RAIDS Update

The Remote Atmospheric and Ionospheric Detection System aboard the ISS

May 5, 2008

Introduction

This RAIDS experiment update has been sent to you because you have previously expressed interest in the RAIDS science mission. The purpose of this newsletter is to convey the progress we have made preparing for the upcoming 2009 launch opportunity. RAIDS is definitely moving forward toward launch, and moving *fast*!

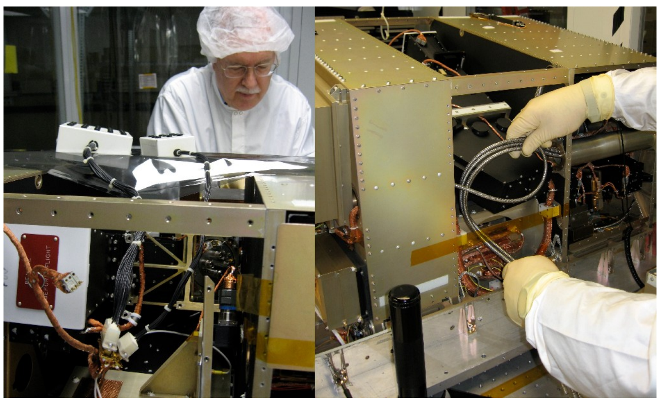

Figure 1: RAIDS refurbishment activities include testing the FUV detector and electronics and routing fiber optics cable to a new IR detector box location.

Current Status

The RAIDS scientific objectives discussed at the May 2007 Science Team Meeting have been adopted for the International Space Station (ISS) opportunity scheduled to launch in July 2009. The RAIDS hardware has undergone extensive inspection and testing to evaluate various hardware performance concerns and retire those risks. Ensuring that RAIDS mission requirements are met by the HICO-RAIDS Experiment Payload (HREP) has been an on-going challenge due to schedule and budget constraints. Nonetheless, the RAIDS program is on-track to perform the minor hardware modifications required for spacecraft accommodation and a desired instrument science upgrade. Refurbishment work has started and RAIDS will be delivered for integration in June 2008.

Milestones Completed

- *2007-Jan-23*
  RAIDS Science Team Meeting
  Discussed RAIDS science achievable from the ISS and identified risks and areas of concern .
- *2007-May-02*
  RAIDS Science Team Meeting
  Prioritized RAIDS science objectives and identified science requirements for mission aboard ISS.
- 2007-Jun-20
  RAIDS Refurbishment Review
  Presented a mission plan, reported on sensor performance, and described a hardware modification approach.
- 2007-Aug-06
  Modification Design Review
  (PDR-level) Presented hardware inspection results and the scope and plan for hardware modification.
- 2007-Nov-14
  Critical Modification Review
  (CDR-level) Presented details of refurbishment plan; immature thermal re-design was source of serious concern.
- 2007-Dec-10
  Delta Critical Modification Review
  (CDR-level) Presented thermal design which met all hardware and science requirements with substantial margin.
- 2008-Jan-14
  HREP CDR
  The HICO-RAIDS Experiment Payload (HREP), which serves as the interface between RAIDS and the ISS, passed its CDR.
- 2008-Apr-07
  Test Readiness Review
  Presented test and verification plan for RAIDS to meet all hardware requirements.
- *2008 Mid-May*
  Receive modified IR Detector Box
- *2008 Late May*
  Environmental Testing and Final Calibration
- *2008 Mid-June*
  Deliver RAIDS to HREP

Once delivered to HREP for integration, RAIDS will undergo further environmental testing at the payload level. The complete HREP package will be delivered to Japan in December 2008, then launch aboard the H-II Transfer Vehicle (HTV) in July 2009.

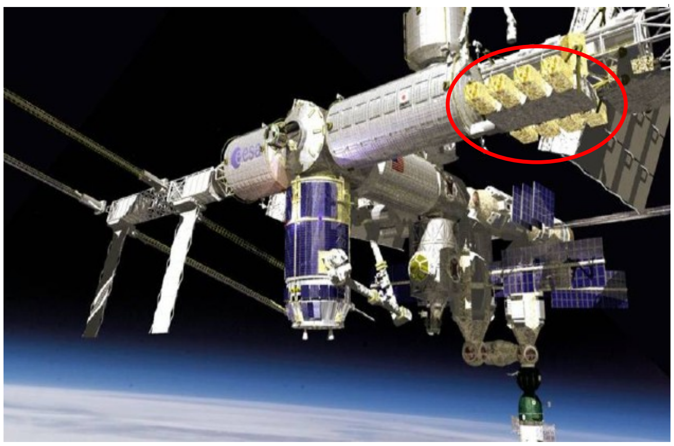

Figure 2: Several experiment payloads are attached to the JEM-EF (upper right) in this graphic depicting the ISS. (Graphic credit NASA).

Mission Overview

The Remote Atmospheric and Ionospheric Detection System (RAIDS) experiment is a multispectral (50-870 nm) remote sensing experiment to study the Earth's thermosphere and ionosphere—regions of the atmosphere with high Navy and DoD relevance due to their effects upon communications, navigation, and satellite drag. The RAIDS sensors scan or image the limb of the Earth to measure profiles of naturally occurring airglow spectra from major ionospheric and atmospheric species. The RAIDS experiment will make global measurements of the temperature and composition of the lower-thermosphere and limited measurements of the ionosphere. Data will be available in real-time or near real time. Environmental data products and scientific results from the RAIDS experiment will contribute to on-going and planned DoD operational and research programs, including on-going initiatives to study the neutral upper atmosphere.

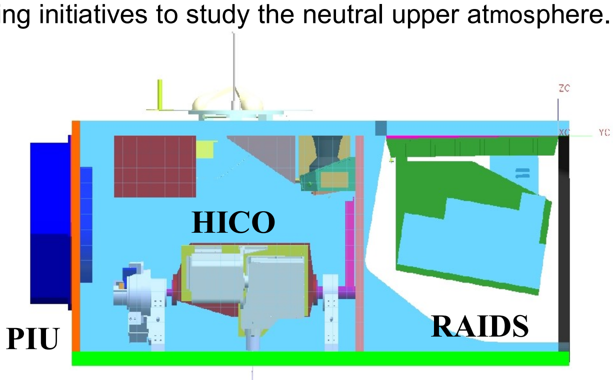

Figure 3: Schematic of the HREP including the HICO experiment, the RAIDS experiment, the Payload Interface Unit (PIU), and support electronics. The manipulator arm grappling fixture sits atop the HREP container.

Mission Profile

RAIDS has been manifested by the USAF Space Test Program (STP) for a July 2009 flight aboard the unmanned Japanese H-II Transfer Vehicle to the International Space Station, where RAIDS will operate from the Japanese Experiment Module – Exposed Facility (JEM-EF, Figure 2). RAIDS will fly with a companion experiment from NRL, the Hyperspectral Imager of Coastal Ocean (HICO). Both experiments will operate inside the HICO-RAIDS Experiment Payload (Figure 3), which is a structure about the size of a refrigerator box that provides power and communications between the experiments and the space station. An astronaut-controlled manipulator arm will remove HREP from the HTV and "dock" it to the JEM-EF. One year of mission operations will be provided by STP, though the experiments could potentially operate aboard the ISS for a much longer period of time, if funding is found. After mission operations cease, the payload is decommissioned, and the manipulator arm will load it into an empty HTV for deorbiting and disposal by atmospheric re-entry.

Other Related Experiments. During the period of RAIDS operations the Atmospheric Neutral Density Experiment (ANDE) from NRL will measure in situ thermospheric composition, total density, and winds in the ISS orbital plane of the space station over the course of approximately 12 months. Operating opposite RAIDS on the JEM-EF will be the Japanese experiment Superconducting Submillimeter-wave Limb Emission Sounder (SMILES) to measure trace gases in the stratosphere. Also present on the JEM-EF facility will be the Space Environment Data Acquisition equipment-Attached Payload (SEDA-AP), a Japanese experiment to measure the local space environment (plasma, atomic O, etc.) in the ISS orbit. These experiments are expected to provide measurements that can complement RAIDS remote sensing observations and provide validation, context, or missing information relevant to RAIDS science.

For more informationabout the other experiments see

http://web.ew.usna.edu/~bruninga/ande-ops.html

http://kibo.jaxa.jp/en/experiment/ef/smiles/

http://kibo.jaxa.jp/en/experiment/ef/seda_ap/

Mission Opportunity & Approach

This launch opportunity for RAIDS was first discussed in October 2006, and from the beginning we knew that the schedule would be extremely tight to make a December 2008 delivery. The approach we adopted was to do the least possible amount of hardware refurbishment necessary to meet the requirements of

- NASA manned mission safety,
- ISS/JEM-EF/HTV accommodation,
- RAIDS primary science objectives,
- and RAIDS secondary science objectives

in order of importance. The HICO-RAIDS payload is a pathfinder mission in being the first US payload to fly aboard the JEM-EF. Additionally, this program will demonstrate to NASA and our international partners at JAXA delivery of a low-cost space experiment with very short development-to-delivery time frame.

Consistent with this approach we identified science objectives for the RAIDS experiment that can be attained with minimal modification of the RAIDS hardware. Due to the schedule constraint, we could be forced to sacrifice sensor measurement capability to maintain schedule—for instance if something were to break during testing. The scientific objectives were defined and prioritized to optimize the science return again this technical risk and the schedule constaints.

Science Objectives

RAIDS was originally conceived and built as a global remote sensing demonstration platform and as a survey experiment to completely characterize the aeronomically important species in the thermosphere and ionosphere. Nowadays, space science missions are generally expected to have objectives which are more tightly-focused than those of the original RAIDS mission. Though a global comprehensive thermospheric and ionospheric survey has never been performed, various space experiments over the last 15 years have advanced our understanding of the thermosphere. Yet compelling, fundamental science questions remain concerning (1) the structure of the thermosphere and ionosphere, (2) their responses to solar and geomagnetic forcing, and (3) the effect of tides and gravity waves upon the upper atmosphere. The RAIDS experiment will measure the composition, density, and temperature from which chemical and dynamical effects can be modeled or inferred to address aspects of these questions.

ISS Mission Science Objective

The International Space Station platform is not well-suited to high latitude (auroral) or ionospheric observations due to its 51.6° orbital inclination and low 330–425 km orbital altitude. Consequently, the ability of RAIDS to address the science questions above will be limited to what can be accomplished in low- to mid-latitudes and in the lower portion of the thermosphere and ionosphere. As discussed at the May 2007 RAIDS Science Team Meeting, our mission objectives have been refined for this ISS mission:

Primary Objective: Measure the lower thermosphere temperature over altitudes 100-200 km to study the vertical temperature and compositional structure, the thermospheric response to solar UV variability, and the effect of tides and waves on the lower thermosphere.

Secondary Objective: Measure the O+ initial 83.4nm emission source in the lower F region ionosphere separately from the multiple scattering 83.4nm source near the F-region peak to validate remote sensing of the dayside ionosphere.

Secondary Objective: Measure the global distribution of minor species in the thermosphere to understand their role in chemical and ionic reaction in the lower thermosphere and ionosphere.

The primary objective of temperature measurements in the lower thermosphere is highly relevant to current community interest in the effects of tides on the thermosphere and ionosphere (Immel et al. 2006), the development and validation of improved empirical models of the thermosphere (Picone et al. 2002, Lean et al. 2006), and understanding the heat balance in the thermosphere with respect to global climate change and satellite drag (Qian et al 2006).

Mission Success Criteria

Based upon the scientific objectives and the instrument complement, we have developed mission success criteria. These criteria define the altitude range covered, the type of limb scan used, and the period of operation necessary to address the scientific objective. The success criteria also flow down to define other RAIDS mission requirements and provide guidance in prioritizing refurbishment tasks, mitigating technical risk, and planning mission operations.

HREP is a Class-D space experiment, which is defined as a higher-risk, minimum-cost effort. The characteristics of Class D experiments usually involve short operational life, low complexity, single-string designs, lowest cost, and short development schedule—all features of the HREP/RAIDS program. This HREP and RAIDS mission is not being designed to *ensure* comprehensive success.

However, RAIDS was originally built to approximately Class-B standards using rad-hard parts and built-in redundancies. Therefore, we fully expect RAIDS to far exceed its minimum success criteria. Minimum Success was achievable by RAIDS even before the RAIDS hardware refurbishment activities.

	Minimum Success	Comprehensive Success
Primary Objective	Thermosphere Temperature & Composition with Variability ● 100-200 km alt. ● discrete altitudes ● 30 days continuous	Thermosphere Temperature & Composition with Variability ● 100-350 km alt. ● full altitude scan ● 1 year continuous
Secondary Objective	Dayside Ionosphere Initial O+ 834 Source ● 200-350 km alt. ● full altitude scan ● 1 day	Dayside & Nightside Ionosphere Variability ● 200-350 km alt. ● full altitude scan ● 1 year
Secondary Objective	MLTI Chemistry and Microphysics ● 100-200 km alt. ● discrete altitudes ● 2 weeks	MLTI Chemistry and Microphysics ● 100-350 km alt. ● discrete altitudes ● 1 year
● 30-day minimum time for Primary Science Objective was defined by ISS precession rate to achieve 24-hour local time coverage, excluding sun-safe periods. (Not merely 30 random days over a one-year period.) ● At least 80% data coverage expected.		

RAIDS Refurbishment

RAIDS Hardware Evaluation

RAIDS underwent a calibration and hardware evaluation during April and May 2007. All sensor were found to be performing nominally, with two exceptions: the 589 nm photometer's photomultiplier tube was noisy, and the FUV spectrograph exhibited significant sensitivity loss wavelengths <145nm. The RAIDS mechanical systems were found to perform very well.

Refurbishment Plan and Status

We identified twelve RAIDS refurbishment tasks that fall into three categories: Repair and Upgrade (RU), Risk Reduction (RR), and Accommodation (A).

Figure 4: Disassembly of a photometer showing the optical stack prior to narrowband filter replacement.

The repair tasks and tasks driven by updated science center upon converting the 589nm Na photometer to sense an O_2 atmospheric band for thermospheric temperature measurement. Additionally, the short-wavelength sensitivity of the FUV spectrograph was low and suggested possible detector degradation.

RU1. Replace noisy photomultiplier tube on Photometer #3.
Status: New PMT's procured and installed in the IR detector box.

RU2. Replace the 589nm narrowband filter on Photometer #3 with 765nm filter.
Status: New filter procured. Photometer filter stack opened and fit check performed.

RU3. Refurbish the FUV detector.
Status: FUV detector and electronics fully evaluated, detector operating properly, but short-wavelength senstivity is still low.

Risk reduction tasks addressed hardware performace risks raised at the RAIDS Science Team meetings. Most of the concerns related to the long period during which RAIDS was in storage.

RR1. Off-axis rejection test and evaluation of NIR spectrometer and photometers.
Status: Off-axis testing verified scattered light performance measured in 1990.

RR2. Performance testing of scan platform

and other mechanisms.
Status: Mechanical testing verified the performance of scan drive, grating drives, and other mechanisms. Analysis retired risks from lubricant aging.

RR3. Replace narrowband 630nm and 774.4nm filters.
Status: Old filter was examined and showed some degradation. New filters procured and fit checks performed.

Most of the RAIDS work centers upon accommodation tasks to prepare for operation aboard the ISS and flight aboard the HTV. RAIDS aboard the ISS must be modified to accommodate the lower ISS altitude, the non-sun-synchronous orbit, a new spacecraft, a new launch vehicle, and a manned mission.

A1. New FUV sensor mounting for ISS orbital altitude.
Status: New mounting feet designed and fabricated.

A2. Replace fiber optic cables and re-route.
Status: New routing designed and new cables procured.

A3. Narrow sun sensor field-of-view.
Status: New sun sensor collimators designed and in fabrication.

A4. Modify the IR detector box.
Status: Modifications required for cooling IR detectors in the ISS orbit. Fabrication and assembly complete.

A5. Optimize scan profile by adjusting jumpers in scan drive electronics.
Status: Determined to required too much time and effort. Using original scan profile.

A6. Fastener replacement and load-path analysis.
Status: New ISS-compliant fasteners ordered to replace safety-critical fasteners in the load path.

Although RAIDS was qualified for spaceflight aboard TIROS, the new requirements for flight aboard HTV and operations on the ISS require additional environmental testing and analysis. Other on-going activities include testing the electrical, command, and data handling interfaces to HREP.

RAIDS Capabilities

The refurbished RAIDS instrument complement will differ slightly from the 1992 configuration. In particular the 589nm sodium photometer has been replaced with a 765nm O_2 band photometer. Other changes include new photomultiplier tubes in the four the NIR instruments, new narrowband filters for the three photometers, and sensitivity loss in the FUV sensor.

EUV Spectrograph	
Passband	55-111 nm @ 1.25nm res.
Field-of-View	0.1° x 2.4°
Integration Time	0.5 sec
Aperture Area	70mm x 70mm
Telemetry Rate	2560 bits/sec
Sensitivity	0.2-0.3 counts/sec/Rayleigh
FUV Imaging Spectrograph	
Passband	130-170 nm @ 0.7nm res.
Field-of-View	4.0° x 0.1°
Integration Time	64-90 sec
Aperture Area	21mm x 25mm
Telemetry Rate	4096 bits/sec
Sensitivity	0.1-0.5 counts/sec/Rayleigh
MUV Spectrometer	
Passband	190-317 nm @ 0.95nm res.
Field-of-View	0.1° x 2.1°
Integration Time	0.025 sec
Aperture Area	42mm x 50mm
Telemetry Rate	800 bits/sec
Sensitivity	1-7 counts/sec/Rayleigh
NUV Spectrometer	
Passband	295-399 nm @ 0.7nm res.
Field-of-View	0.1° x 2.1°
Integration Time	0.025 sec
Aperture Area	21mm x 25mm
Telemetry Rate	800 bits/sec
Sensitivity	4-7 counts/sec/Rayleigh
NIR Spectrometer	
Passband	722-874 nm @ 0.84nm res.
Field-of-View	0.1° x 2.1°
Integration Time	0.025 sec
Aperture Area	21mm x 25mm
Telemetry Rate	800 bits/sec
Sensitivity	~0.15 counts/sec/Rayleigh

630nm Photometer	
Passband	1.5 nm @ 630nm
Field-of-View	0.2° x 2.1°
Integration Time	0.1 sec
Aperture Area	42mm x 50mm
Telemetry Rate	200 bits/sec
Sensitivity	4 counts/sec/Rayleigh*
777.4nm Spectrometer	
Passband	1.5 nm @ 777.4nm
Field-of-View	0.2° x 2.1°
Integration Time	0.1 sec
Aperture Area	42mm x 50mm
Telemetry Rate	200 bits/sec
Sensitivity	~1.5 counts/sec/Rayleigh*
765nm Spectrometer (formerly 589 nm)	
Passband	1.5 nm @ 765nm
Field-of-View	0.1° x 2.1°
Integration Time	0.1 sec
Aperture Area	21mm x 25mm
Telemetry Rate	200 bits/sec
Sensitivity	not available*
Notes: Sensitivities from pre-refurbishment values.	

Command Capability. To supplement command modes already built into RAIDS, the new HREP interface will provide command scripting capability to facilitate more complex observing modes. RAIDS will operate most of the time in a default mode, with regular shutdowns for sun-safing or ISS operations and occasional campaign observations.

Real-time Data. The RAIDS data will be transmitted on the Low-Rate Data downlink from the ISS. These data are continually transmitted via TDRSS. Thus the RAIDS science data will be available in near real time with a latency of ~10 minutes.

RAIDS Science Team

Currently, the RAIDS Team is focused upon hardware preparation and meeting our agressive delivery schedule. But after RAIDS is delivered to HREP for integration in June, the RAIDS Team focus will shift toward planning mission operations, data management, data processing, and scientific algorithms.

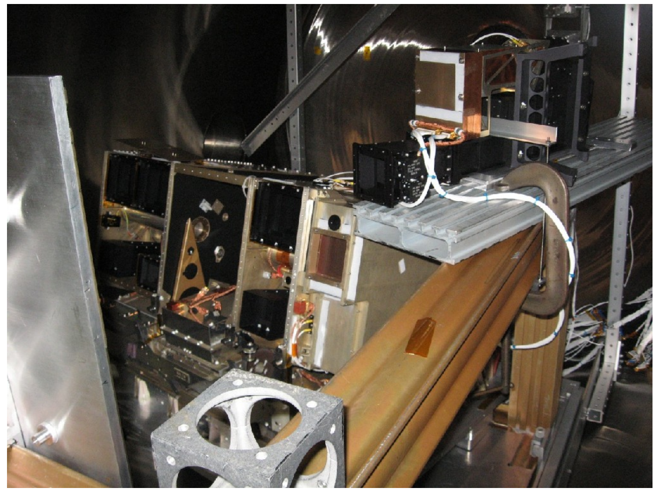

Figure 5: RAIDS in the vacuum chamber for pre-environment UV calibrations during final assembly.

With a guaranteed mission length of only 1 year, we will need to hit the ground running. Time is short to perform mission planning and to prepare for data analysis, if operations will indeed start in Fall 2009. Science Team members will be key to these efforts.

Here are a few areas into which the Science Team members might put some thought:

- Mission Planning. Attaining minimum success (30-day time frame); attaining comprehensive success (1-year time frame); special observing modes and targeted campaigns; effective and innovative use of multiple sensors.
- Algorithms & Data Processing. Temperature from O_2 atmospheric bands (NIR only, NIR+765nm); dayside ionosphere from 61.7, 83.4 nm; data reduction; data distribution; measuring tides and waves; data products.

Perhaps we can present a few posters about RAIDS at the Fall AGU, e.g. a mission/hardware poster and posters laying groundwork for each of the science objectives? I propose that we have one Science Team meeting in mid-summer to work toward that goal, then possibly a follow-up meeting during Fall AGU.

I look forward to hearing from you as we move into the science planning phase of the RAIDS program.

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