA/Deployment Act
  - Temp Heaters IF
  - TR Drivers

25 April 2013  Spring CubeSat Workshop 13
### EPS Requirements

**SwRI Peak Power Tracker**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument power (orbit avg)</td>
<td>10W</td>
</tr>
<tr>
<td>Instrument duty cycle</td>
<td>Continuous</td>
</tr>
<tr>
<td>S/A power (orbit avg, EOL worse case)</td>
<td>≥48.8W</td>
</tr>
<tr>
<td>Minimum State-of-Charge (EOL @ longest eclipse)</td>
<td>&gt;70%</td>
</tr>
</tbody>
</table>

- **SNC Solar Array**
  - Deployed
  - Stowed

- **EnerSys Battery**
  - SwRI Low Voltage Power Supply

*Image: CYGNES logo*
# CDS Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor performance</td>
<td>≥14.5 MIPS</td>
</tr>
<tr>
<td>Data Storage (&gt;10 days)</td>
<td>370 MB</td>
</tr>
<tr>
<td>Max Sci data storage rate</td>
<td>&gt;4.2 kbps</td>
</tr>
<tr>
<td>Max data playback rate</td>
<td>1.25 Mbps</td>
</tr>
<tr>
<td>Cmd Storage</td>
<td>&gt;100 RTS/ATS 15 cmd sequences</td>
</tr>
<tr>
<td>All Comm links margin</td>
<td>&gt;3 dB</td>
</tr>
</tbody>
</table>

*Excess capability results from the use of existing heritage designs*

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**AntDevCo Antenna**

**SwRI S-Band Transceiver**

**SwRI C&DH**

**Merrimac Coupler/Duplexer**
## ADCS Requirements

<table>
<thead>
<tr>
<th>Parameter/Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude Determination</td>
<td></td>
</tr>
<tr>
<td>Horizon Sensor</td>
<td>Earth horizon and mag field reference</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>0.5 deg accuracy, ±5 deg range</td>
</tr>
<tr>
<td></td>
<td>10 nT sensitivity, +/- 50,000 nT range</td>
</tr>
<tr>
<td>Attitude Control</td>
<td>3-axis stabilized, momentum biased</td>
</tr>
<tr>
<td>Mom Wheel</td>
<td>30 mNms @ 5600 rpm, 2mNm torque</td>
</tr>
<tr>
<td>Torque Rods</td>
<td>1 Am^2, residual moment &lt; 0.1 Am^2</td>
</tr>
</tbody>
</table>

- **Honeywell Magnetometer**
- **Sinclair Momentum Wheel**
- **MAI Horizon Sensor**
- **SatServ Torque Rod**
Lot’s of Great People

- Tim Henderson, ADCS Subsystem Engineer
- Robert Atlas, Co-I
- Paul Chang, Co-I
- James Cutler, Co-I
- James Garrison, Co-I
- Scott Gleason, Co-I
- Zorana Jelenak, Co-I
- Stephen Katzberg, Co-I
- Sharanya Majumdar, Co-I
- Manuel Martin-Neira, Co-I
- Donald Walter, Co-I
- Valery Zavorotny, Co-I
- Joel Johnson, Co-I
- John Dickinson, Comm, Data, and Power Subsystem Lead
- Brian Johnson, DDMI Program Magager
- Martin Unwin, DDMI Systems Engineer
- Robert Ricks, Deployment Module Electrical Engineer
- Elwood Agasid, Deployment Module Lead
- Abraham Rademacher, Deployment Module Lead Engineer
- Derek Posselt, Deputy PI/Co-I
- Greg Fletcher, Deputy Project Manager
- Walter Lockhart, Electrical Power Analyst
- Robert Klar, Flight Software Technical Lead
- Scott Miller, FSW Team
- Alan Henry, I & T Lead
- Aaron Ridley, Instrument Scientist/Co-I
- Debbie Shaffer, ITAR Lead
- Joerg Gerhardus, Mission Assurance
- Jillian Redfern, Mission Operations Analyst
- Michael Vincent, Mission Operations Analyst
- Chelle Reno, Mission Operations Consultant
- Debi Rose, MOC Manager, Mission Ops Lead
- Marissa Brummitt, Other Professional
- Chris Ruf, Principal Investigator
- John Scherrer, Project Manager
- Randy Rose, Project Systems Engineer
- Andrew O'Brien, Science Team Member
- Jim Raines, SOC Engineer
- Stephen Musko, SOC Lead Engineer
- Ronnie Killough, Software Systems Lead
- John Bultena, Spacecraft SystemsAnalysis
- Jon VanNorde, Thermal Analyst
- Will Wells, Systems Analyst
- Damen Provost, UM Project Manager
- Bruce Block, UM Technical Manager
Shameless Plug: Check out the CubeSat Avionics Section (7.7) at the IEEE Aerospace Conference in Big Sky Montana