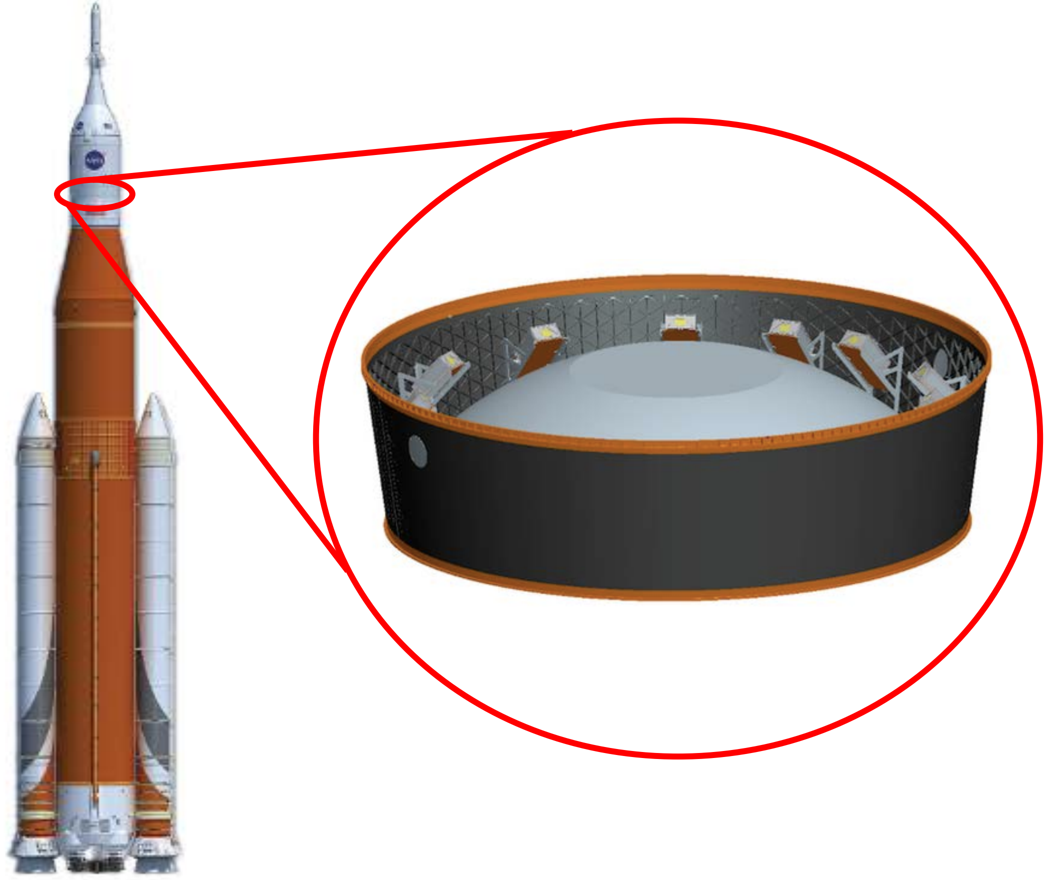
School of Earth and Space Exploration
Arizona State University

The Lunar Polar Hydrogen Mapper (LunaH-Map) Mission and Systems-Level Status

Craig Hardgrove

LunaH-Map Mission Overview



- NASA SMD SIMPLEx mission led by ASU: Craig Hardgrove (PI, Planetary Geology); AZ Space Technology (Engineering, spacecraft, I&T); ASU (Operations, science)
- 6U+ CubeSat to launch on SLS EM-1
- Objective: map hydrogen enrichments at the moon's south pole at small spatial scales, ~1 year cruise & spiral to science phase, 2 month science phase
- Demonstrate planetary neutron spectroscopy from a CubeSat

The ASU LunaH-Map Team

LunaH-Map Team

Principal Investigator
Craig Hardgrove, ASU

Deputy Principal Investigator
Jim Bell, ASU

Project Management (*ASU*)
Teri Crain – *Project Coordinator*
Kevin Reinhart - *Budget*
Stephanie Holaday - *Purchasing*

Science Team
Richard Starr, *Catholic Univ.*
Anthony Colaprete, *NASA/Ames*
Mark Robinson, *ASU*

SLS Secondary Payload
Carole McLemore, MSFC

Chief Engineer
Igor Lazbin, *AZ Space Tech*

Student Project Systems Engineer
Stephen West, ASU *PhD Student*

SLS Safety/Requirements
Dawn Gregory, *AZ Space Tech*

Navigation / Mission Design

Navigation
Derek Nelson, *KinetX*

Mission Design
David Dunham, *KinetX*
Anthony Genova, *NASA/Ames*

Spacecraft Bus

EPS, ACS, C&DH
Steve Stem
Blue Canyon Technologies

Propulsion
Mike Tsay
Busek

Radio/Ground Comm (DSN)
Alessandra Babuscia
Jet Propulsion Laboratory

Solar Arrays
Sean Parlapiano
MMA Designs

Flight Software
Steve Stem
Blue Canyon Technologies
Hannah Kerner, ASU *PhD Student*

Assembly, Integration & Test

Electrical Integration and Test
Bob Roebuck, *AZ Space Tech*
Wayne Fornwalt, *AZ Space Tech*
Savannah Puckett, *AZ Space Tech*

Instrument Integration
Paul Scowen, *ASU*

Payload

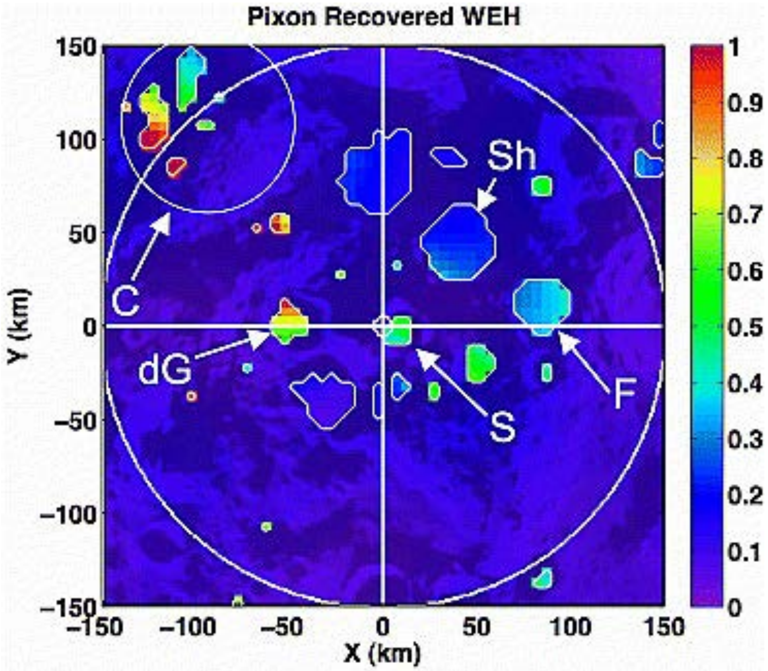
Mini-Neutron Spectrometer
Erik Johnson
Radiation Monitoring Devices

Camera
Amber Keske, ASU *PhD Student*

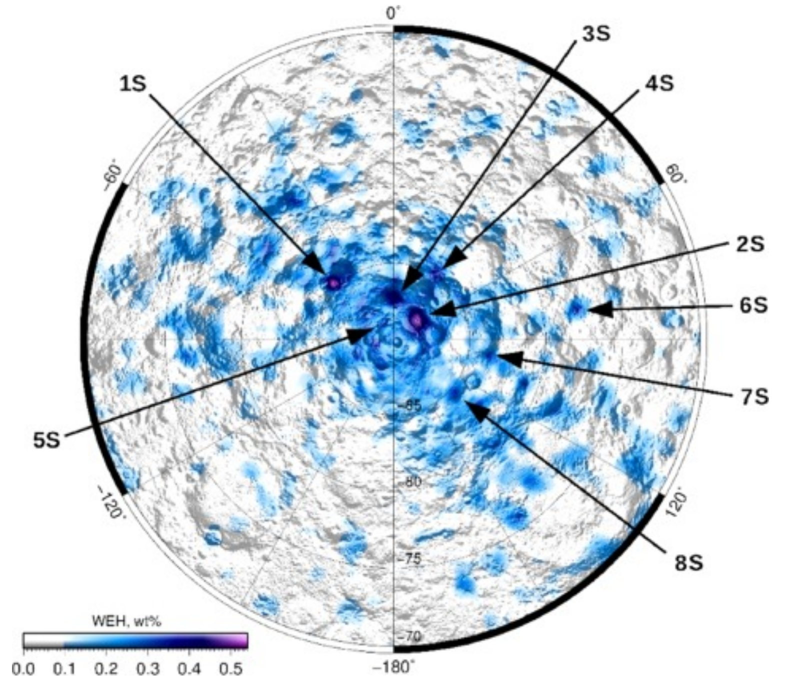
Mission Operations
Patrick Hailey, *Qwaltec*
Ernest Cisneros, *ASU*
TBD - *Student*

Thermal/Structure
Joe DuBois, *ASU*
Valentin Ivaniski, *AZ Space Tech*
Nathaniel Struebel, *Student*
Robert Amzler, *Student*
Ricky LeDesma, *Student*

Lunar Neutron Spectroscopy from Previous Missions



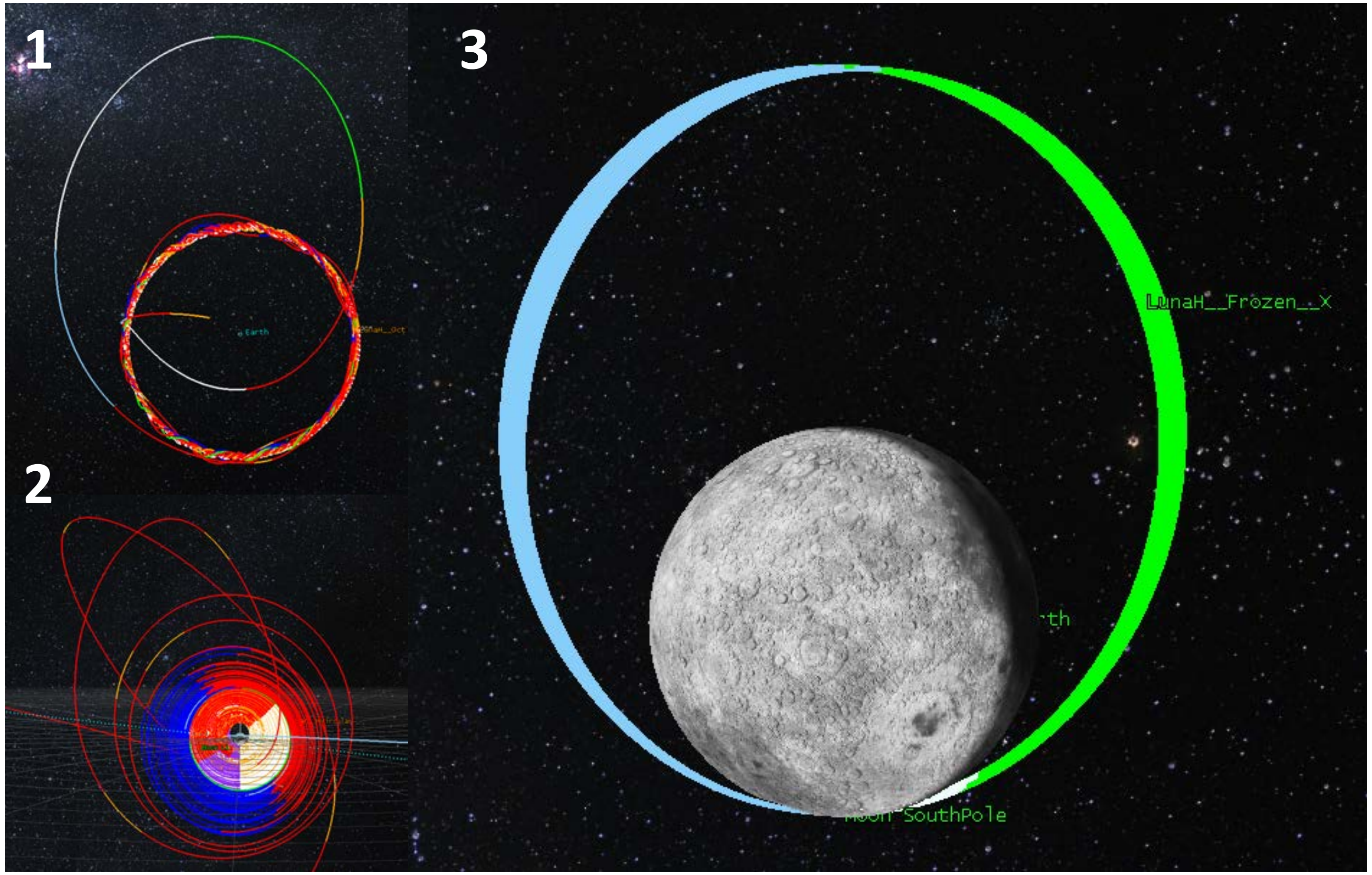
Pixon-based reconstruction of LPNS data (Elphic et al 2007) reveals high WEH abundances in Cabeus (near 1 wt%) and lower abundances in Shoemaker, Haworth, and Faustini (~0.3 wt%)



Analysis of LEND data (Sanin et al 2017) reveals higher WEH abundances (~0.5 wt%) in south polar craters Shoemaker, Haworth, and Faustini

LunaH-Map will acquire similar neutron data from lower altitudes to constrain abundances at small spatial scales (~10km x 10km)

Trajectory Design



Period	4.76 hour
Aposelene Altitude	3150 km
Periselene Altitude	RAAN dependent 15-25 km
Inclination	90°
Argument of Periselene	273.5°

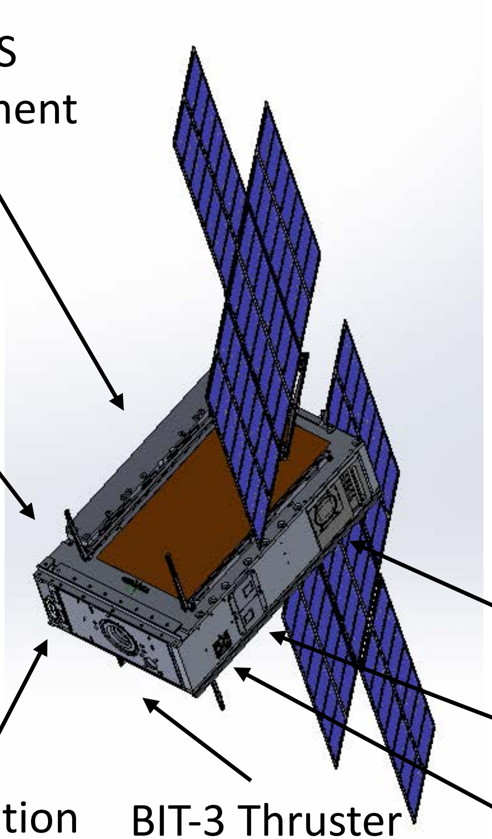
Genova, A. L. and Dunham, D. W. (2017) 27th AAS/AIAA Space Flight Mechanics Meeting 17-456.

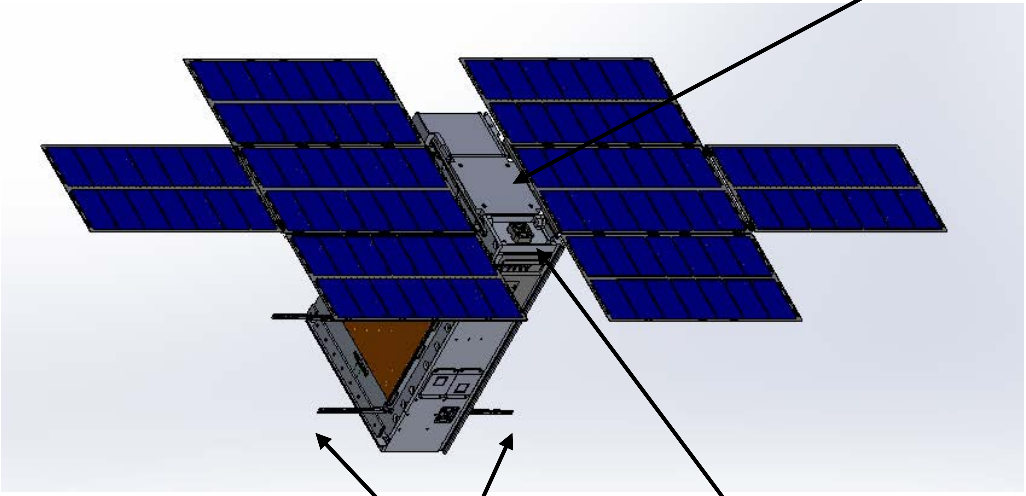
LunaH-Map Flight System

Single Axis
Solar Array Drive

Mini-NS
Instrument

LGA





XB1-50 /
Star Tracker

Solar Array
Hold Down
Arms

Primary Coarse
Sun Sensor

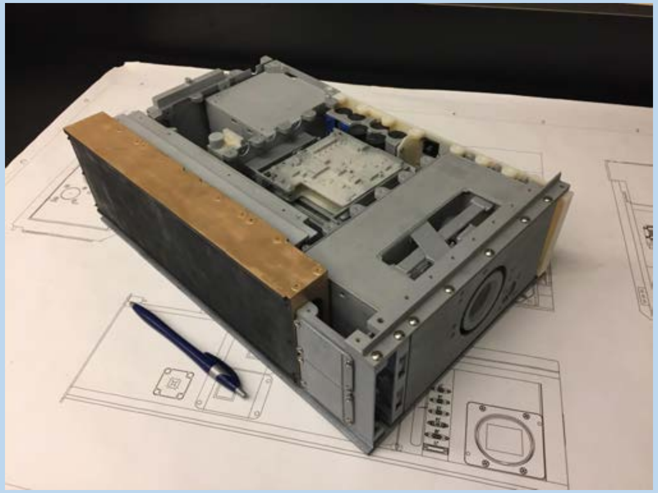
LGA

Coarse Sun Sensor

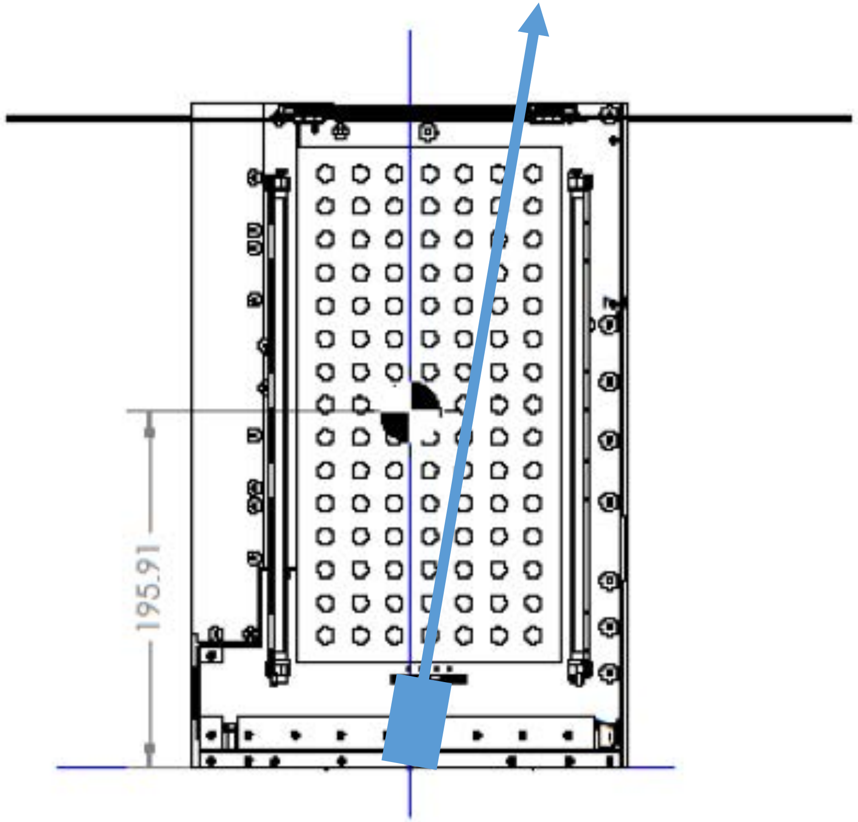
Separation
Connector

BIT-3 Thruster

1:1 3D Printed Model of
LunaH-Map Flight System



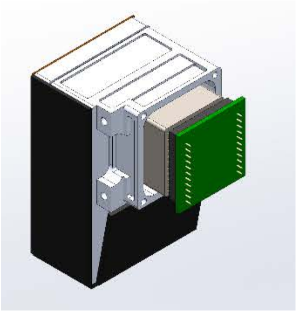
Propulsion (BIT-3)



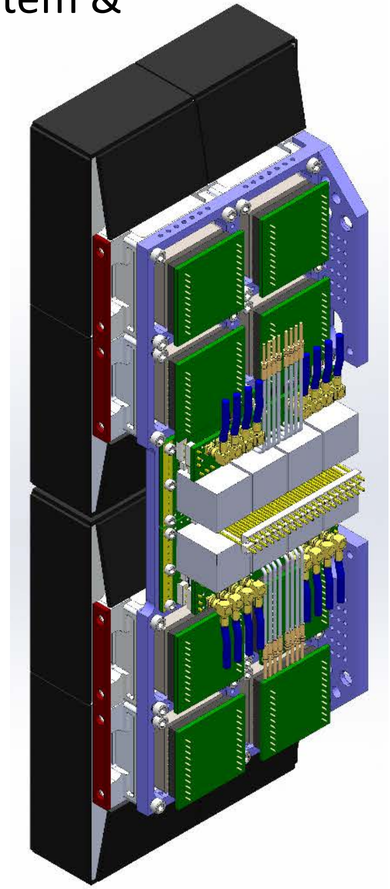
- Busek BIT-3 ion thruster
- Iodine propellant
- 10° gimbal for momentum management

Miniature Neutron Spectrometer (Mini-NS)

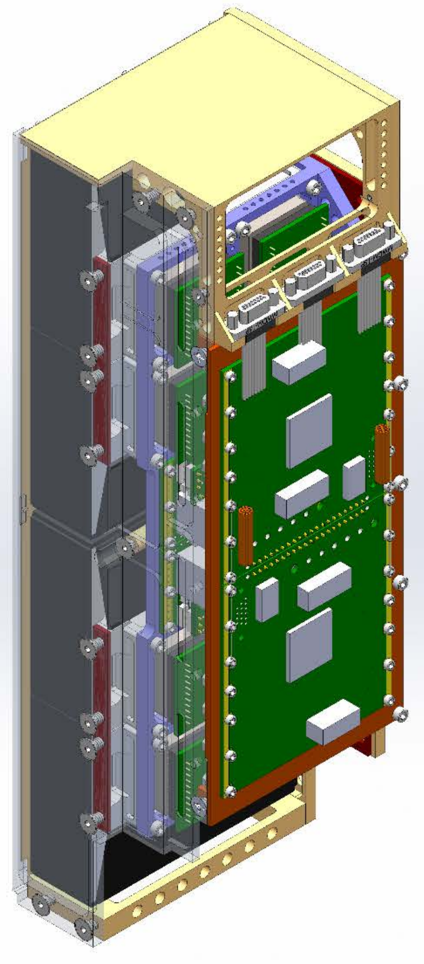
CLYC Module



Detector System & Cold Plate

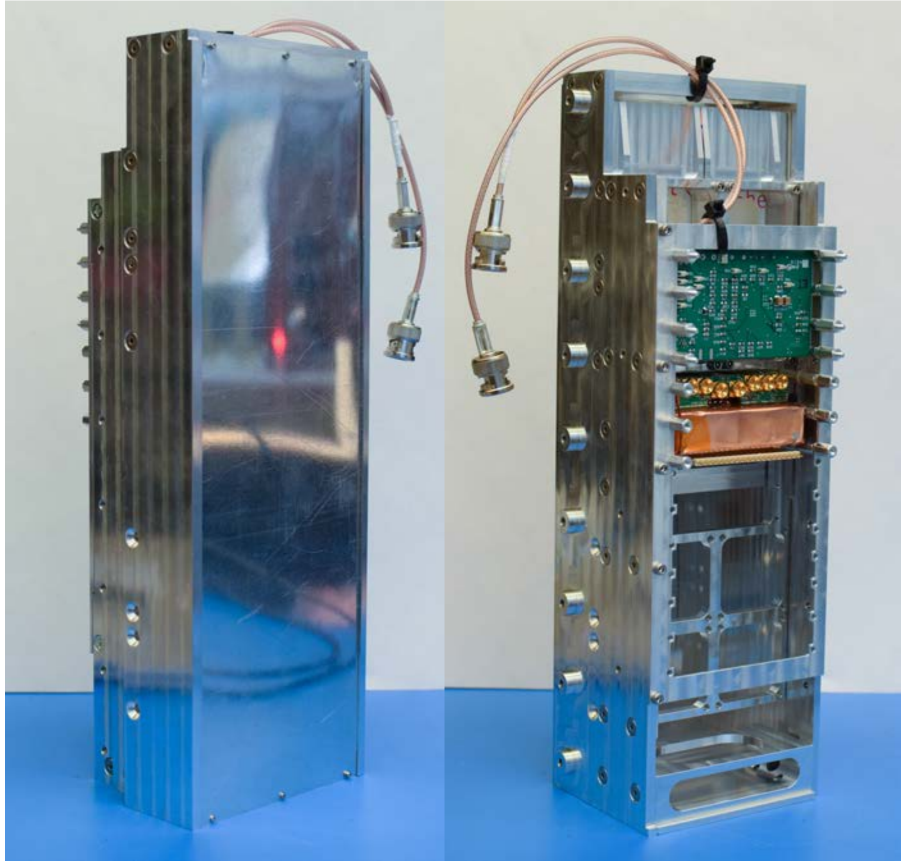


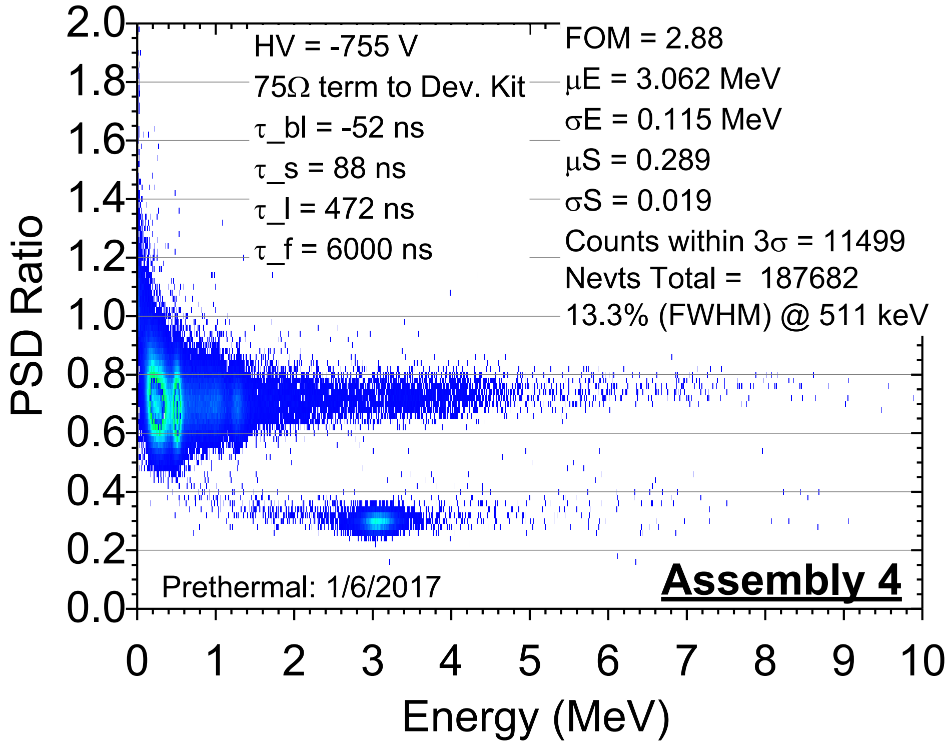
Instrument Housing & Digital Electronics Board



Detector	2x4 array of CLYC (elpasolite scintillator, Cs_2LiYCl_6:Ce) crystals, each crystal 4 cm x 6.3 cm x 2 cm
Dimensions	25 cm x 10 cm x 8 cm
Mass	3.3 kg
Power	10W (min), 22W (max)
Data Acquisition	Counts binned every 1 sec

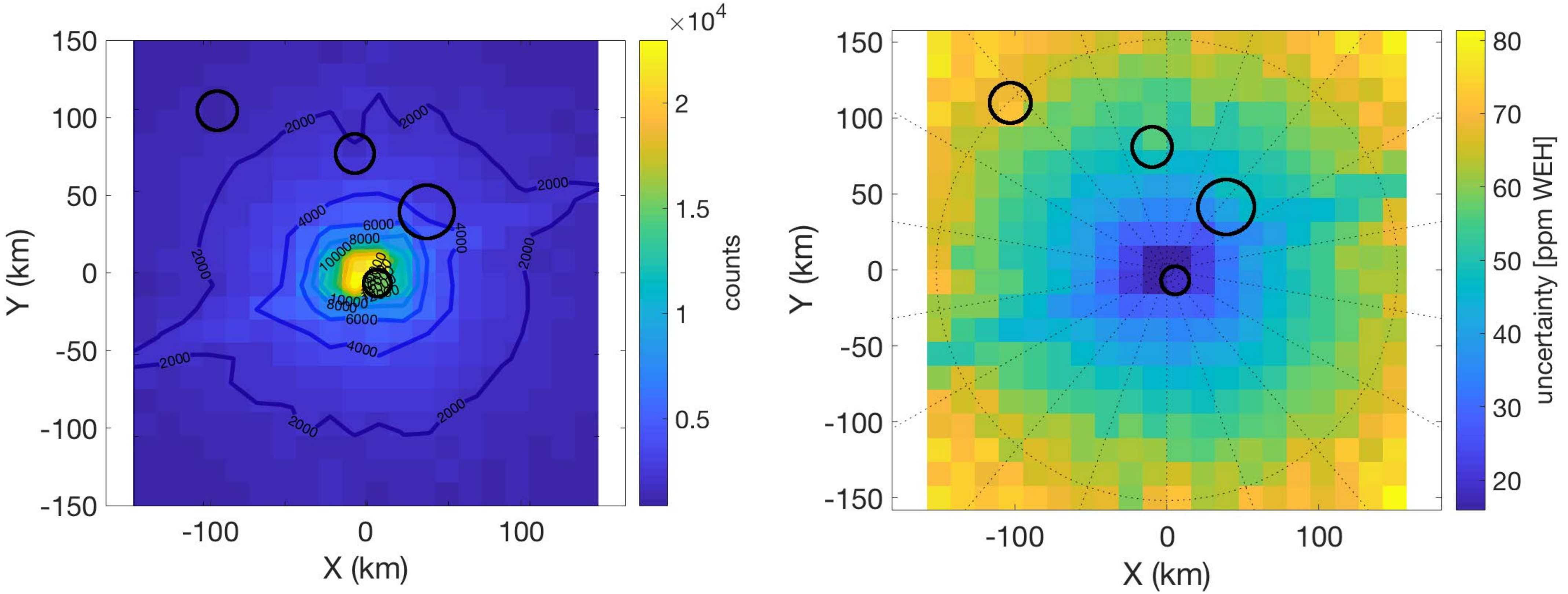
Mini-NS EDU





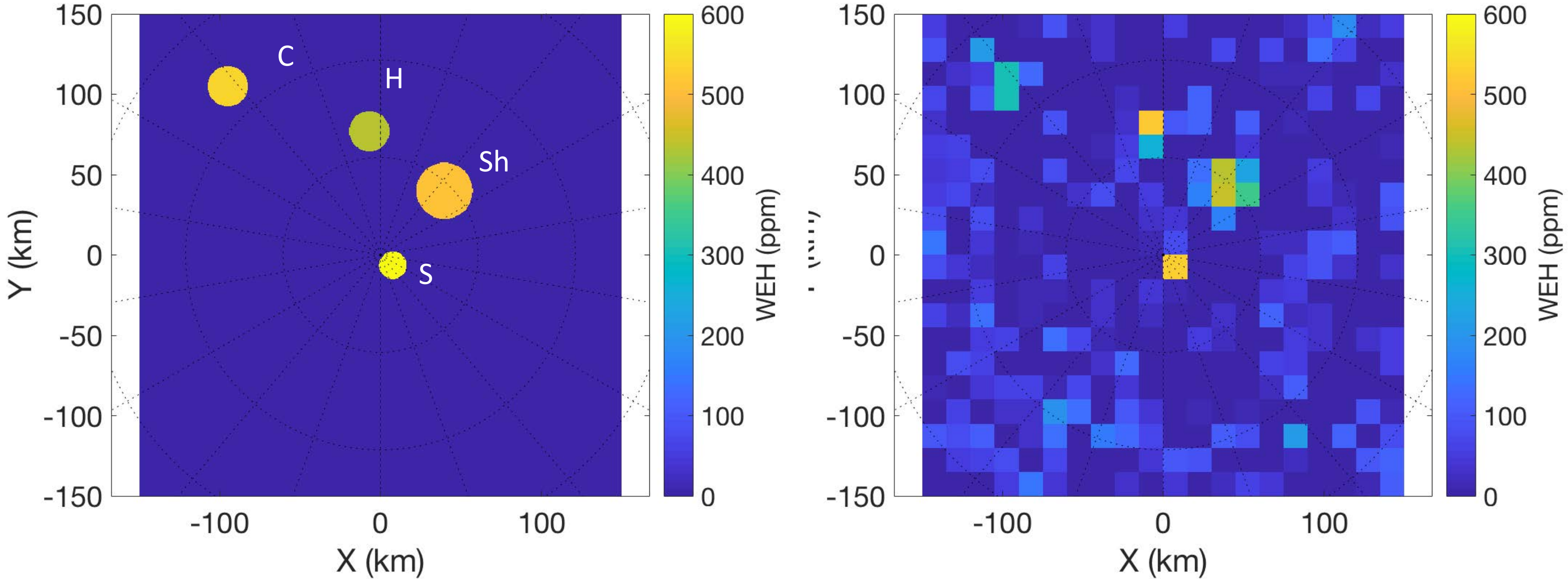
Test results from single EDU module exposed to Na-22 and AmBe

LunaH-Map Mini-NS Sensitivity



Enrichments of 600 ppm +/- 120 ppm WEH are detectable for ~94% of the surface poleward of 85°S in spatial bins of 15km x 15km.

LunaH-Map Predicted South Polar Volatile Mapping



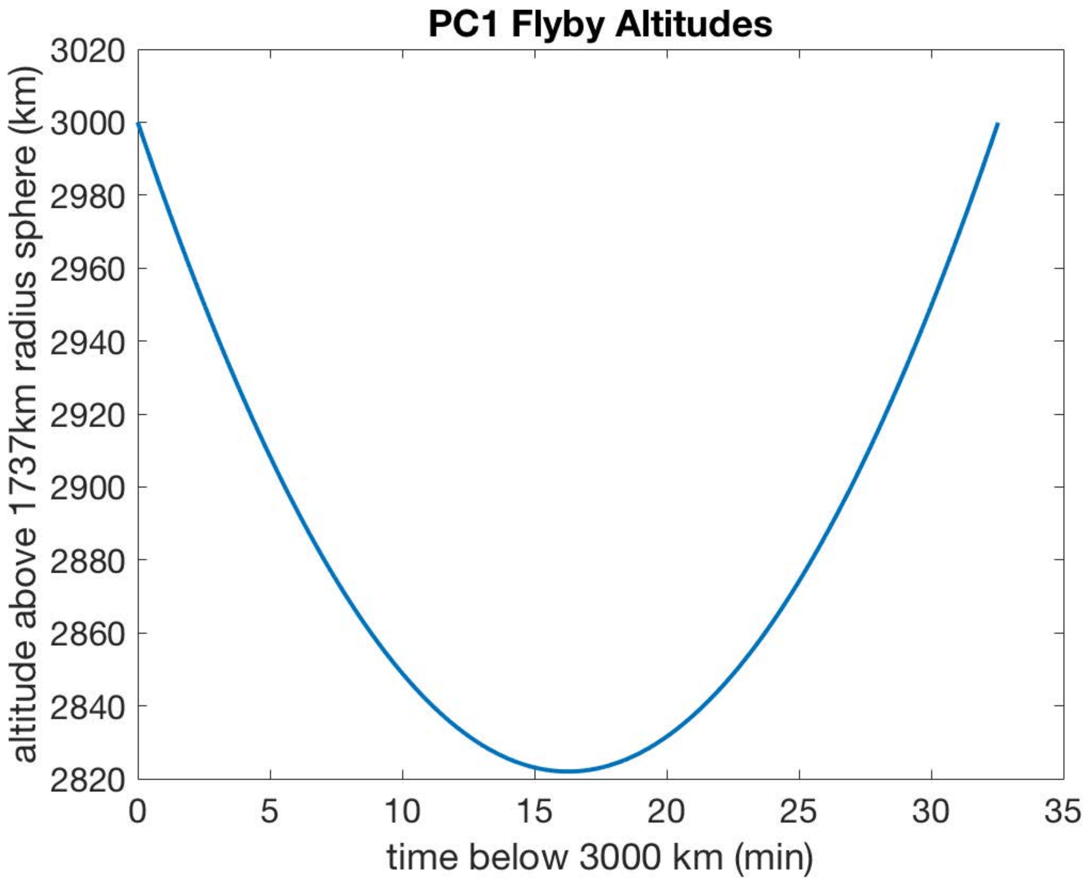
Simulations of maps made from 15x3150km science orbit. Basemap combines LEND high H regions (Sanin et al., 2017) and the Shackleton enrichment from pixon-reconstructed LPNS data (Elphic et al, 2007) to illustrate the type of map LunaH-Map will be able to create.

PC1 – Instrument Qualification

During first lunar flyby, LunaH-Map will observe the lunar neutron count rate of ~3.15 cps at the PC-1 flyby altitude of ~2800 km.

LunaH-Map is below 3000 km altitude for >30 minutes. The predicted epithermal neutron count rate of 3.15 cps can be measured to +/-0.04 cps.

Demonstrate Mini-NS operation in the lunar environment



Qualification

- FM components are tested to GEVS prior to delivery
- S/C at proto-qual vibe and TVAC levels
- Mini-NS calibration at Los Alamos Neutron Free In-Air Facility (LPNS and Dawn GRaND instrument calibration)

Test

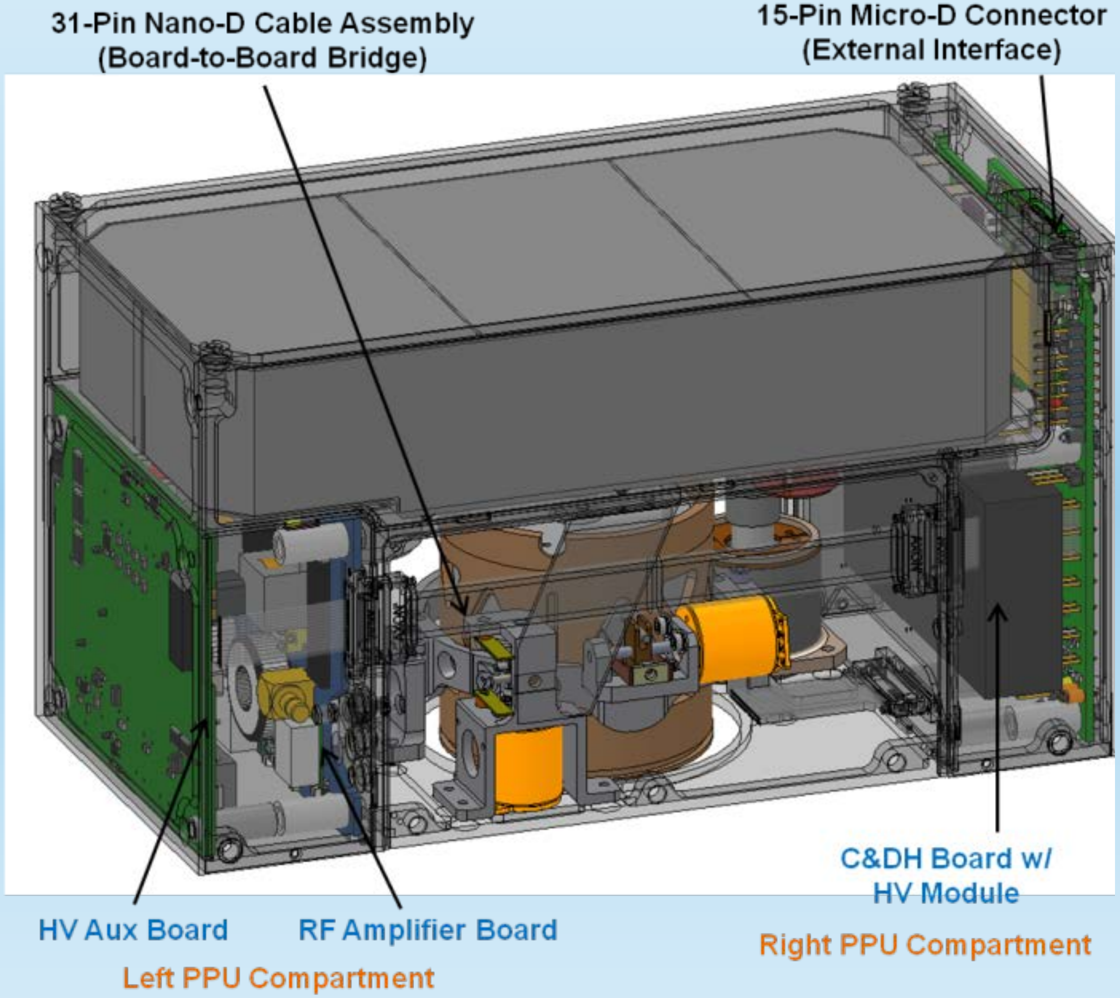
- Component functional testing integrated in S/C
- S/C level functional testing – operational modes, day-in-the-life
- GDS testing with Flat sat and flight components, S/C
- Flat sat development: EM (C&DH, EPS, Expansion Board, Solar Arrays, Iris radio), Emulators (BIT-3 propulsion, Iris radio, Mini-NS, SATA), EDU (Mini-NS)

Radiation

- Critical components are rad tolerant (10 krad)
- Upsets of non-critical components trigger reboot
- Many components are not powered ON for long duration (exception is prop)
- FSW capability to autonomously recover from an aborted burn

PPU Design Methodology and Radiation Approach

- Complex subsystem by nature
  - Process command & power from s/c bus (RS-485, $28V_{DC}$ input)
  - Includes various HV and RF converters to perform BIT-3 functions
  - **Major challenge is to balance efficiency/volume/cost/rad-tolerance; there is no magic solution for all!**
- "Rad-Hard Fence"
  - PPU core is immune to 37MeV SEU; FPGA has additional Triple Modular Redundancy
  - Peripheral converters trade risk for performance and size, but still follow EEE-INST-002 de-rating guide
  - ~10kRad TID protection is provided by 0.100" Al shielding from chassis and spacecraft



BIT-3 System's Unique Split PPU Design

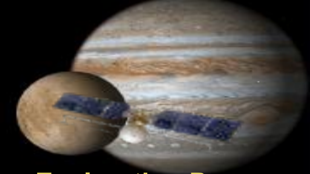
Road to Launch

- Critical Design Review – Completed June 29, 2017
- Phase 2 Safety Review – August 8, 2017
- Enter Assembly, Integration, and Test – Q4 2017
  - AI&T Review/Workshop with review board
- Launch – SLS EM-1, NET Dec 2019

LunaH-Map Program Milestones to Date		
IAA	11 December 2015	Δ-IAA REQUIRED
Δ-IAA	24 February 2016	PASSED with RFAs
SRR	8 April 2016	PASSED with RFAs
I-PDR	9 June 2016	PASSED with RFAs
P1SR	21 June 2016	PASSED
M-PDR	25 July 2016	PASSED with RFAs
CDR	29 June 2017	COMPLETED

LunaH-Map CubeSat
Mission Manager's Assessment

PI: Craig Hardgrove, ASU
PM: Teri Crain, ASU
Mission Manager: Rick Turner
PS: Bobby Fogel
PE: Gordon Johnston



Solar System Exploration Program

Technical		Cost		Schedule		Programmatic		Overall	
JUL	AUG	JUL	AUG	JUL	AUG	JUL	AUG	JUL	AUG
G	G	G	G	Y-G	G	G	G	Y-G	G

Technical:

No significant issues

Cost:

No significant issues

Schedule:

No significant issues

Programmatic:

No significant issues

G	On plan, adequate margin	Y	Problems, working to resolve within planned margin	R	Problems, not enough margin to recover