New Science Opportunities on COSMIC-2/FORMOSAT-7

Anthony J Mannucci\(^1\)
Thomas K Meehan\(^1\)
Stephen T Lowe\(^1\)
Chi O Ao\(^1\)
Garth Franklin\(^1\)
Xiaoqing Pi\(^1\)
Lawrence E. Young\(^1\)

Ying-Hwa (Bill) Kuo\(^2\) and William S Schreiner\(^2\)

Jet Propulsion Laboratory, California Institute of Technology
University Corporation for Atmospheric Research

C/NOFS Results and Equatorial Dynamics:
A Technical Interchange Meeting
Albuquerque, NM

FORMOSAT-7/COSMIC-2

2013

SSAEM
- 6 satellites
- 24° inclination
- 520 km alt
- 5-year life

TriG Radio Occultation System
Space science payloads

SSTL-150

Surrey Satellite Technology, Ltd

March 14, 2013

2015

First
Launch Falcon-9

2018

Second
Launch, possible
Falcon-9

- 6 satellites
- 72° inclination
- 800 km alt
- 5-year life

TriG Radio Occultation System

Additional
payloads TBD

Figure: Dave Ector, OPAC 2010
Assimilating Radio Occultation Data

Day-Time RMS VTEC Differences Compared to Jason-2 on Nov 21, 2008

Butala et al., American Meterological Society Annual Meeting, January 2013
GNSS Receiver Payload

TriG GNSS Radio Occultation System → TGRS-Reflections and DORIS (RAD)

Equatorial/First launch

Polar/Second launch

Diagram of GNSS Receiver Payload components including POD Antenna Fore, POD Antenna Aft, Modified TGRS Receiver Unit, RO Antenna Fore, RO Antenna Aft, Nadir Reflections Antenna, and DORIS Antenna.
TGRS Payload

- Precise orbit determination (cm-level)
- Radio occultation
  - Atmosphere
  - Ionosphere – TEC and scintillation indices
  - Digital beam steering for improved performance
- GPS and GLONASS (or Galileo, COMPASS, ...)
  - Frequency agile
- Navigation and science processors
  - Simplified development environment for uploads

RAD:
- Reflected signal processing (scatterometry+TEC)
- DORIS TEC and scintillation
## Resources on COSMIC-2 Polar

<table>
<thead>
<tr>
<th>Item</th>
<th>Available Resources</th>
<th>Additional Resources Needed by SOVIA (current best estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>14 kg</td>
<td>3 kg</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>Average: 28 W, Peak: 34 W</td>
<td>10 W</td>
</tr>
<tr>
<td>Data Rate</td>
<td>38.4 kbps</td>
<td>38.4 kbps</td>
</tr>
</tbody>
</table>
GNSS reflections concept (GNSS-R)

Tomographic approach: see Pallarés et al. (2005)

- 24-hour coverage for the COSMIC-2 six-satellite polar constellation
  - 72° inclination
- TEC precision of ~2-4 TECU every 70 km
- Significant data source for GAIM
TOGA Instrument
(NASA Instrument Incubator Program)

Meehan et al., IGARSS 2007

5-cm altimetric precision per pass
1 TECU ~ 16.2 cm

ST Lowe et al., GRL, 2002
GNSS-R Takes Off

Earth-Ventures 2
Cost-capped
PI-led missions
$150M

CYGNSS was recently selected by NASA to launch the first GNSS reflection constellation of 8 microsatellites for the measurement of wind stress to aid in the prediction of severe storms.

- Launch 2017

- Ocean wind speed
- Eight nano-satellites in low inclination orbit (34°)
- Surrey satellite GPS receiver (single frequency)
- Ocean wind speed
- Low revisit time, penetrates cloud and precipitation

Chris Ruf, PI
University of Michigan
Satellite: SWRI
Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

DORIS Ground Network

- TEC
- Scintillation at S-band and UHF

Modified TGRS tracking DORIS

[Bernhardt and Siefring, 2010]
Lower Atmosphere-Ionosphere Coupling Science

Mid to upper troposphere temperature, pressure, geopotential height

Number of measurements per 500x500 km area per 24 hours
Tropics (±30 degrees latitude)

COSMIC-2
Equatorial

9X Factor Improvement vs COSMIC-1 (assumes 2x penetration yield from TriG/TGRS)
Vertical Coupling of Equatorial Atmosphere by Upward Propagating Atmospheric Waves

Because of intense solar radiation in the tropics, convections are actively generated, which further excite various atmospheric waves, such as equatorial waves (Kelvin waves, mixed Rossby gravity waves), atmospheric tides and gravity waves.

Energy and momentum are transported upward by the vertically propagating atmospheric waves.

Wave-wave and/or wave-mean flow interactions drive QBO and SAO in the middle atmosphere.

T. Tsuda, Kyoto U, private comm
Summary

- COSMIC-2 Polar (second launch) is an excellent opportunity to extend SSAEM capabilities to global coverage
- Enhanced ionospheric remote sensing via oceanic TEC and DORIS
- Science: lower-upper atmosphere coupling
- Additional payloads are being considered by NSPO/Taiwan