RAX – Initial Flight Summary

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RAX Mission: High-resolution mapping of natural and artificial ionospheric irregularities

Team: SRI International
University of Michigan
NASA GSFC/Wallops Flight Facility

Payload: UHF radar receiver (426 – 510MHz)

Transmitter: MW-Class IS Radars (i.e. AMISR & ESR)

Funding: NSF Small Satellite Program for Space Weather Research. Launch paid separately by NSF.

Delivery: October 2010 (RAX I)

Launch: Late 2010, DOD STP Minotaur-4 vehicle, Kodiak

Orbit: (Feb 2011) RAX I: 650 km circ, 72 deg. inclination
(Oct 2011) RAX II: LEO elliptical, 104 deg. Inclination

Lifetime: 1 year (expected)
RAX Mission: Measurements made with a novel bistatic radar configuration.
RAX Mission: A “Wall-less Space Plasma Lab” with student and PI led investigation teams.

\[
\eta(k) = 4\pi r_e^2 \langle |n(k)|^2 \rangle
\]

\[
S(k, \omega) = |N_{0e}(k, \omega)|^2 \left[1 - \frac{\chi_e}{1 + \chi_e + \chi_i}\right]^2 + |N_{0i}(k, \omega)|^2 \left[1 + \frac{\chi_e}{1 + \chi_e + \chi_i}\right]^2
\]
The SRI-developed radar receiver was integrated into the Umich-developed satellite bus.
The payload was developed at SRI using heritage and experience from related radar efforts.

**Primarily Analog Industrial Components**
- Pulse (>2μS) or CW operation
- 426 – 510 MHz (1 MHz steps)
- 4-bands
- Adjustable Gain
- Internal Voltage Regulation
- Continuous Sampling at 14-bit Resolution
- In-phase and Quadrature (I/Q) Signals
- Internal 500 MHz Calibration Source

Provides EMI Shield
- Thermally Dissipative
- 9.7cm x 9.7cm x 3.6cm
- Weight 320 g
- Power 2.6 W
The satellite was composed of many COTS and custom subsystems, more custom than initially expected.
Launch was a success from Kodiak, Alaska, 19 November 2010.
First signal acquisition was made by HAMS in Hawaii (KH6HAK and AH6NM). Mahalo!
Assessment of RAX noise floor on orbit over Indian Ocean was good and as expected.
The first RAX experiment was with PFISR on December 10, 2010.
RAX Experiment: Science mission tools calculate expected aspect angles for echo assessment.
RAX Experiment: The receiver and radar worked as expected—an end to end system test. (Alaska)
RAX Experiment: The receiver had excellent recovery from direct radar transmissions.
RAX Experiment: There was excessive interference during the RAX experiment over Alaska.
RAX Experiment: Pave Paws radar painted the entire path of the experiment.
Bus Systems: Magnetometer calibration and noise removal was successful. Magnetic measurement uncertainty reduced by an order of magnitude.

Initial:
5.8° uncertainty

Post processing:
0.6° uncertainty
Bus Systems: GPS operated as predicted and maintained lock in experimental zones.
Bus Systems: UHF Lithium-1 radio performed extremely well, however we had interference issues.

-80dBm Expected max Power at RAX from Ground Station
-70dBm Measured signal levels at RAX.
Bus Systems: Regulation and power systems worked well, panels did not, which degraded over time.
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Recovery from the RAX power anomaly is in process in preparation for an October 2011 launch.

- Anomaly panel convened to identify failure and resolve.
  - Umich, SRI, Aerospace Corp, NASA Glenn, Emcore, etc.

- Aggressive ground testing
  - Thermal imaging
  - Flash thermography
  - Extreme thermal/vac testing.

- New design for panels
  - Cover glass plus diodes.
  - Layout upgrades.
  - Improvements to fabrication.

See poster...
Lessons learned...again and again.

- Nothing is for free. Make sure you know the cost.
- Beacons are simple, but a well thought out beacon strategy is an important mission capability.
- Power systems are still an “Achilles” heal of satellites.
- Test. Test until you have no time left. Our failures were in environments we did not or could not test.
Synopsis

• RAX1 flight qualified the mission and the technology.

• NSF has fostered an environment that enables...
  – Novel science mission exploration
  – In-situ student training, both science and engineering (pre, during, post mission)
  – Distributed collaboration of science and engineering teams.

• RAX2 will recover from the failure and enable additional science measurements.

• Details of the RAX design, operations, testing and analysis are being written for publication.