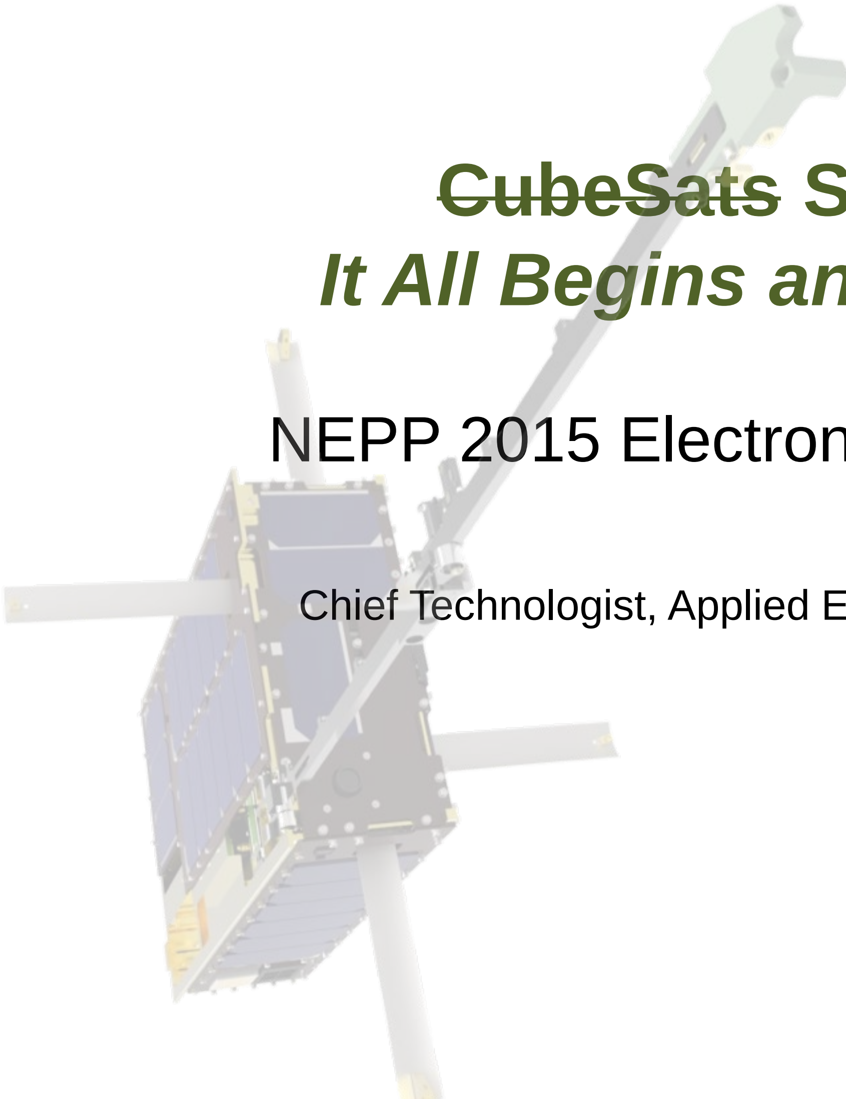


~~CubeSats~~ SmallSats at Goddard
It All Begins and Ends with Science

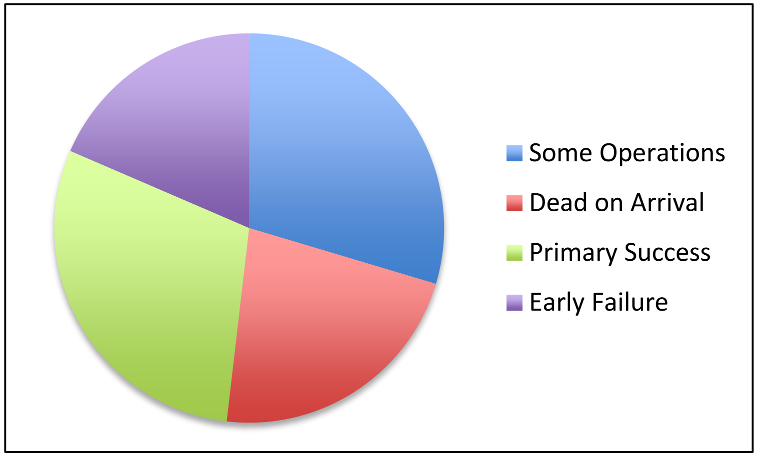
NEPP 2015 Electronics Technology Workshop

Michael Johnson
Chief Technologist, Applied Engineering and Technology Directorate
NASA/ Goddard Spaceflight Center

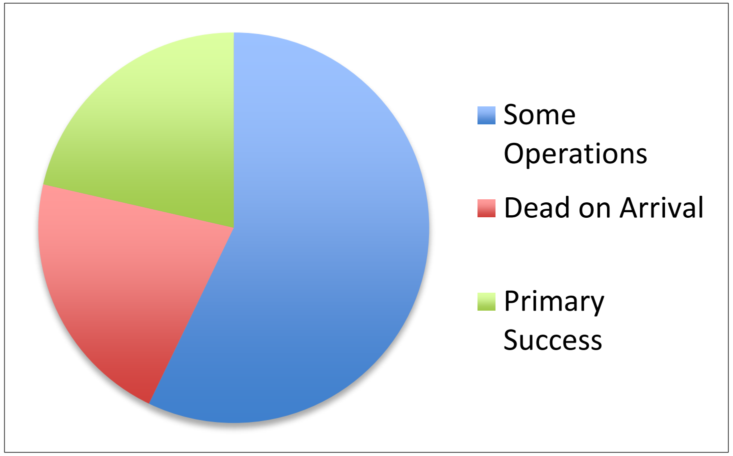
24 June 2015

The historical CubeSat mission success is less than 50%

- Whether this is good or bad depends…



University Mission Status for Spacecraft Reaching Orbit - Second Mission – (2000-2014). Ref. M. Swartwout



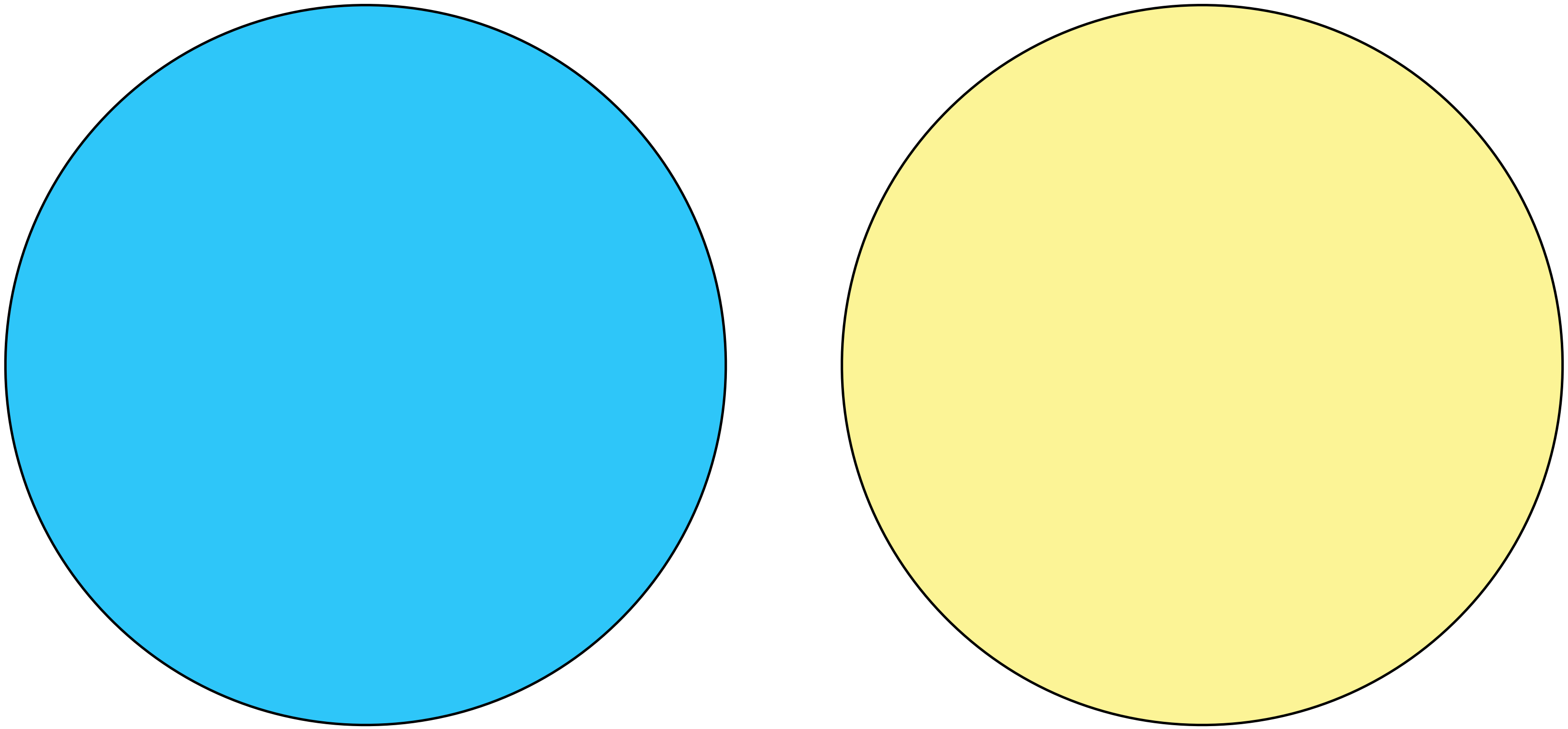
Industry Mission Status for Spacecraft Reaching Orbit - Second Mission - (2000-2014). Ref. M. Swartwout

As one might expect, the *First Mission Success* rate is worse.

Ref: M. Swartwout, CubeSat Database, https://sites.google.com/a/slu.edu/swartwout/home/cubesat-database#plots

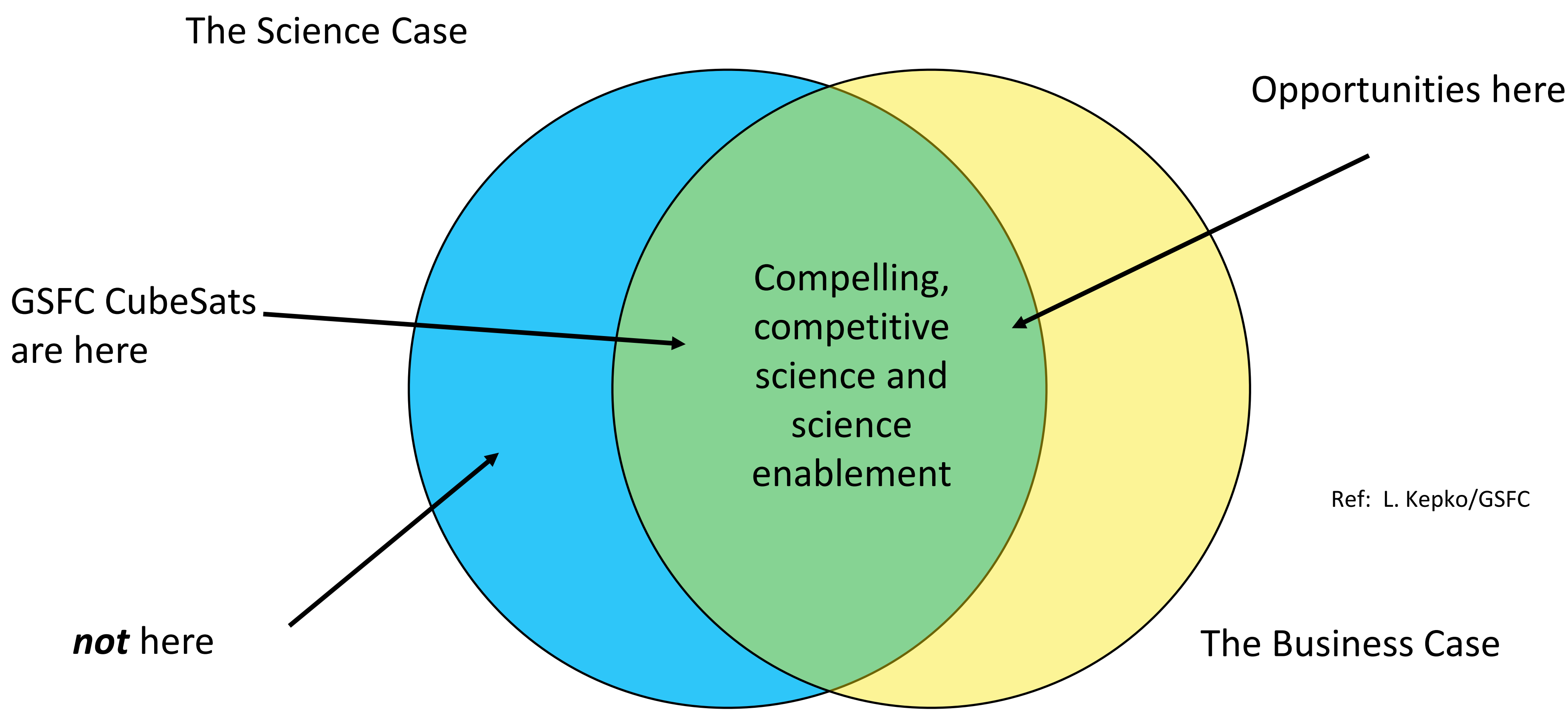
It depends on your model…

The Science Case



The Business Case

Ref: L. Kepko/GSFC



Numerous factors constrain the overlap area

Small Satellite Systems Technology

Increasing capabilities of miniaturized systems is transforming spaceflight, expanding what is possible

- Growing cognizance of the "tipping point" is indicated by numerous small spacecraft capabilities solicitations

SPACENEWS

Op-ed | Launching the Small-satellite Revolution

by George Whitesides — May 11, 2015

Virgin Galactic's LauncherOne spacecraft shown in low Earth orbit after payload separation. Credit: Virgin Galactic

Smaller and cheaper satellites are important for national security, for the space industry and for our planet. They also happen to be great investments.

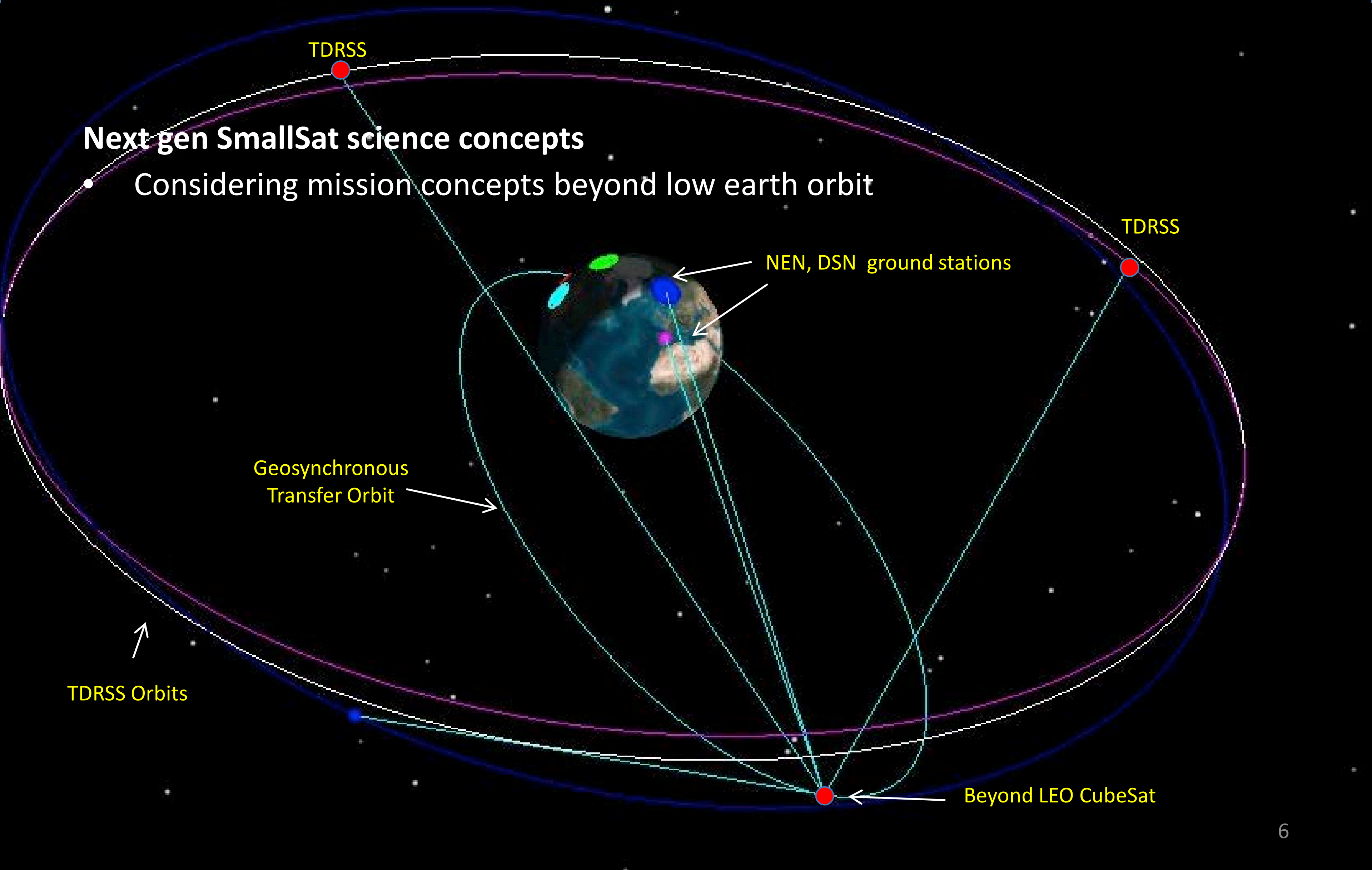
Innovators in industry, academia and government have already proved that small satellites can be built quickly and affordably while still being capable of doing significant things. Such satellites are now in space sending back high-definition video, providing important climate data, helping to track the world's maritime shipping assets, expanding our knowledge of the universe and helping test advanced technologies that will someday be used in the biggest satellites.

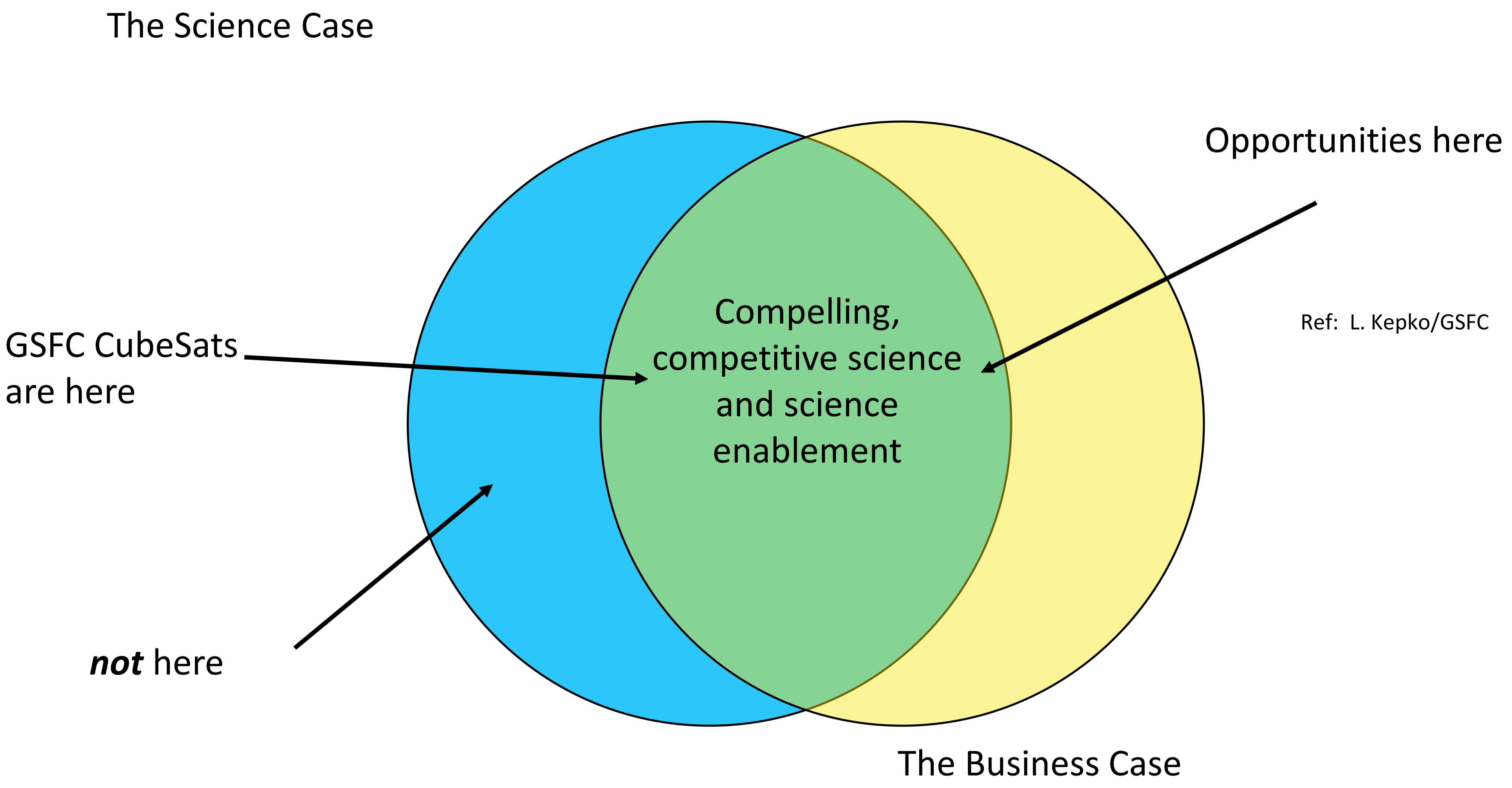
Advancing technology will enable novel SmallSat science mission concepts and inform future larger mission concepts

Next Steps- Beyond Low Earth Orbit (LEO)

Next gen SmallSat science concepts

- Considering mission concepts beyond low earth orbit





Expanding the overlap requires robust, highly capable systems

Applied Engineering and Technology Directorate Directions

- Science-engineering collaboration- a Goddard strength- is key to imagining novel science mission concepts based on small satellites.
- Advance miniaturized technologies and capabilities- to enable novel SmallSat science mission concepts and inform future larger mission concepts.
- Implement systems and processes to increase systems robustness- while minimally impacting cost.
- Leverage 50 years of engineering acumen and lessons learned to increase the small satellite mission success rate.
- Avoid the “not invented here” mindset.
- Identify and close capability gaps.
- **Learn by doing- the Dellingr Project**

Build, buy, and partner

A Path to Compelling Science: Dellingr- Goddard 6U CubeSat Project

Learn by Doing

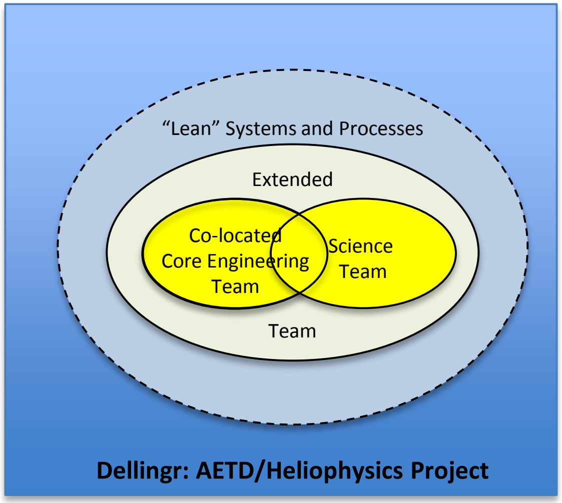
Questions:

- Are CubeSats ready for compelling, formidable science?
- What are the issues associated with building them in "heritage" institutions?
- Can we improve reliability while minimally impacting cost?

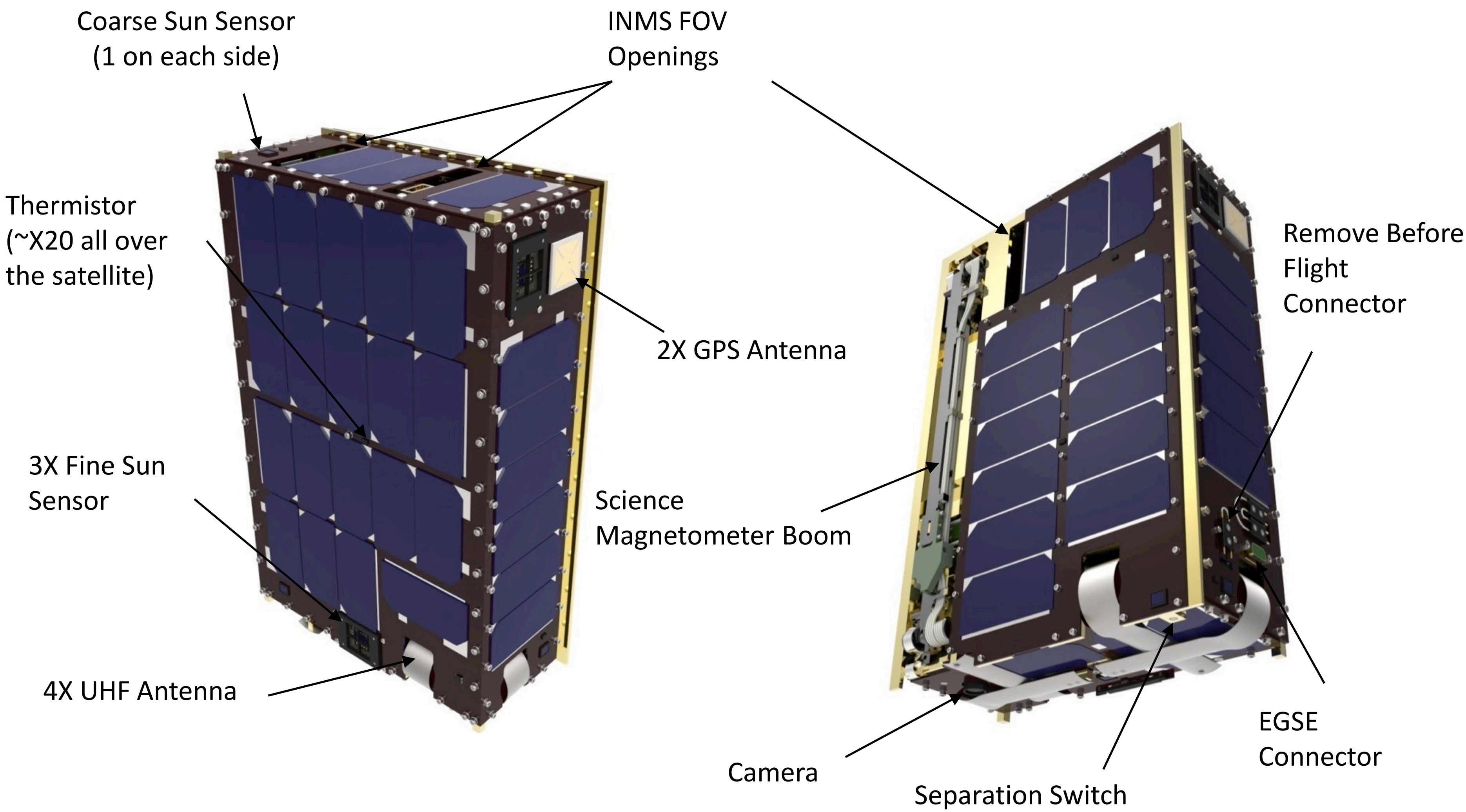
Challenge: Develop a flight-ready 3-instrument 6U Heliophysics CubeSat in 1 year with ~$100K procurement funding and minimal FTEs.

Objectives

1. Deliver compelling science from three GSFC-developed flagship quality instruments
   - Compact Ion and Neutral Mass Spectrometer (INMS)
   - Magnetometers
   - Compact Relativistic Electron SSD Telescope (CREPT)
2. Develop "lean" end-to-end systems and processes for lower-cost, scalable risk systems
3. Acquire "lessons learned"



Dellingr
External Components, Stowed



Surplus Solar Cells All-Around

Dellingr
Internal Systems

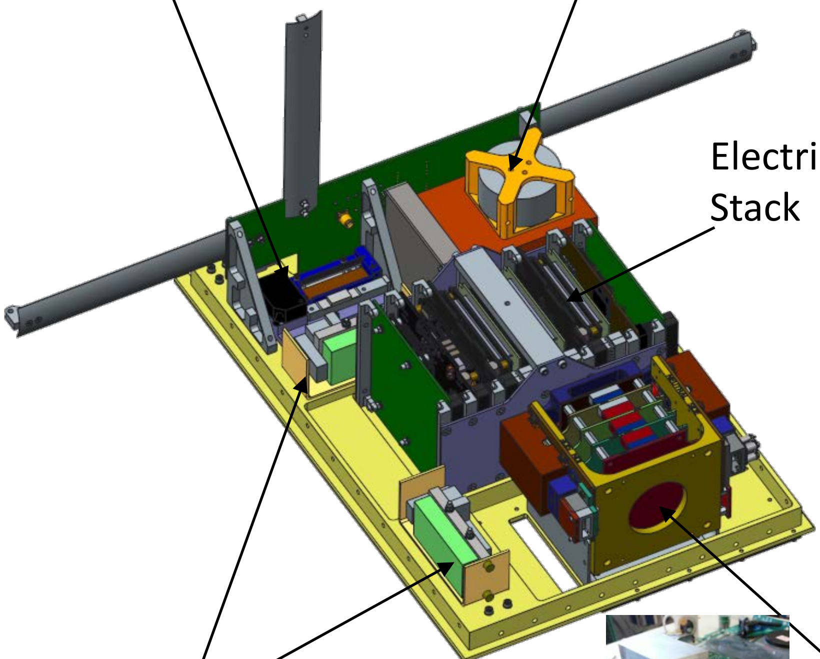
Thermal Louvers Experiment

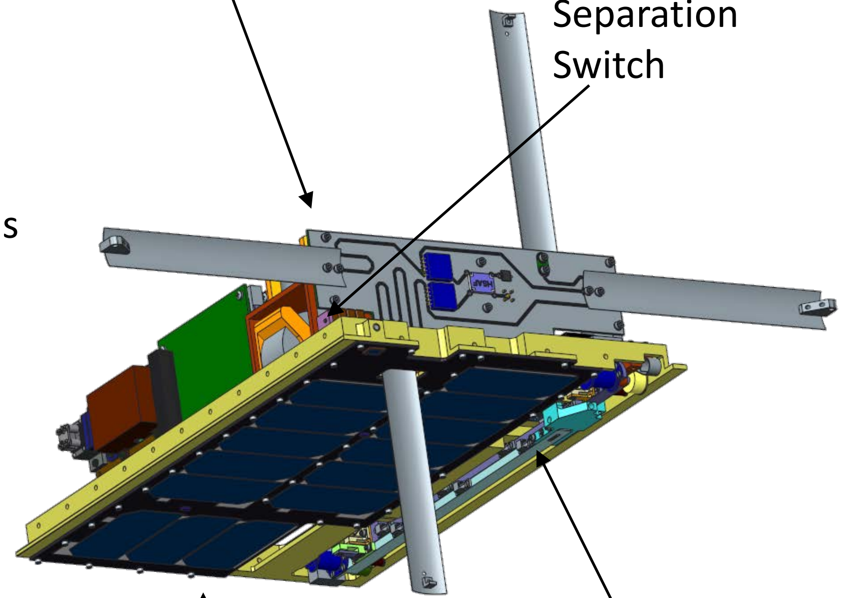
Reaction Wheels and Radio Assembly

UHF Antenna Assembly

Separation Switch

Electrical Cards Stack

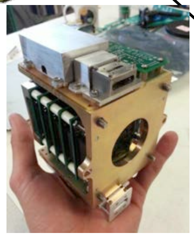




-Y Solar Panel

Science Magnetometer Boom

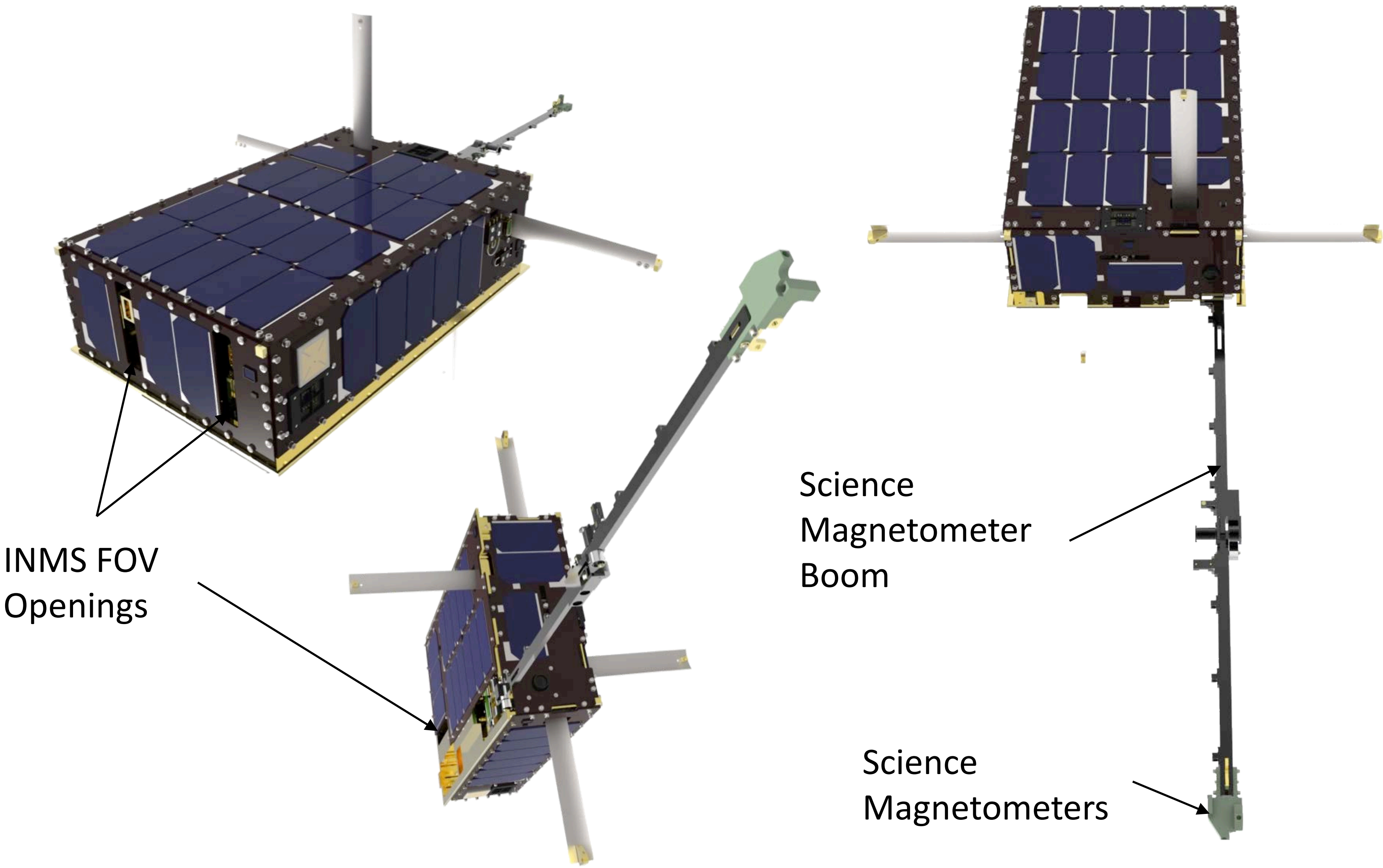
Science Magnetometers



INMS

Ion and Neutral Mass (INMS) Spectrometer- Paschalidis/GSFC

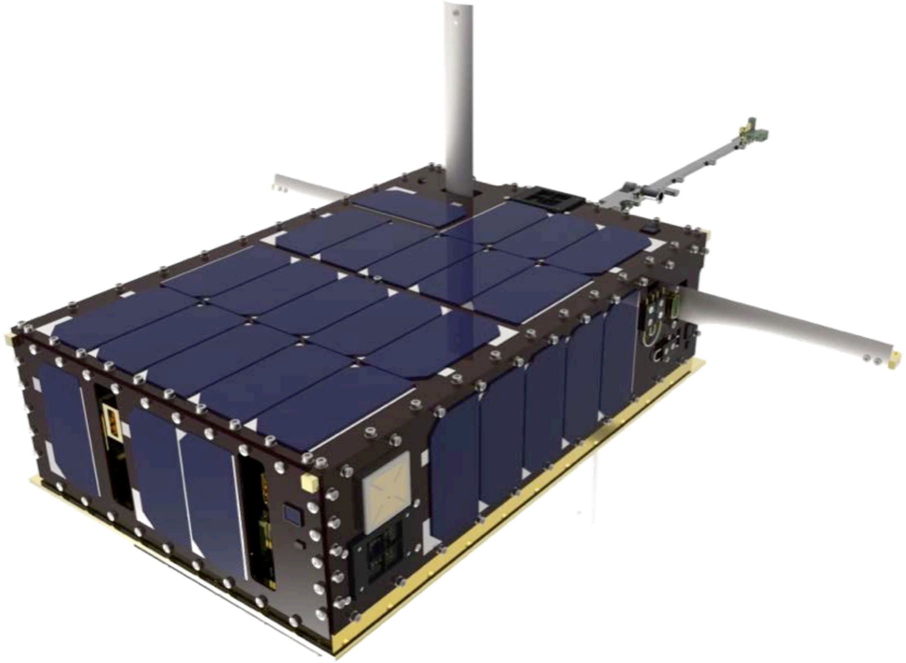
Dellingr
Science Instruments Location



Dellingr
Status

Status

- Systems integration underway
- Environment test to begin ~July/August 2015
- Flight readiness late summer 2015



CubeSat/SmallSat Part Selection Tool

Status – Based on User inputs, the tool answers:

- Notional radiation risks: What are we dealing with?
- What does a similar radiation environment look like?
- How do similar devices react to that environment?
- What can you do to bring down the risk of that reaction?

Typical radiation requirements in a word cloud

Ref: M. Campola/GSFC

CubeSat/SmallSat Part Selection Tool

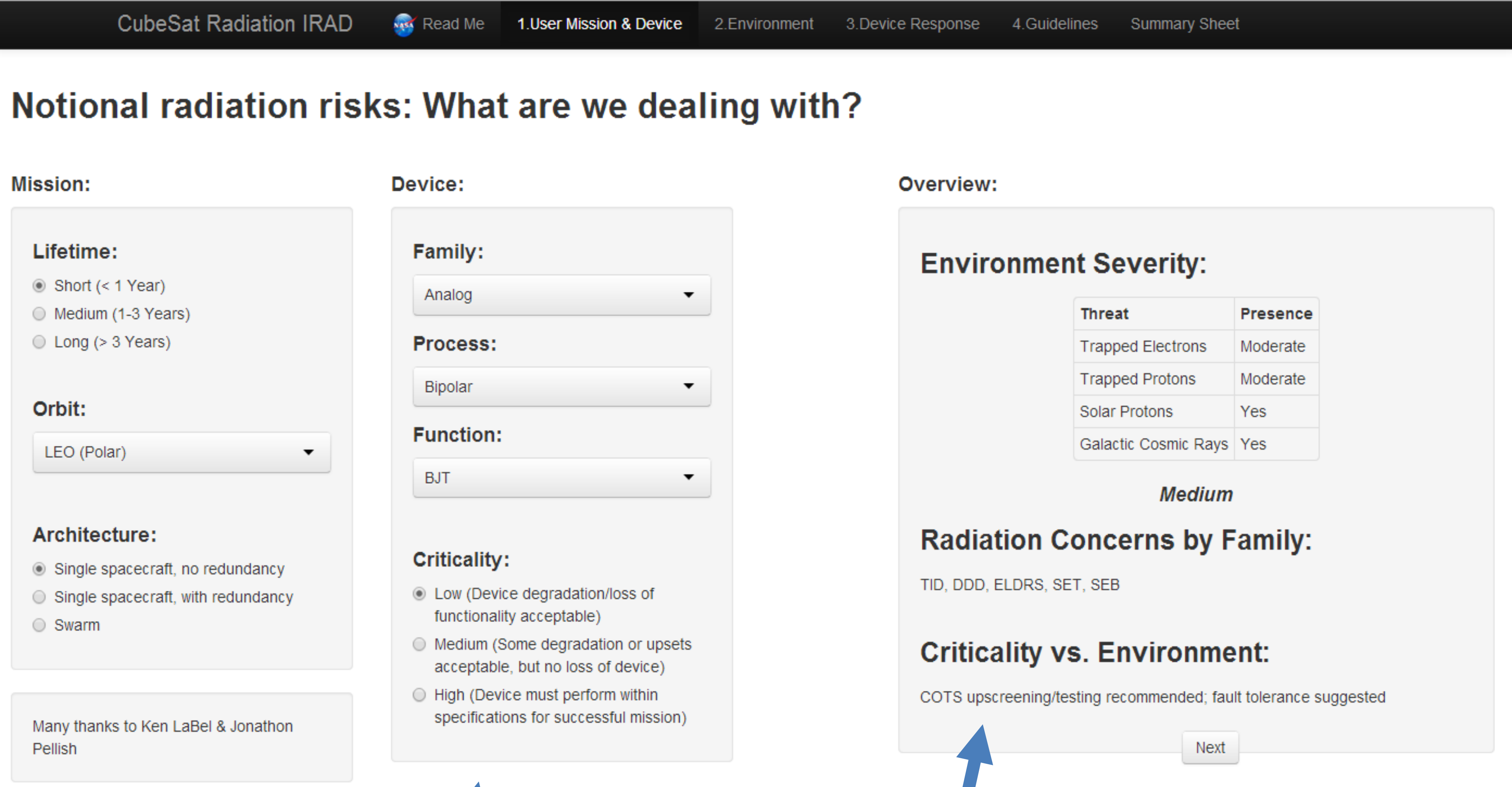
Why is this tool necessary?

- **Address** the realm of higher reliability small spacecraft
- **Reduce driving risks** for low cost based on best design practices
- **Understand trades** early on in design phase rather making fixes later
- **Communication** between engineers and science, common language of radiation concerns

Plans forward

- Improve statistical relations on similar parts
- Build path forward rather than catalog institutional knowledge
- Present simplified output of more complex tools used by radiation engineers, and when it is **appropriate** to use the more complex tools

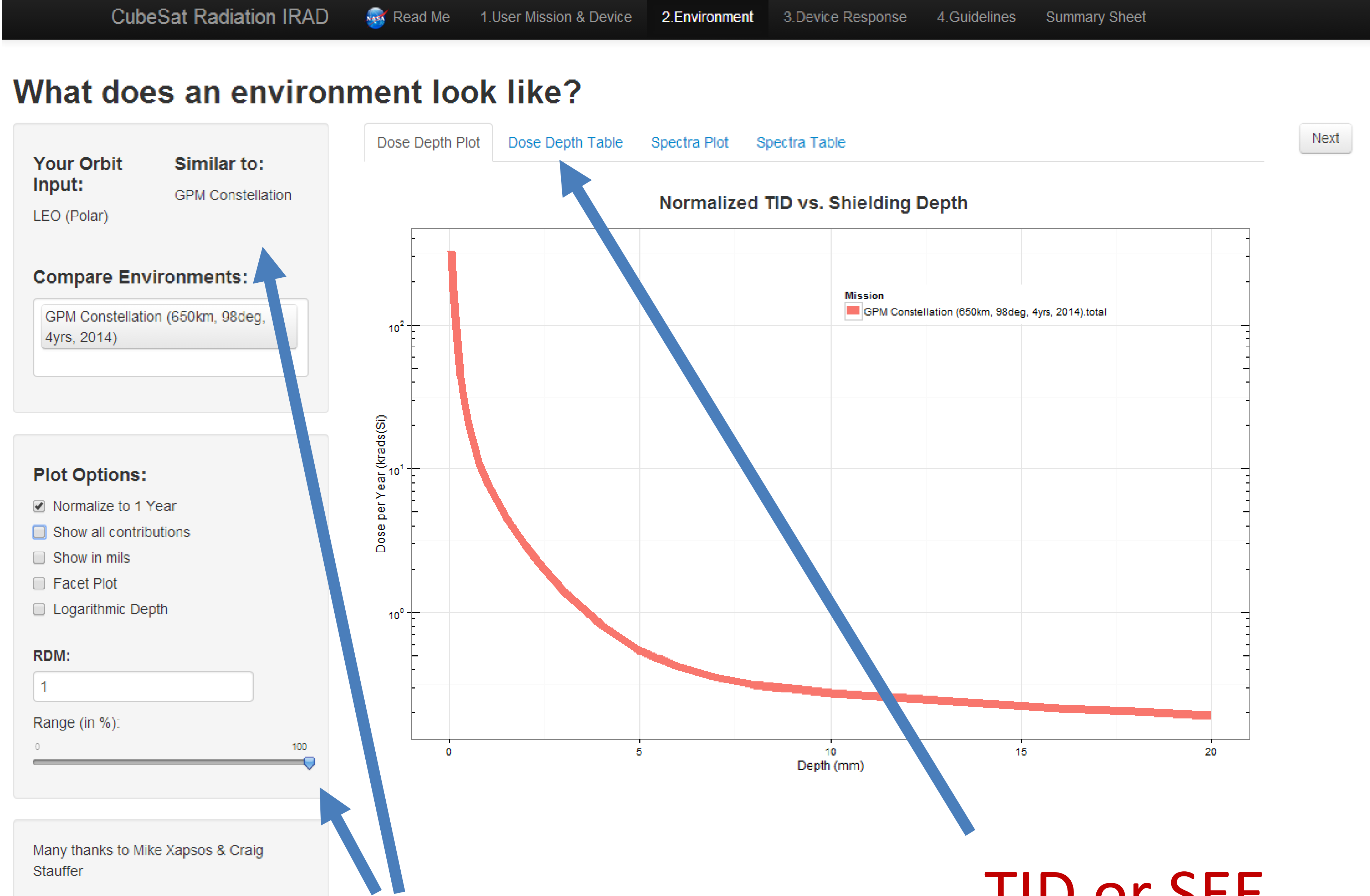
Ref: M. Campola/GSFC



User Inputs

Interactive synopsis of concerns and environment

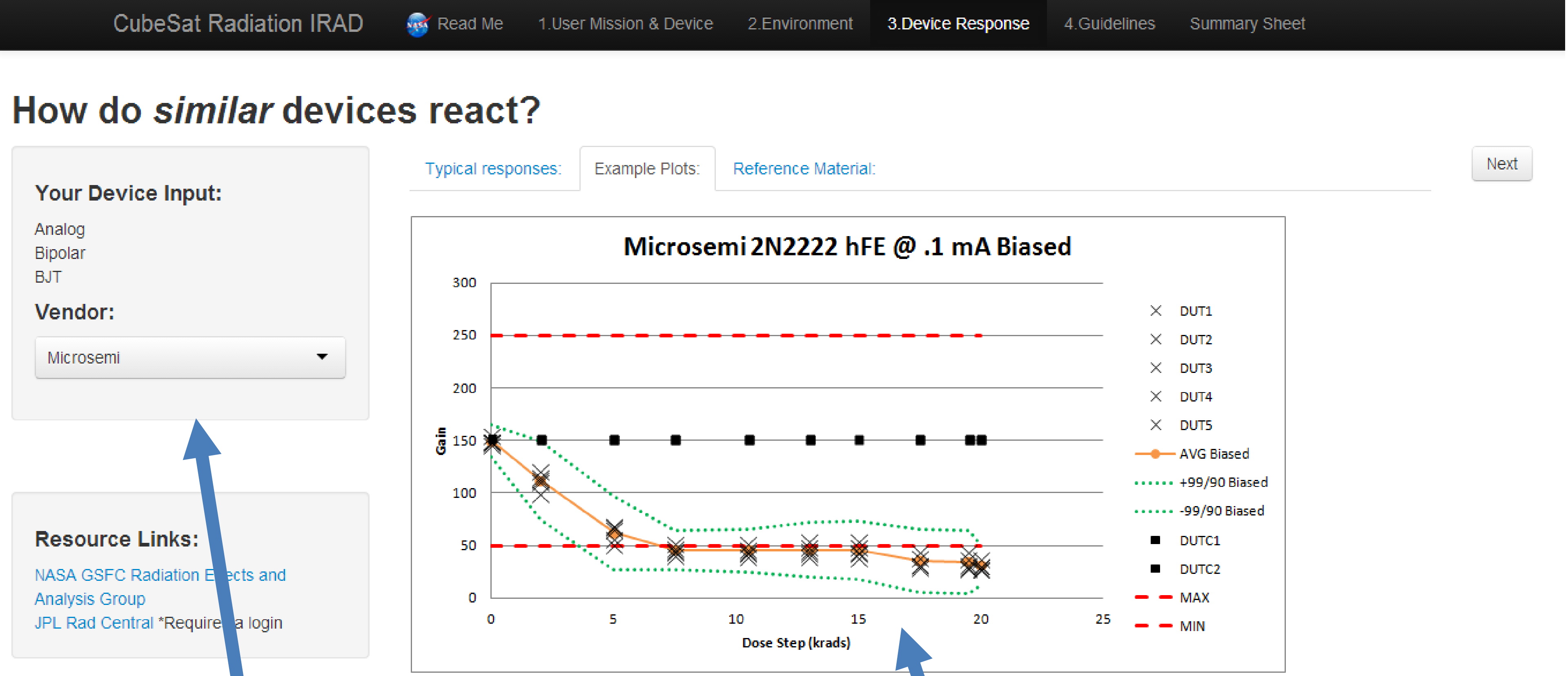
Ref: M. Campola/GSFC



Interactive Plot Parameters and Automatic Selection from Previous User Input

TID or SEE plots

Ref: M. Campola/GSFC



User Selects from available vendor data

Previous Results showing worst case responses

Ref: M. Campola/GSFC

CubeSat Radiation IRAD | Read Me | 1.User Mission & Device | 2.Environment | 3.Device Response | 4.Guidelines | Summary Sheet

What should you do to bring down the risk?

The typical line of radiation questioning for: Analog Bipolar BJT with regard to TID, DDD, ELDRS, SET, SEB

No concern for SEB unless harsh environment. No concern for transients. Can the design live with gain degradation? Displacement damage can cause bulk defects leading to gain degradation as well.

Considered for Low criticality component on a Single spacecraft, no redundancy ...

Your Part	Radiation concerns	Greatest System Rad Concern	As-is Risk	Post Recommendation Risk
#	TID, DDD, ELDRS, SET, SEB	Degradation & Single Event	Low	Low

Save to Summary Sheet

Recommendation and Guidelines:

No concern for SEE.

Class:

C

Class Guidelines:

Whenever possible, components shall be radiation-hardened with guarantees for TID, DDD, and SEE performance designed to meet mission requirements for the specified orbit/trajectory. All required radiation testing (TID, DDD, and/or SEE) shall be on the flight lot and conducted at the part level. In some cases, qualification can be conducted via similarity or architecture. The PM/DPM-T can consider waivers for radiation requirements at the part level. Fault-tolerant designs recommended for COTS parts. Impacts include cost, schedule, and moderate technical risk acceptance.

Interactive guidance on design based on class

Parts Control Board line of questioning

Line Item Risk Assignment with and without mitigation

Build Parts list out of Line Items

Ref: M. Campola/GSFC

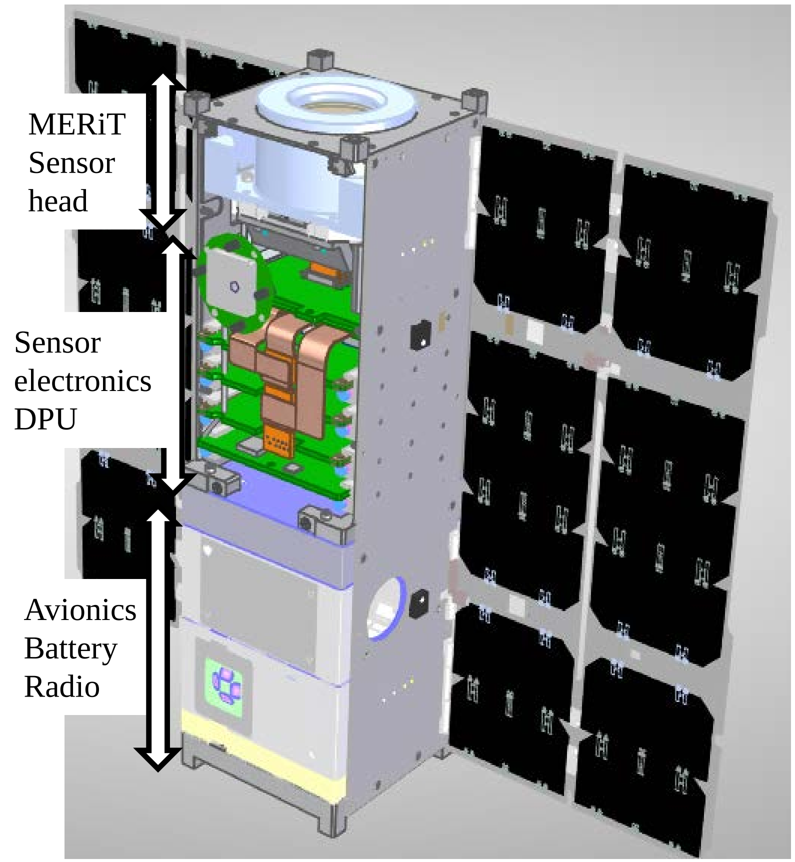
Other CubeSat development activities

- CeREs: A Compact Radiation Belt Explorer
- IceCube: Spaceflight Validation of an 883-GHz Submillimeter Wave Radiometer for Cloud Ice Observations
- Cubesat Application for Planetary Entry (CAPE) Missions

CeREs: A Compact Radiation Belt Explorer
PI Shri Kanekal, GSFC

Mission

- First fully-NASA funded CubeSat
- 3U s/c with 1.5U each for payload and bus
- Expected launch November 2016
- High inclination sun-synchronous LEO
- Co-I institution - SWRI



Payload

- Miniaturized Electron Proton Telescope (MERiT)
  - Compact innovative particle sensor using solid state and avalanche photodiode detectors

    e- : ~10keV to ~10MeV ΔE=30% Δt=5ms

    p : ~200keV to ~100MeV ΔE=30% Δt=1mn

Science

- Radiation belt electron dynamics (primary)
  - Are microbursts capable of emptying rad. Belts?
- Solar electron energization and transport (secondary)
  - How & where are supra-thermal electrons energized ?
- Solar proton access to Geospace (space weather)
  - How strong are space weather effects of SEP proton during geomagnetic storms?

Ref: S. Kanekal/GSFC

IceCube: Spaceflight Validation of an 883-GHz Submillimeter Wave Radiometer for Cloud Ice Observations

D. L. Wu, J. Esper, N. Ehsan, T. E. Johnson, W. R. Mast, J. R. Piepmeier and P. E. Racette

NASA Goddard Space Flight Center, Greenbelt, Maryland

Objective

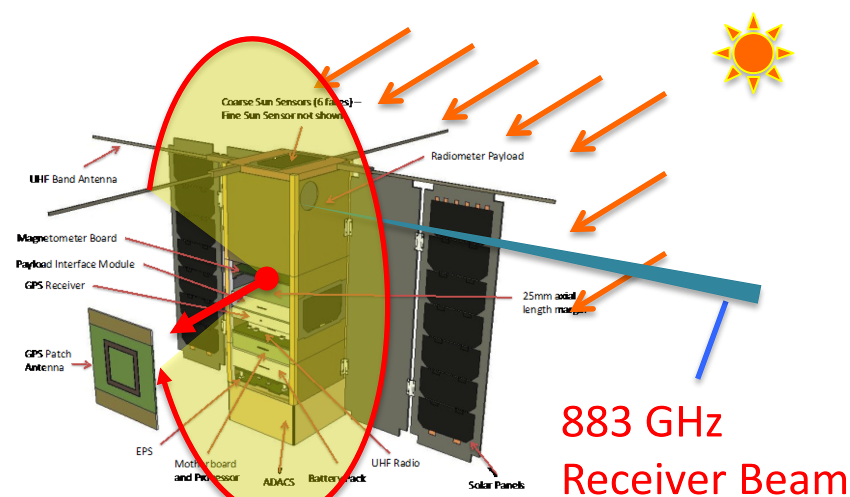
- Develop and validate a commercially available flight-qualified 883-GHz receiver to enable future cloud ice remote sensing from space

Technologies

- Submillimeter wave 883-GHz receiver with accuracy < 2 K and precision <0.2 K
- Intermediate frequency (IF) calibration (noise injection)

Approach

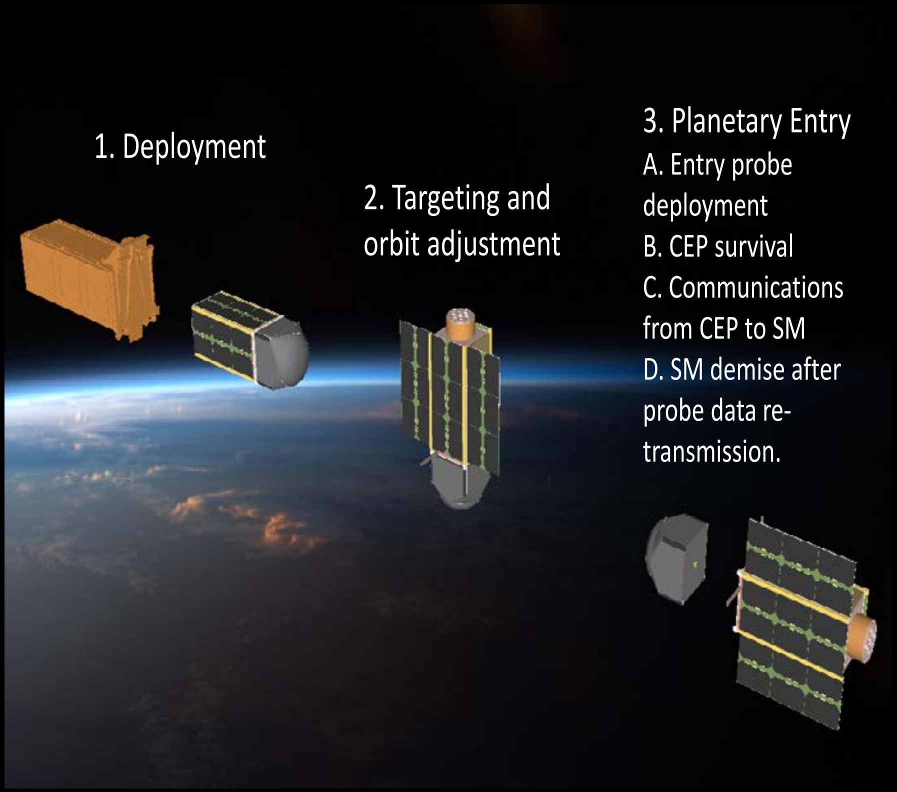
- GSFC/Greenbelt design and I&T of 874-GHz VDI receiver
- GSFC/WFF design and I&T of 3U COTS-component CubeSat
- Launch to and release from ISS for 28+ days science operation
- Spinning CubeSat around the sun vector for periodic 883-GHz radiometer calibration



Ref: D. Wu/GSFC

Cubesat Application for Planetary Entry (CAPE) Missions

- Concept is based on the Cubesat design specification.
- Within a science operational context, CAPE probes may be sent from Earth to study a celestial body's atmosphere, or to "land" on some high-value target on its surface.
- Either one or multiple probes may be targeted to distributed locations throughout the geographic landscape and could be released systematically and methodically from an orbiting spacecraft.
- CAPE consists of two main functional components: the "Service Module" (SM), and "CAPE's Entry Probe" (CEP).
- The Micro-Return Capsule (MIRCA) is CAPE's first prototype entry vehicle.



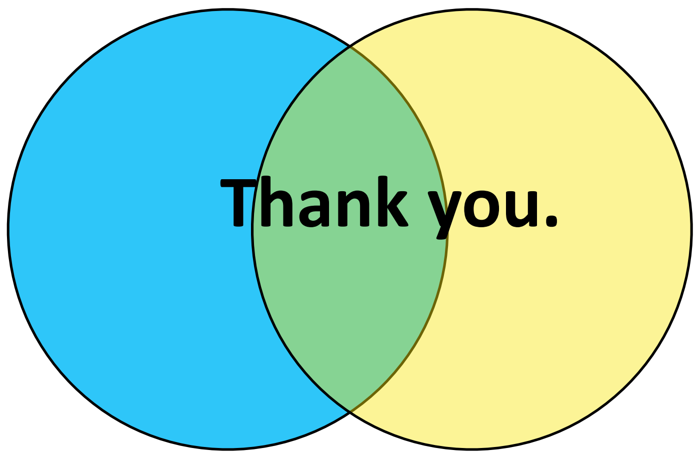
CAPE Operations Concept

Ref: J Esper/GSFC

In Closing

- It all begins and ends with science. But there is a lot of engineering in the middle.
- Increasing capabilities and systems robustness will expand what's possible
- Learn by doing
- Share knowledge

It's an exciting time!



Michael.A.Johnson@nasa.gov