National Aeronautics and Space Administration

Silicon Micro Dosimeter for High-Altitude Measurements of Cosmic Radiation

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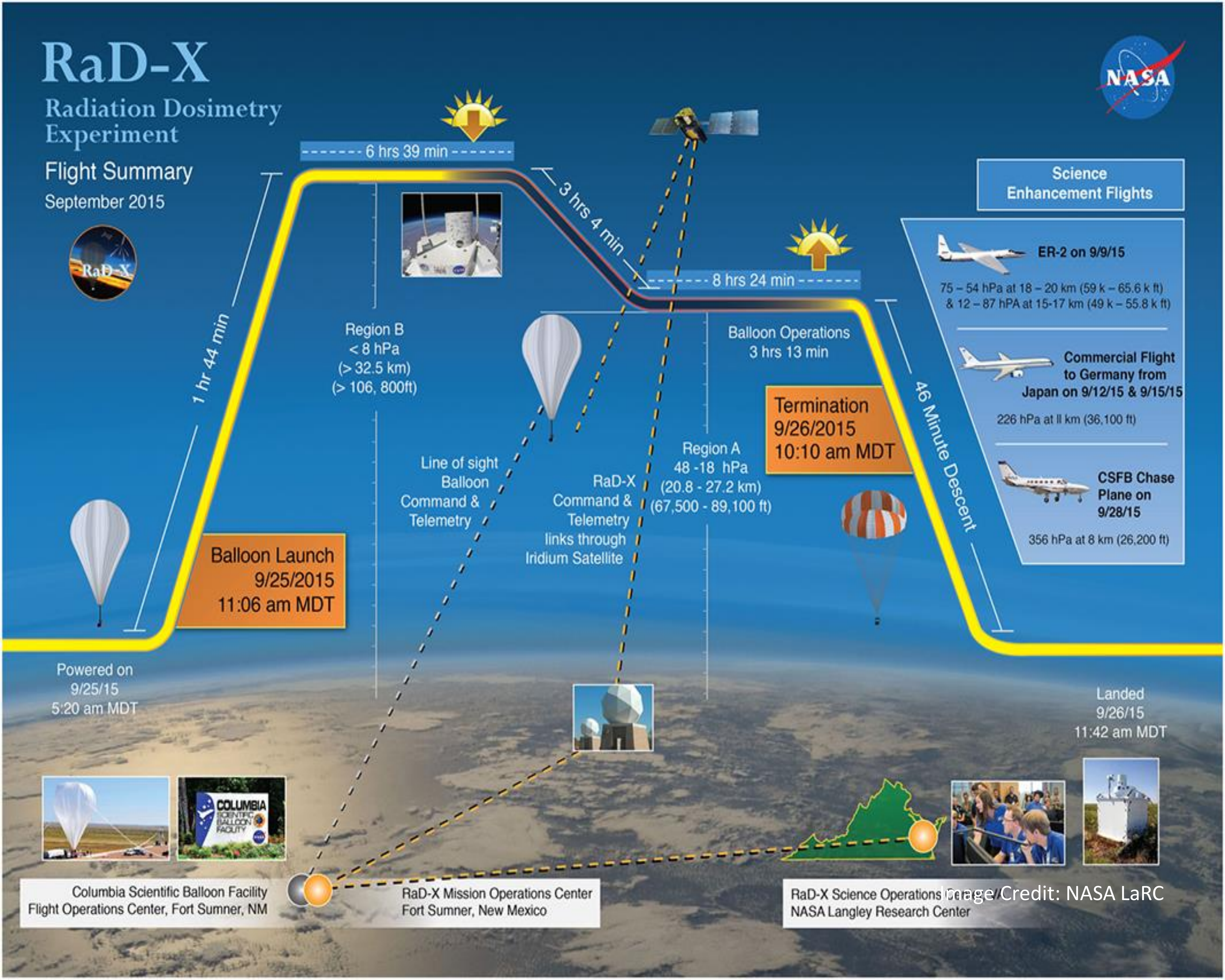

RaD-X
Radiation Dosimetry Experiment
Flight Summary
September 2015
6 hrs 39 min
3 hrs 4 min
8 hrs 24 min
1 hr 44 min
Region B
< 8 hPa
(> 32.5 km)
(> 106, 800ft)
Balloon Operations
3 hrs 13 min
Termination
9/26/2015
10:10 am MDT
46 Minute Descent
Line of sight
Balloon
Command &
Telemetry
RaD-X
Command &
Telemetry
links through
Iridium Satellite
Region A
48 -18 hPa
(20.8 - 27.2 km)
(67,500 - 89,100 ft)
Balloon Launch
9/25/2015
11:06 am MDT
Powered on
9/25/15
5:20 am MDT
Landed
9/26/15
11:42 am MDT
Science
Enhancement Flights
ER-2 on 9/9/15
75 – 54 hPa at 18 – 20 km (59 k – 65.6 k ft)
& 12 – 87 hPA at 15-17 km (49 k – 55.8 k ft)
Commercial Flight
to Germany from
Japan on 9/12/15 & 9/15/15
226 hPa at ll km (36,100 ft)
CSFB Chase
Plane on
9/28/15
356 hPa at 8 km (26,200 ft)
Columbia Scientific Balloon Facility
Flight Operations Center, Fort Sumner, NM
RaD-X Mission Operations Center
Fort Sumner, New Mexico
RaD-X Science Operations
NASA Langley Research Center
Image Credit: NASA LaRC

Outline

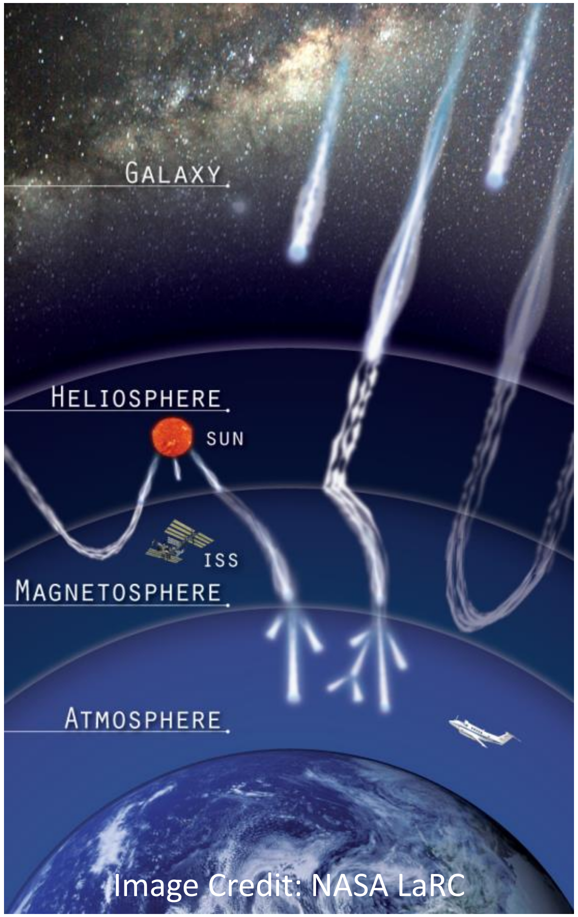
1. Background & Motivation
2. Dosimeter Requirement
3. Measurement Data
4. Future Work & Improvements

RaD-X Science Motivation

NASA Strategic Goal:
Improve prediction of biologically harmful radiation at aviation altitudes

Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (**NAIRAS**) model

RaD-X: Important step in the V&V process en route to making NAIRAS operational



RaD-X Science Goals

1. **Improve tools that predict energy deposition characteristics of penetrating GCR in Earth's atmosphere**
   – Combine different dosimeter measurements and two flight altitudes to assess model uncertainty in GCR primaries

2. **Identify and characterize low-cost radiation measurement solutions**
   Continuous, global measurements for real-time data assimilative modeling

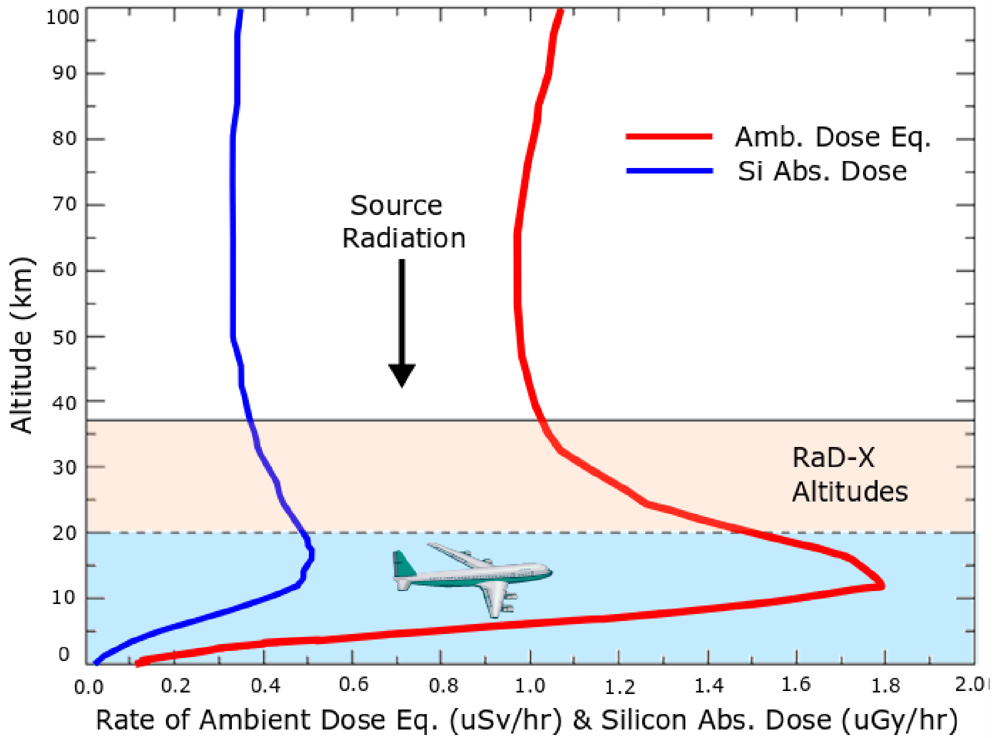


Image Credit: NASA LaRC

Project Overview

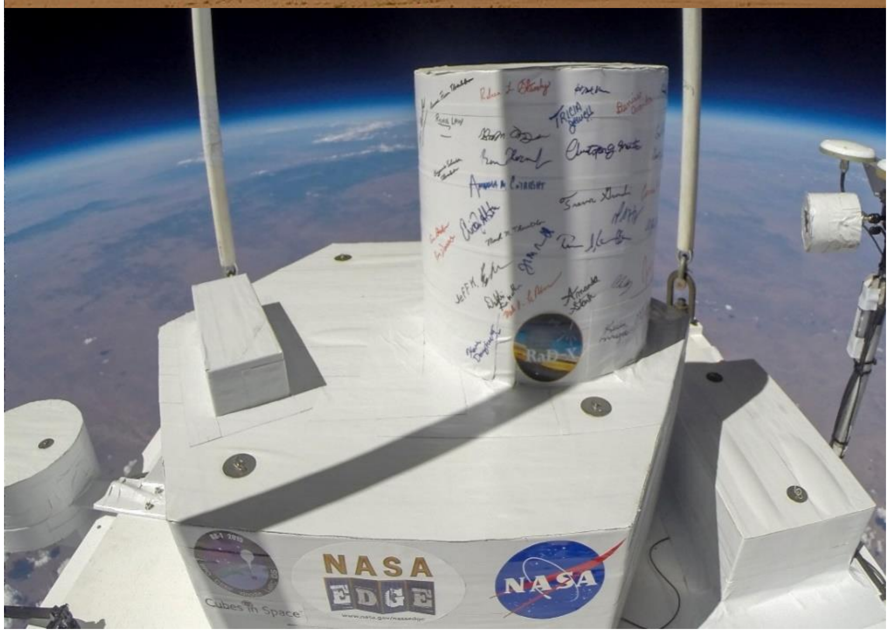
Flight Overview

- Launched Sept. 25th, 2015
- Over 18 hours of dosimetric data above 20 km altitude

Science Instruments

- Teledyne UDOS001 micro dosimeter (TID)
- FarWest Technologies tissue equivalent proportional counter (TEPC)
- Bulgarian Academy of Sciences Liulin linear energy transfer (LET) spectrometer
- University of Surrey RaySure dosimeter

Image Credit: NASA LaRC



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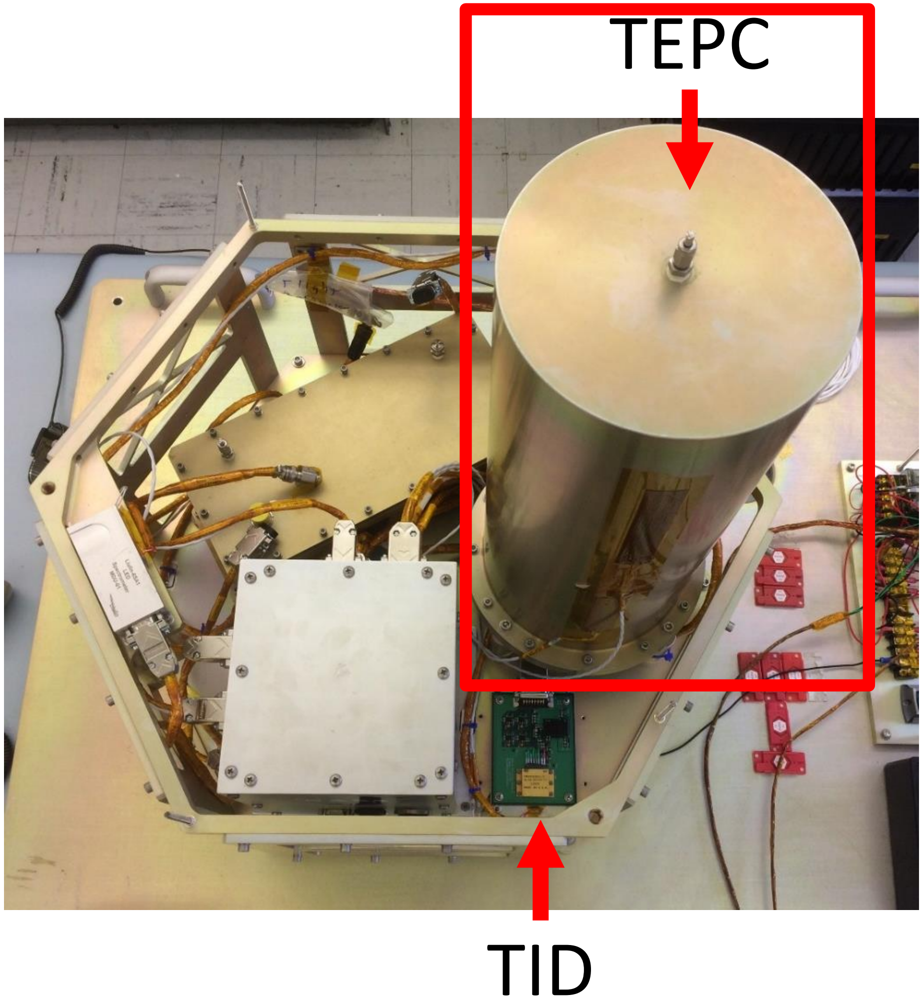
TEPC Reference Dosimeter

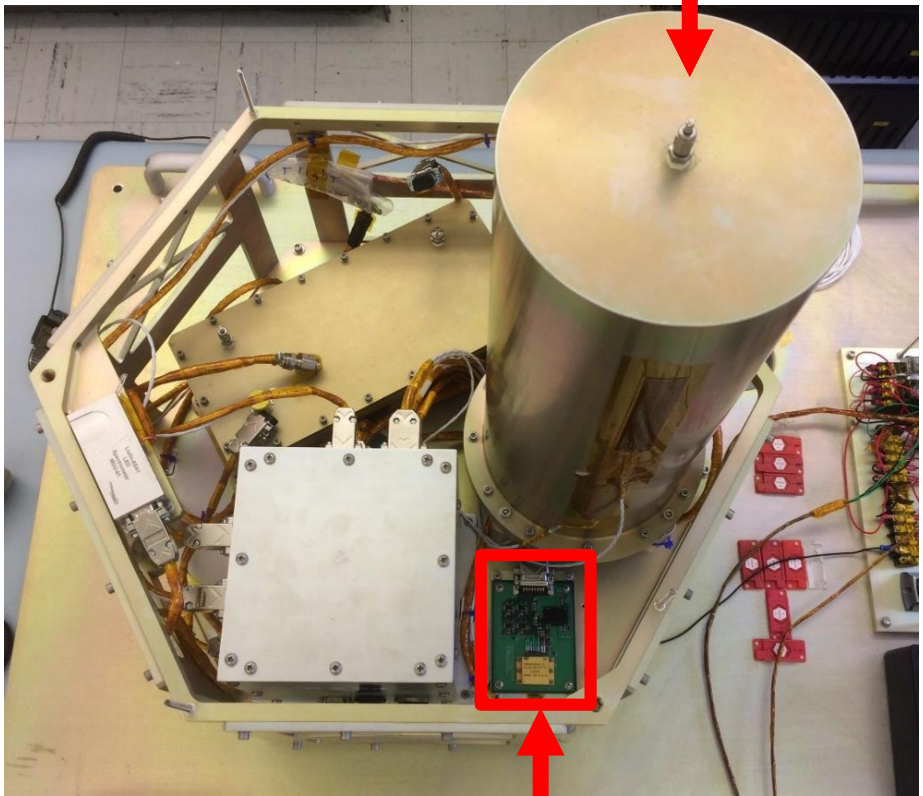


TEPC Specifications

Parameter	Value(s)
Total Mass	4 kg
Power	0.5 W
Dosimeter outer dimensions	160 mm diameter x 340 mm height
Detector size (spherical)	12.7 cm diameter
A150 detector wall thickness	0.21 cm

TID Silicon Dosimeter

TEPC

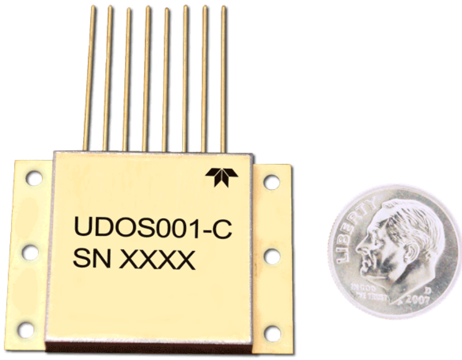


TID

TID Sensor Specifications

Parameter	Value(s)
Measured quantity	Accumulated dose
Total Mass	20 g
Power	0.28 W
Dosimeter outer dimensions	35 x 25 x 4.5 mm
Silicon detector dimensions	5 x 5 x 0.25 mm
DAC low range	0 – 3.5 mRads
DAC low step size	13.6 μRads
DAC low step size	19.5 mV
DAC logarithmic range	0 – 68 kRads

Teledyne UDOS001



Flight Heritage

- NASA's Lunar Reconnaissance Orbiter [Mazur et al., 2011]
- DC-8 aircraft for the Automated Radiation Measurements for Aerospace Safety (ARMAS) project [Tobiska et al., 2011]

Radiation Beam Characterization

- [Lindstrom et al., 2011]
- [Straume et al., 2016]

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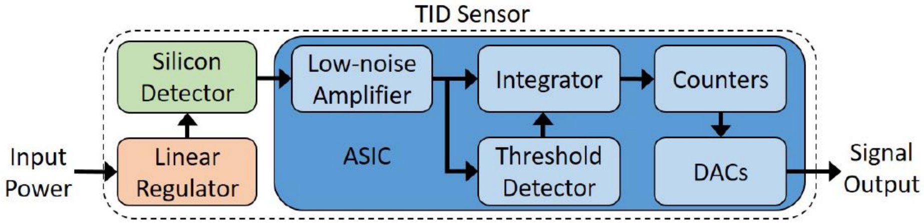
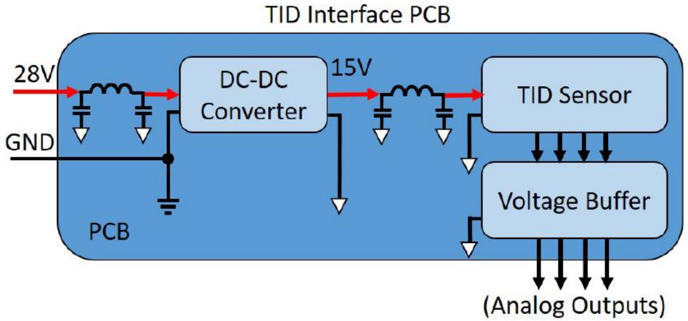
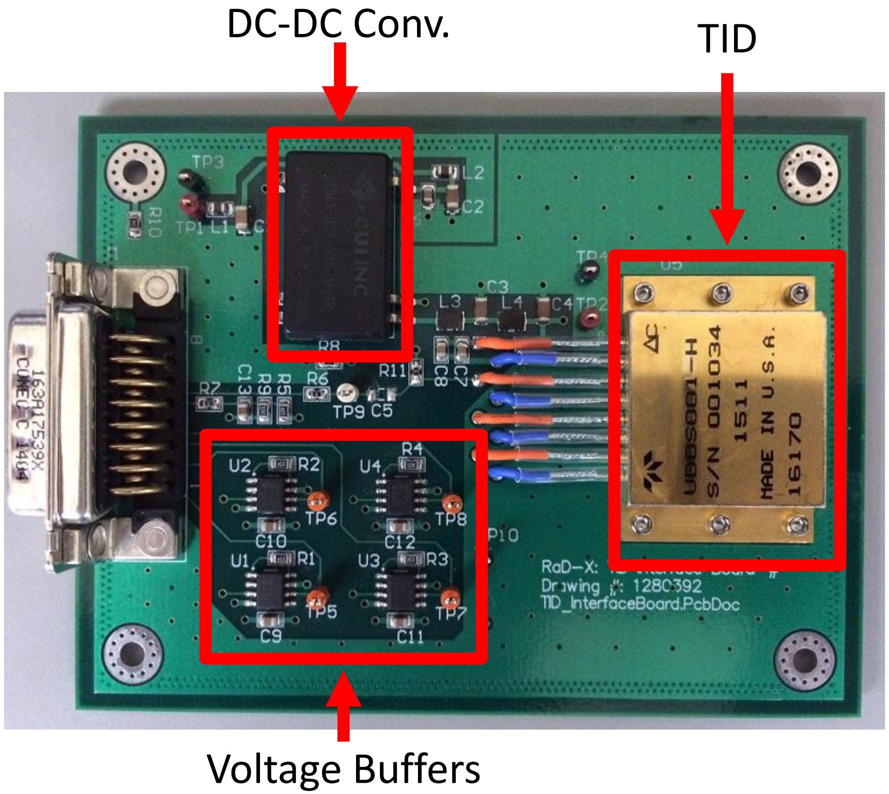
TID Interface Design







Requirements

- **Power:** 13 to 40 VDC at 10 mA
- **Data:** Four analog channels, 0-5V output, low impedance to ADC (TID sensor has ~ 10 kΩ Zo)
- **Control**: On/Off switching capability
- **Mechanical:** Survive ~15g, view of the sky

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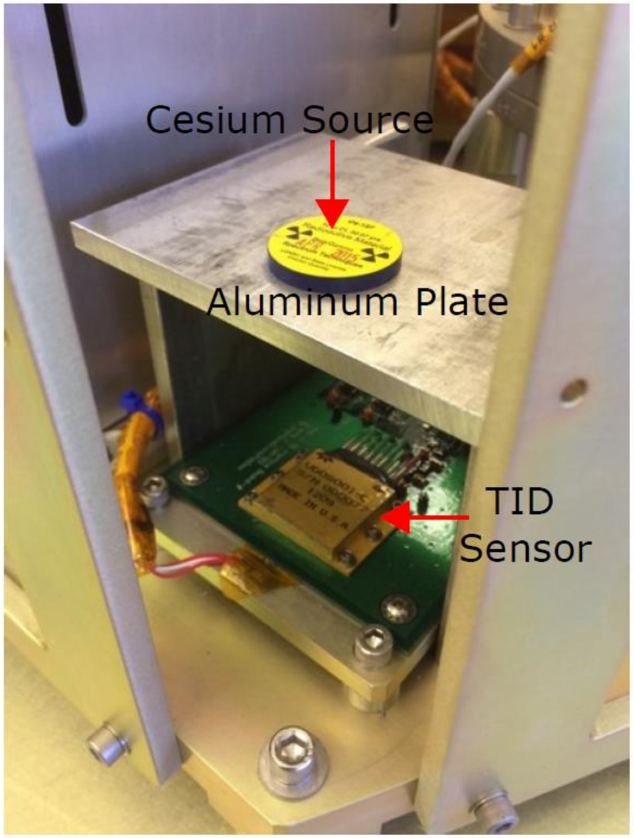
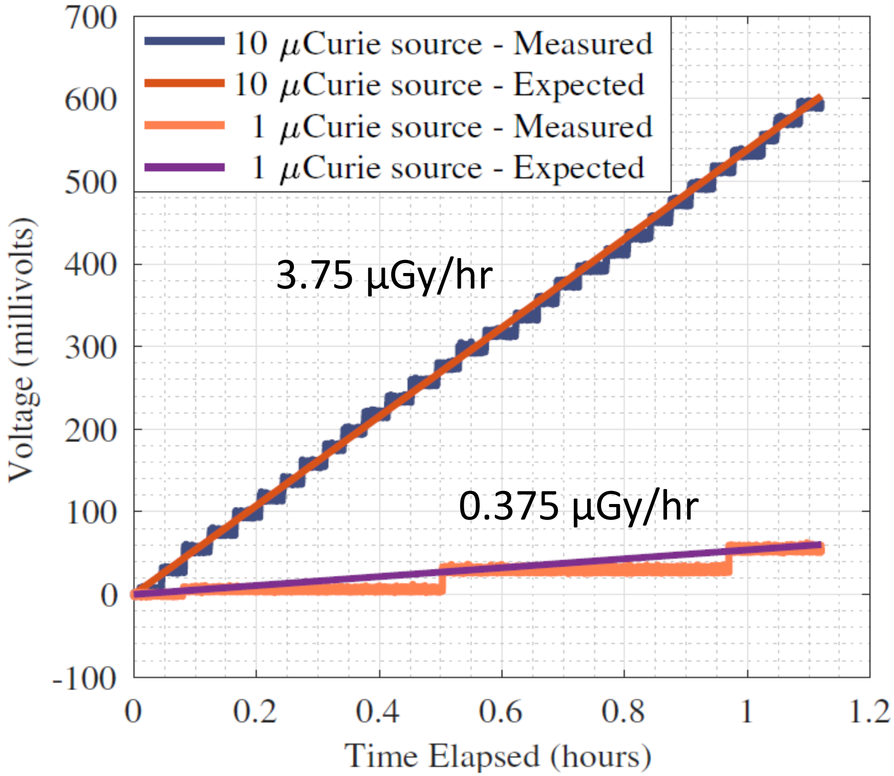
Laboratory Measurements

Laboratory measurements with flight hardware showed good agreement with theory



Not shown: 5 cm piece of L200 minicell polyethylene to attenuate secondary electrons generated in the air gap

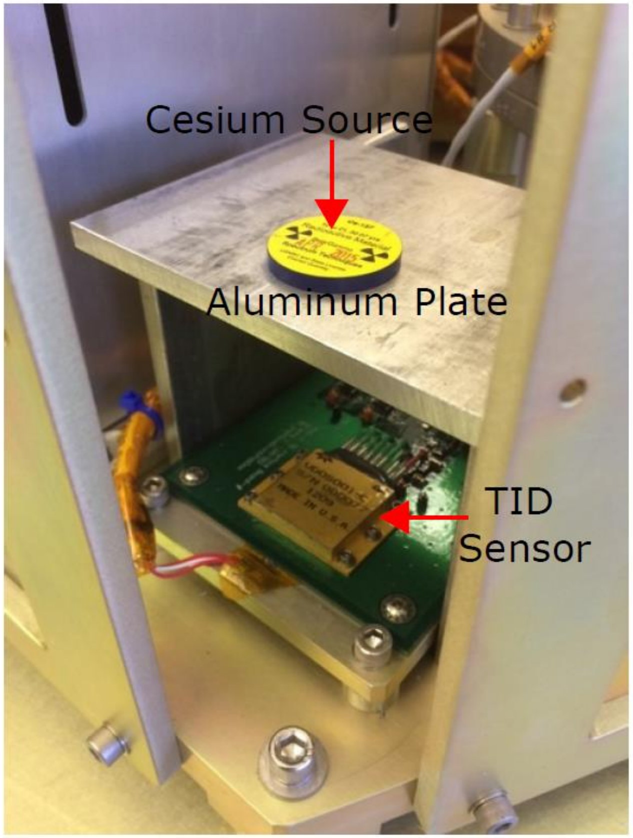


TID Laboratory Measurements (Low and Med. channels)

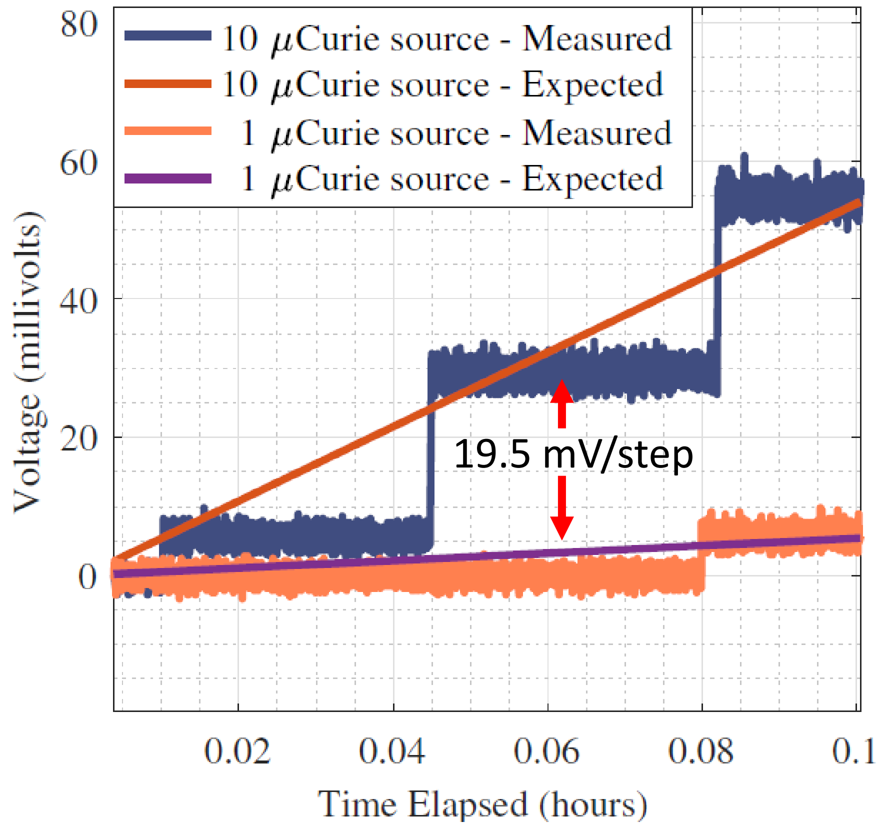
$$\#\ \text{of steps} * \frac{\text{Rad}}{\text{step}} * \frac{0.01\,\text{Gy}}{\text{Rad}} * \frac{1}{t} = \text{Dose Rate}\left[\frac{\mu\text{Gy}}{\text{hour}}\right]$$

Laboratory Measurements

Observed < 10 mV peak-to-peak noise on TID analog outputs



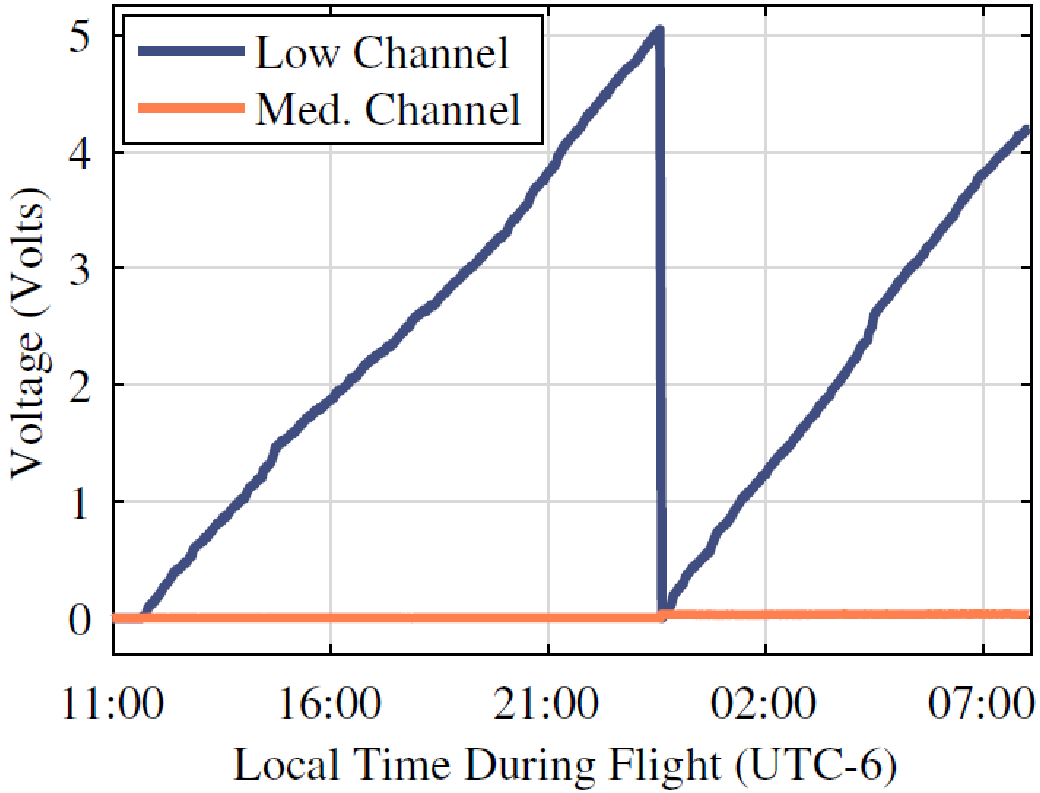
Not shown: 5 cm piece of L200 minicell polyethylene to attenuate secondary electrons generated in the air gap



Zoomed TID Laboratory Measurements (Low and Med. channels)

Flight Measurements

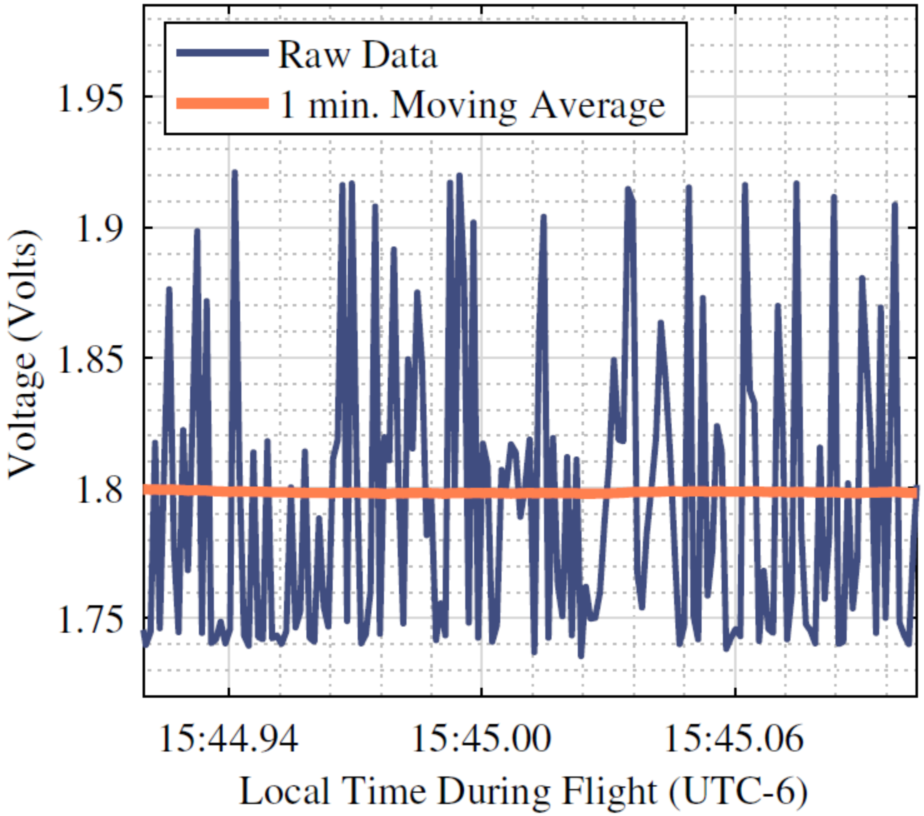
TID flight data showing the Low and Medium channels
Average dose rate of roughly 3.15 µGy/hr for the entire mission



TID measurements from flight
(Low and Med. channels)

Flight Measurements

Flight data showed significant noise injected by a different instrument (~150 mV peak-to-peak)



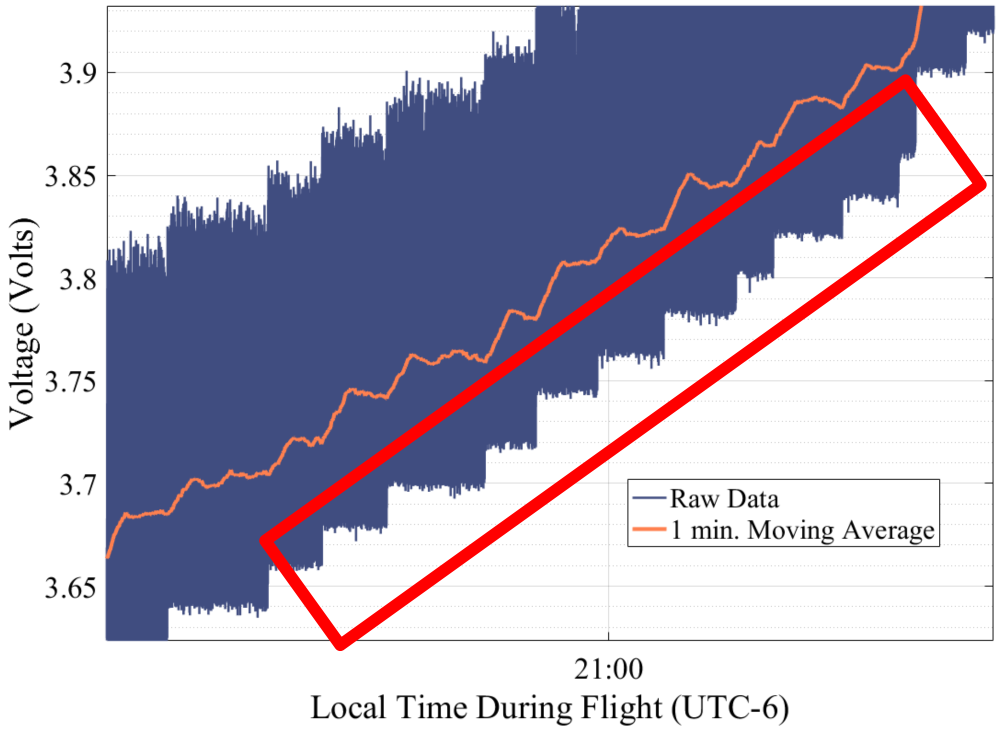
TID measurements from flight (Low channel zoomed in)

Noise Source

- Upstream DC-DC converter used for a different instrument
- Noise identified during EMI/EMC test
    - Project decided to accept the risk without modification

Flight Measurements

TID output steps are still clearly visible in the noisy data

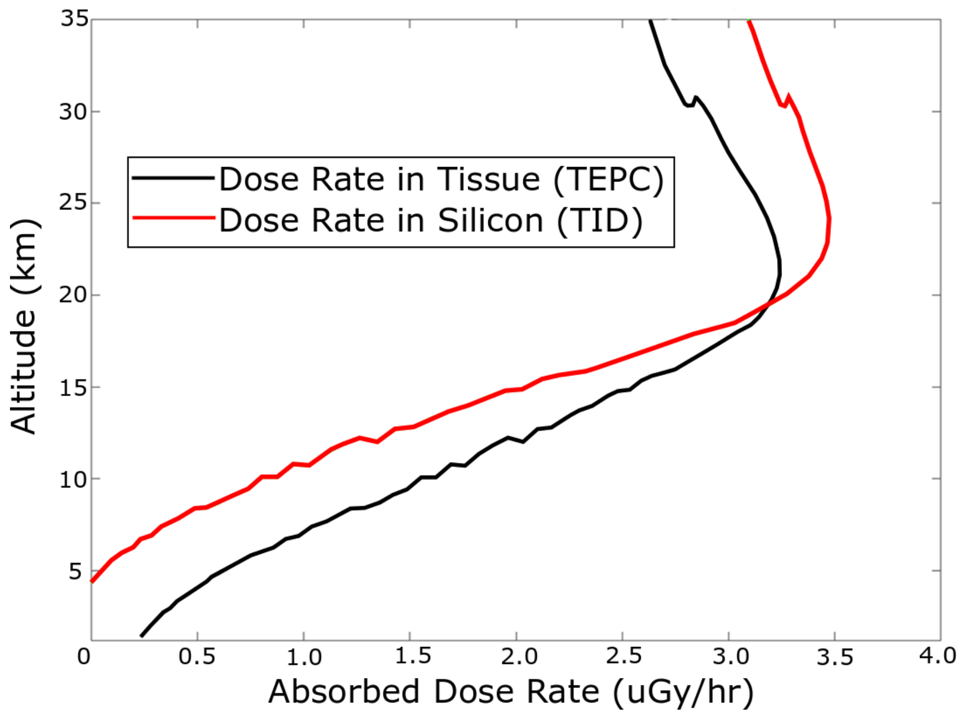


TID measurements from flight (Low channel)

Post-Processing

- Convert voltage to dose (μGy)
- 5-min average for each data sample
- Convert to instantaneous dose rate (μGy/hr)

Comparison of TID to TEPC



Flight-averaged TID measurements show good agreement to the TEPC measurements

Barometric Altitude (km)	TEPC Reference Dosimeter Dose Rate (uGy/hr)	TID Dose Rate (uGY/hr)
24.6	3.05 ± 0.48	3.52 ± 0.70
36.6	2.58± 0.41	2.55 ± 0.51

Figure and table from [Mertens, et al., 2016]

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1. Background & Motivation
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3. Measurement Data
4. Conclusions & Future Work

Conclusions

Silicon Dosimeters for Quantifying Biologically Harmful Radiation

- TID measurements are consistent with well-validated and verified dosimeter (TEPC)
- Accurate empirical calibration between the TID's measured absorbed dose in silicon and effective dose are needed

Conclusions

NAIRAS Findings

- Model was missing pion-initiated electromagnetic cascade processes
- Preliminary results with updated transport algorithm show significant improvement
  - More extensive validation is needed

Future Work

- Additional high-altitude balloon flights with the RaD-X payload
- Revised power distribution layout

Image Credit: NASA LaRC

Questions

Contact Information:

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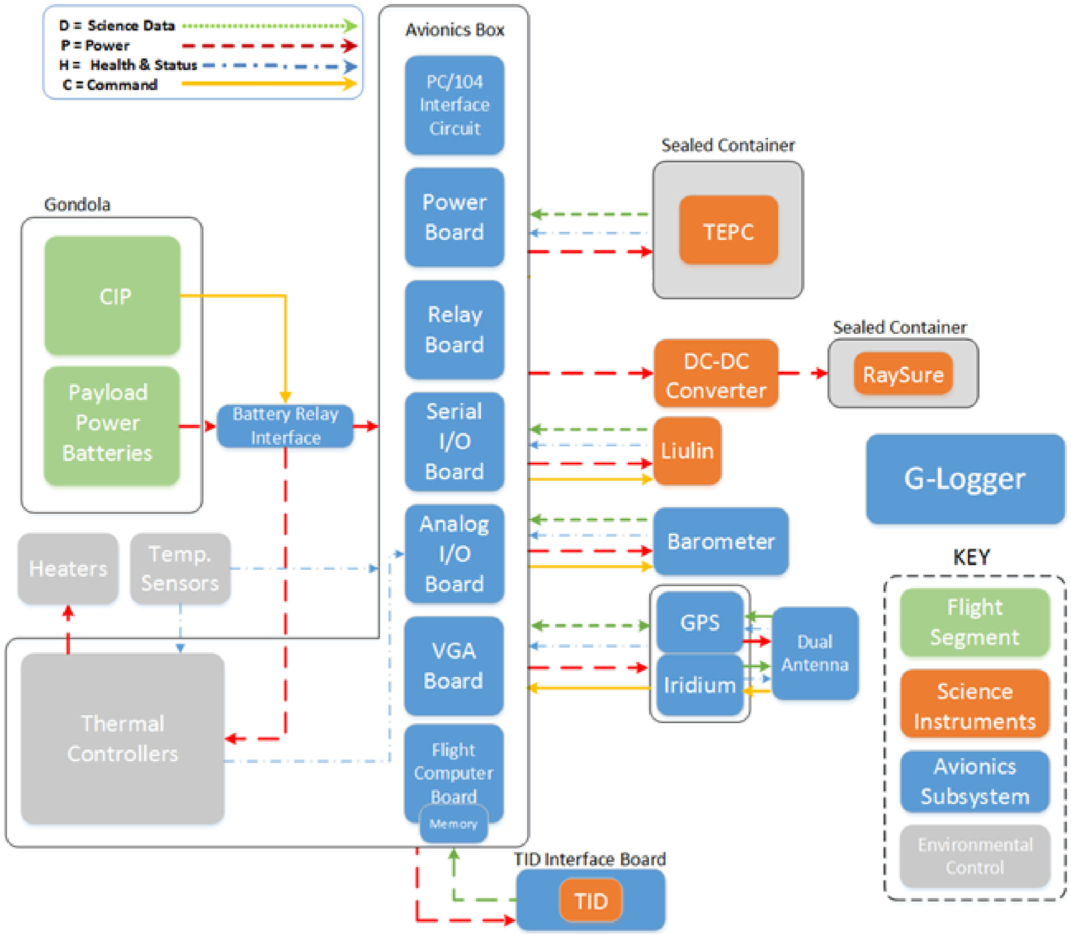
Image Credit: NASA LaRC

Calibration Measurements

- Four instruments were characterized at LLNL
  - Cobalt-60 gamma ray source (NIST-traceable)
  - Californium-252 fission radiation neutron and gamma ray source (NIST-traceable)
- Provided a functional test for the TID sensor
  - Did not simulate RaD-X radiation environment
- More information: [Straume et al., 2016]

Payload Avionics



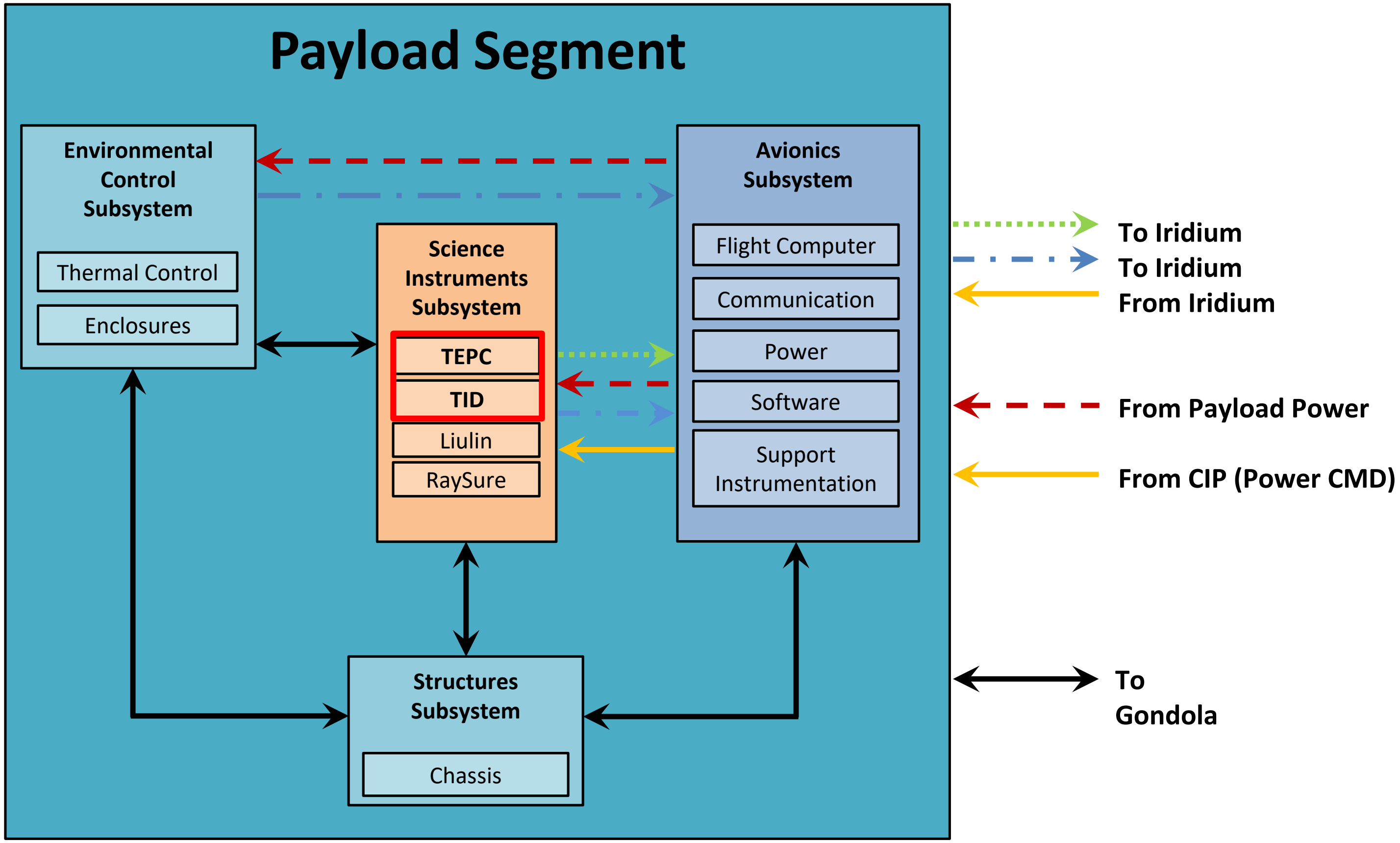
All avionics are COTS with exception of PC/104 Interface Circuit, TID Interface Circuit, and most cables

- Flowed down interfaces and requirements to the subsystem level
- Analyzed power and data interfaces to ensure correct part selection
- Collaborated with other subsystem leads to ensure payload level requirements were met

Payload Overview

M = Mechanical	
D = Science Data	
P = Power	
H = Health & Status	
C = Command	

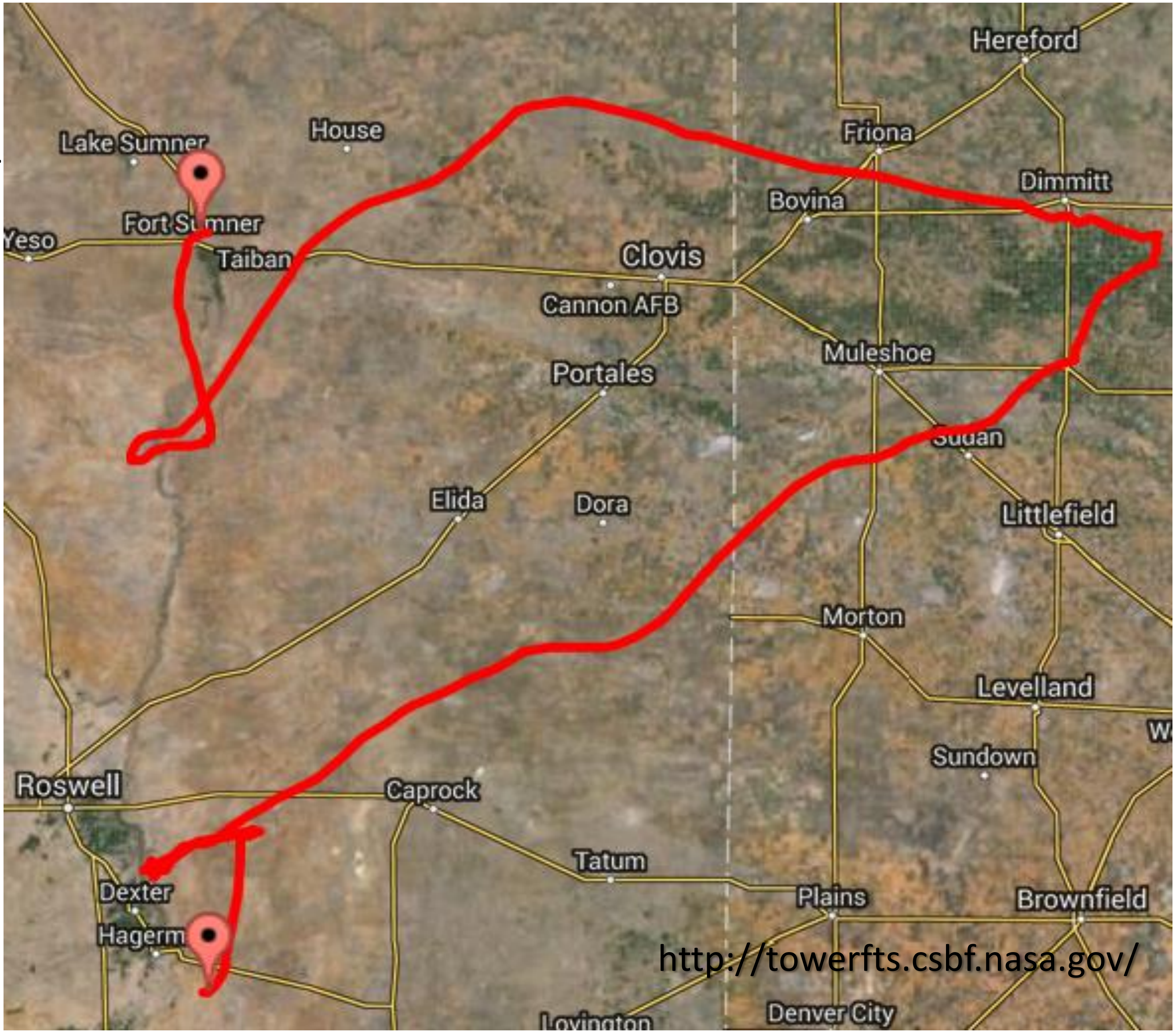
All avionics are COTS with exception of PC/104 Interface Circuit, TID Interface Circuit, and cables



RaD-X Flight Track

Launch
1:15 PM EDT

Ascent to
Region B



RaD-X Team

Photo Credit: C. Giersch NASA EDGE