Interplanetary CubeSat Architecture and Missions

LunarCubes #2 (2013)

2013 April 11

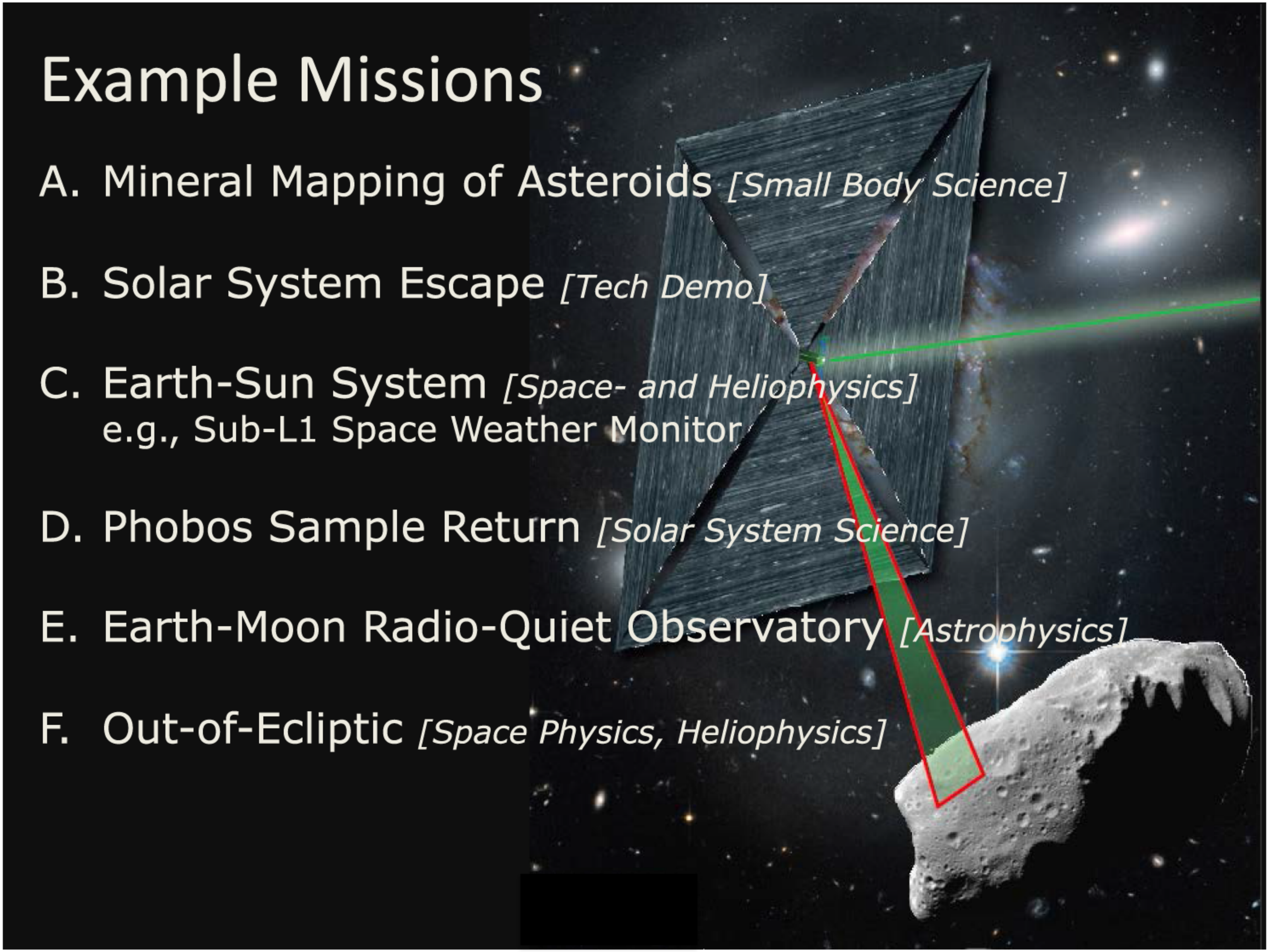
Joseph Lazio, Robert L. Staehle, Andrew Klesh, Andrew Romero-Wolf, Diana Blaney, Hamid Hemmati, Dayton Jones, Paulett Liewer, Martin Wen-Yu Lo, Pantazis Mouroulis, Neil Murphy, Paula J. Pingree, Thor Wilson, Chen-Wan Yen
Jet Propulsion Laboratory, California Institute of Technology

Jordi Puig-Suari, Austin Williams
California Polytechnic University, San Luis Obispo

Tomas Svitek
Stellar Exploration

Bruce Betts, Louis Friedman
The Planetary Society

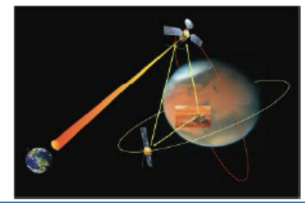
Brian Anderson, Channing Chow
University of Southern California


Example Missions
A. Mineral Mapping of Asteroids [Small Body Science]
B. Solar System Escape [Tech Demo]
C. Earth-Sun System [Space- and Heliophysics]
e.g., Sub-L1 Space Weather Monitor
D. Phobos Sample Return [Solar System Science]
E. Earth-Moon Radio-Quiet Observatory [Astrophysics]
F. Out-of-Ecliptic [Space Physics, Heliophysics]

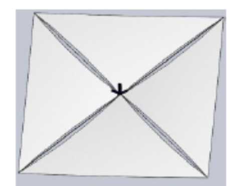
Getting to Interplanetary CubeSats

Six Technology Challenges

1. Interplanetary environment



2. Telecommunications



3. Propulsion (where needed)

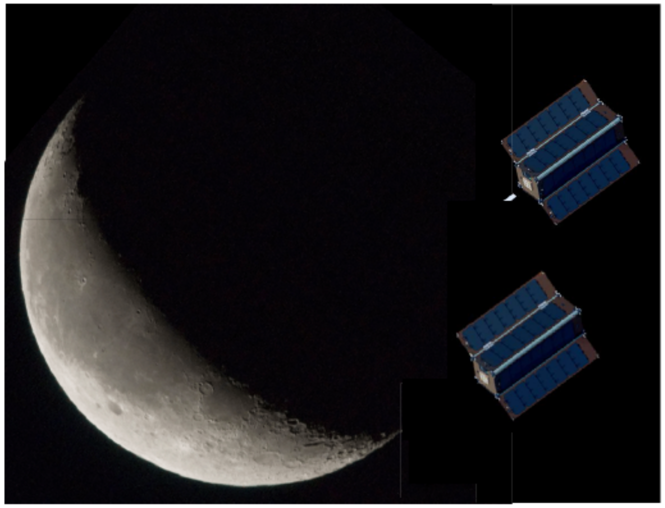
4. Navigation

5.Instruments

6. Maximizing downlink info content

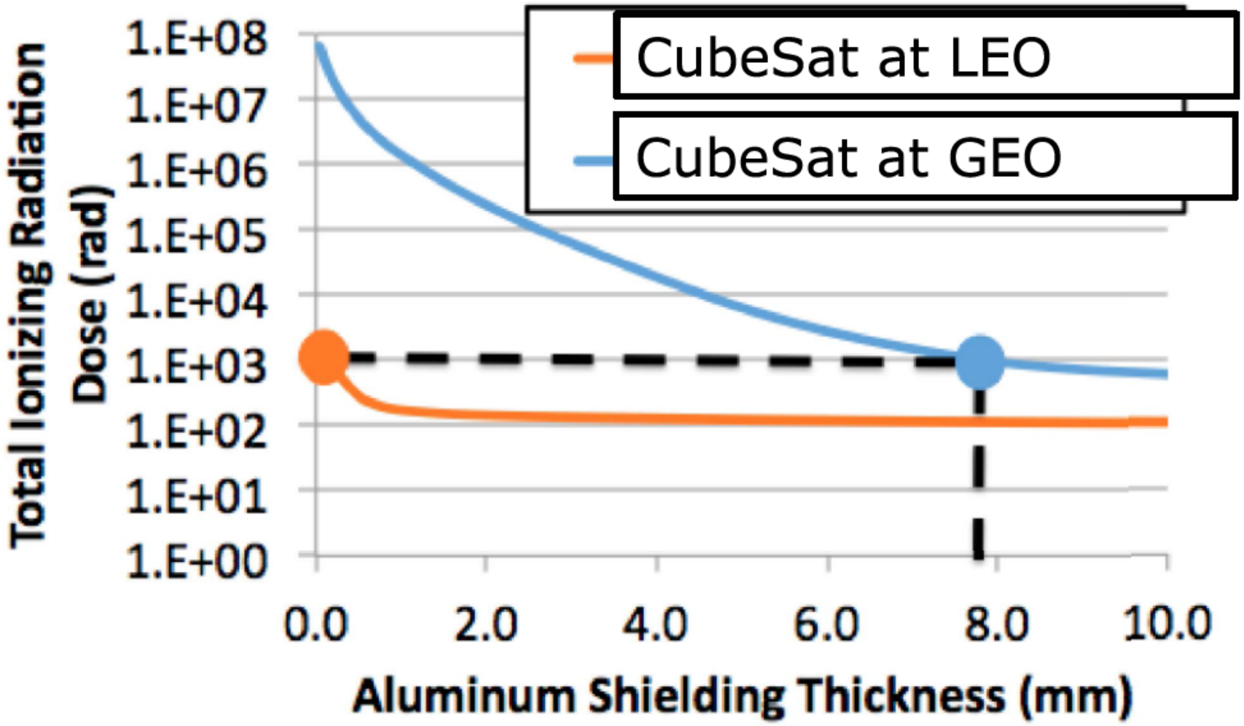
Taxonomy

- Mass <~ 10 kg
- Cost < $30 M
- Durations up to 5 years
- Target volume is 6U (10 × 20 × 30 cm
  - 2U = payload, mission specific
  - 2U = propulsion, e.g., solar sail (if needed)
  - 1U = two-way (optical) telecomm
  - 1U = spacecraft housekeeping



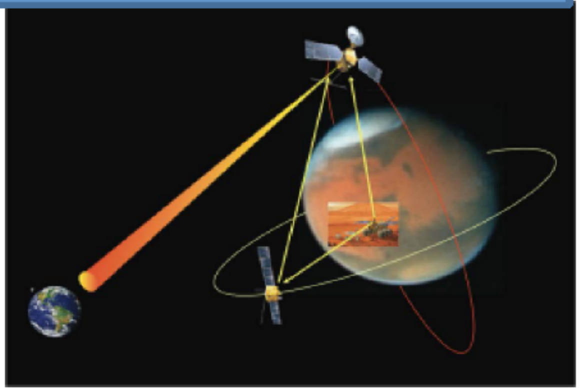
1. Interplanetary environment

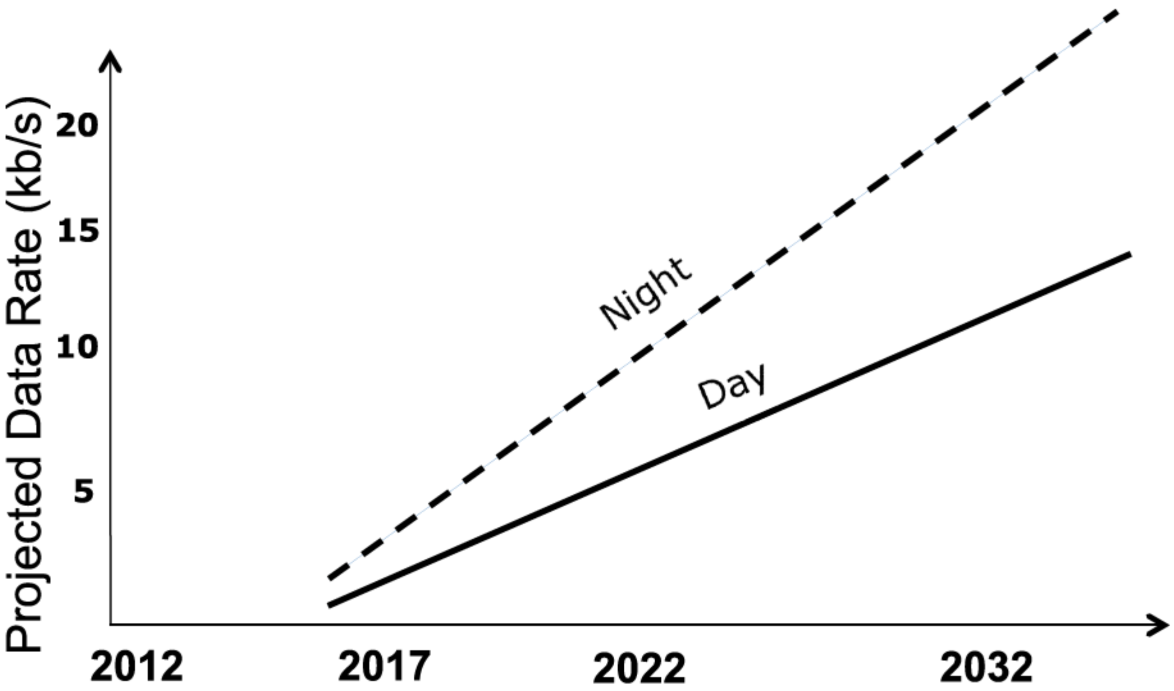
- Select based on LEO experience
- Multiple computers
- Asymmetric redundant data paths
- Watchdog timers



2. Telecommunications

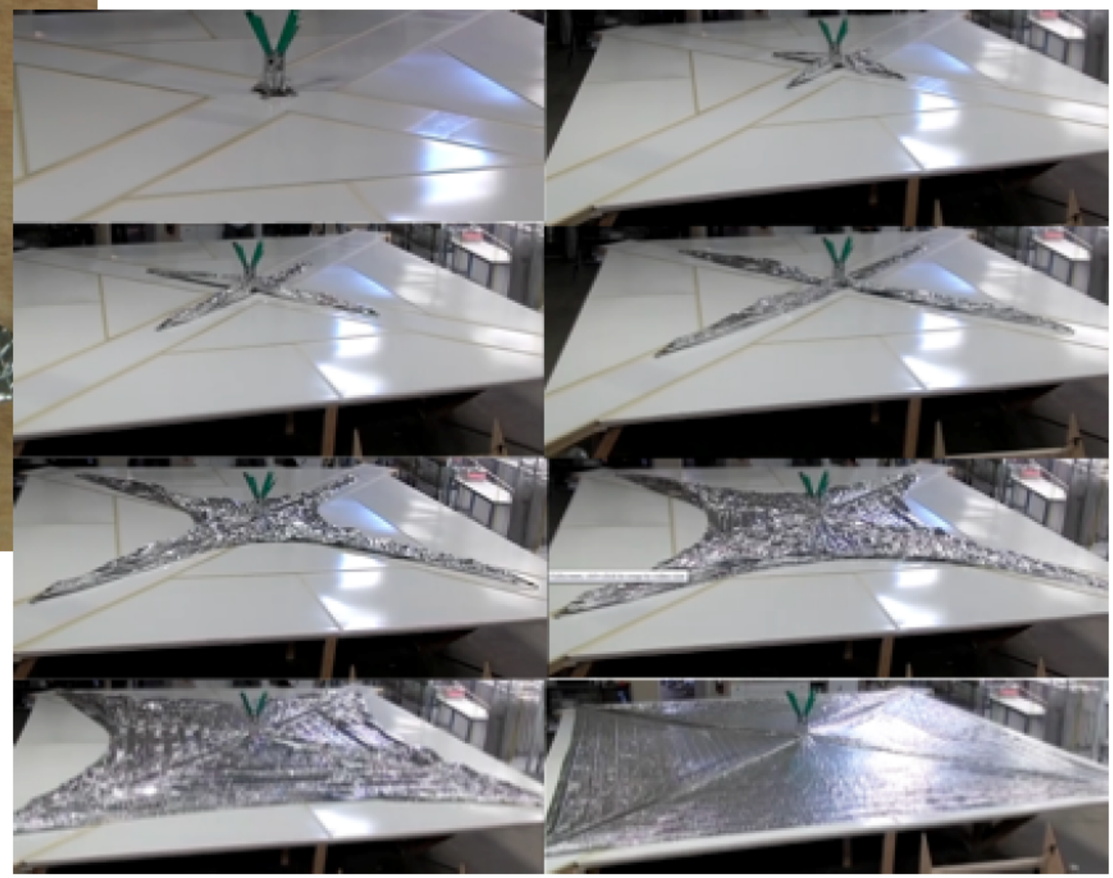
Expected Lasercomm Data Rate Improvements afforded by larger ground telescope diameters, greater laser power on CubeSat, and higher quantum efficiency ground detectors.



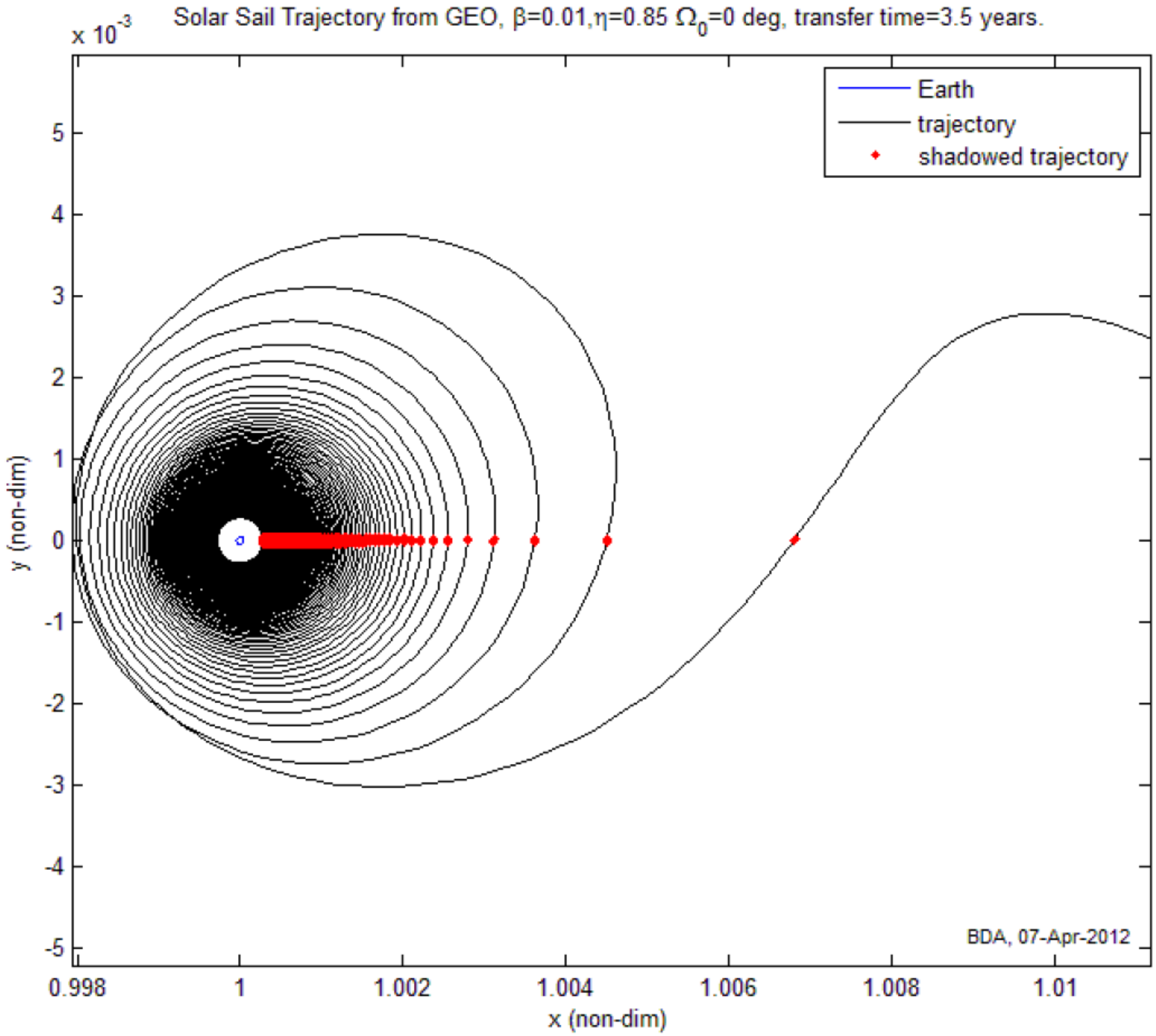


But…
RF can deliver 10 b/s out to 0.2 au using Universal Software Radio Peripheral (USRP) and 34 meter dish. Onboard HGA can yield higher rate.

3. Propulsion



Earth Escape 5.6m Solar Sail, 3.5 Yr



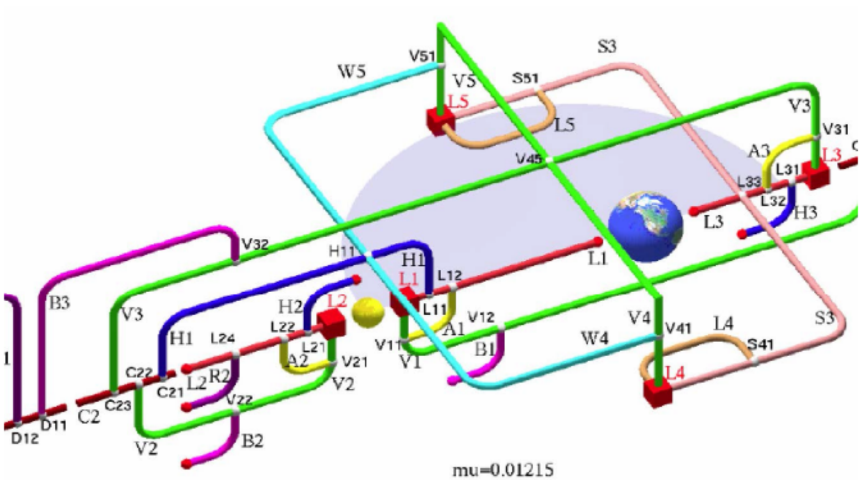
Brian Anderson (USC), Martin Lo

Interplanetary Superhighway Trajectory Technology Roadmap

4. Navigation

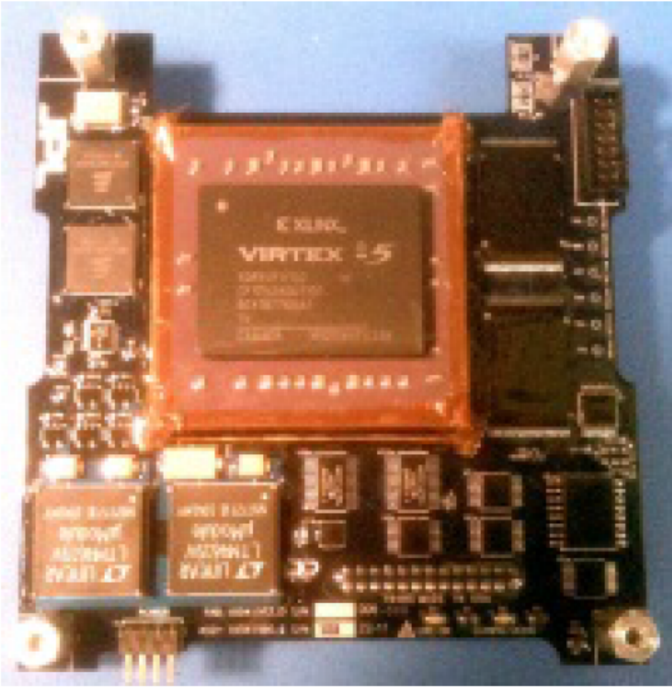
- Earth-Moon Example (Doedel et al.)

  Orbit Families Around L1, L2, L3, L4, L5



- Currently Only Halo Orbit Families Are Used

  Only around Earth-Moon L1 and L2
- Many Identified Families Yet To Be Used
- Many Other Families Yet To Be Identified & Mapped
- Families for Other Planets and Moons To Be Mapped



6. Maximizing downlink information content

CubeSat Onboard processing Validation Experiment (COVE)*

- Funded by NASA Earth Science Technology Office (ESTO)
- JPL payload aboard University of Michigan's M^3 CubeSat
- Launched 2011 Oct 28 with NPP

- Intended to demonstrate Xilinx V5QV FPGA with an algorithm to reduce output data rate from MSPI's 9 multi-angle cameras by more than 200×.

? Executed unintentional first autonomous docking with Montana State's E1P CubeSat?

- Funded for re-build/re-flight.

* Dmitriy L. Bekker, Paula J. Pingree, Thomas A. Werne, Thor O. Wilson, Brian R. Franklin, *The COVE Payload – A Reconfigurable FPGA-Based Processor for CubeSats*, USU SmallSat Conf, Logan, UT 2012 August.

INSPIRE

***I**nterplanetary **N**ano**S**pacecraft **P**athfinder **I**n a **R**elevant **E**nvironment*

Low-cost mission leadership with the world's first CubeSat beyond Earth-orbit

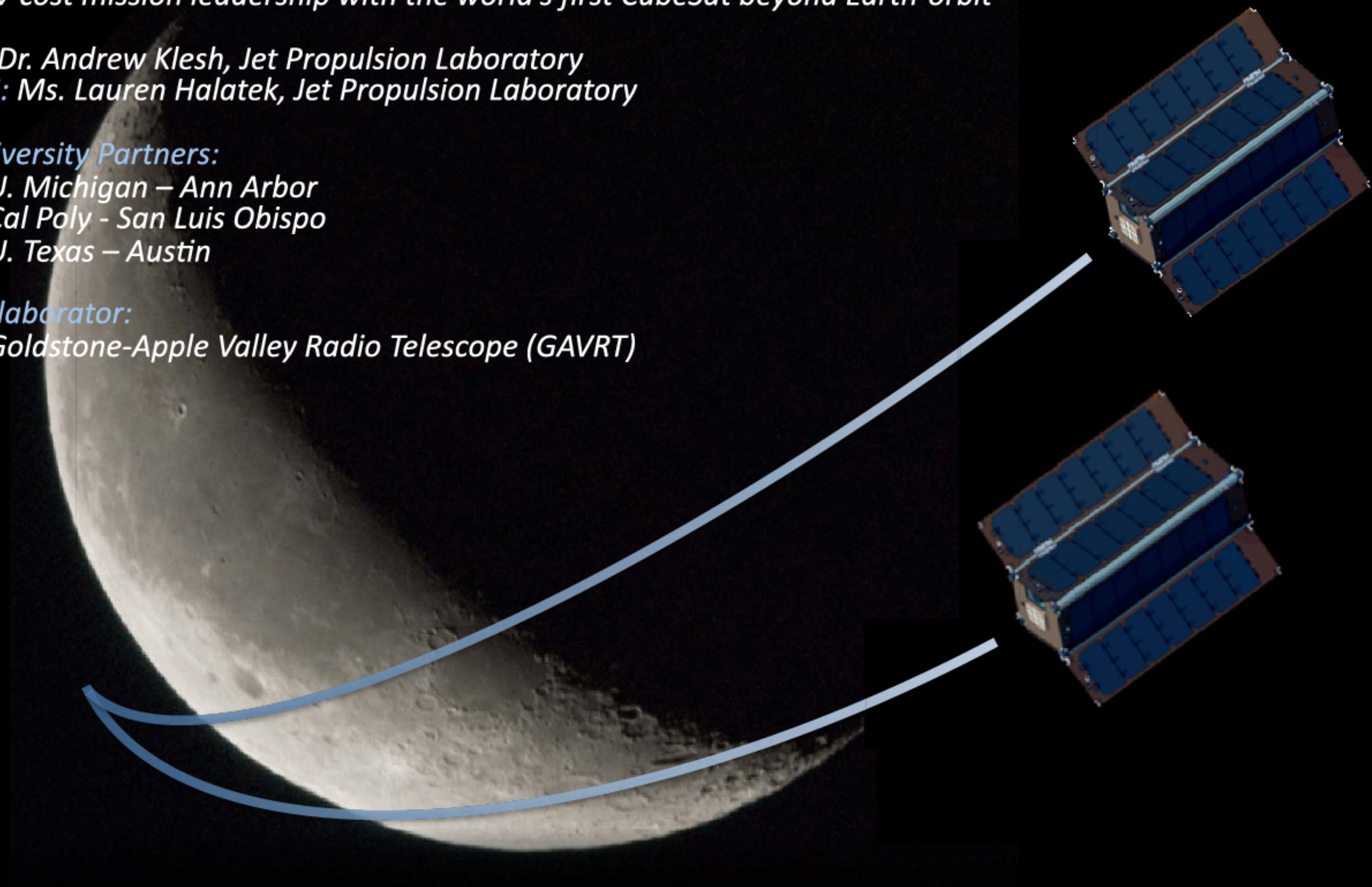
PI: Dr. Andrew Klesh, Jet Propulsion Laboratory
PM: Ms. Lauren Halatek, Jet Propulsion Laboratory

University Partners:

- *U. Michigan – Ann Arbor*
- *Cal Poly - San Luis Obispo*
- *U. Texas – Austin*

Collaborator:

- *Goldstone-Apple Valley Radio Telescope (GAVRT)*



Pre-Decisional--For Planning and Discussion Purposes Only

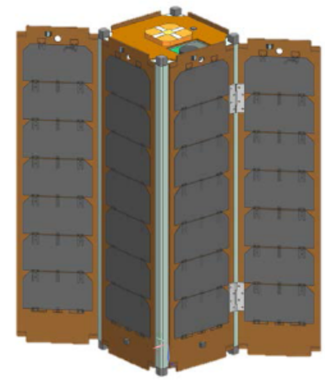
Jet Propulsion Laboratory
California Institute of Technology

CAL POLY GAVRT MICHIGAN THE UNIVERSITY OF TEXAS – AT AUSTIN –

INSPIRE Fact Sheet

Enabling a new class of interplanetary explorer, while providing components to reduce the size and cost of traditional missions

Mission Objectives



1 • Demonstrate and characterize key nano-spacecraft telecommunications, navigation, command & data handling, and relay communications for mother-daughter

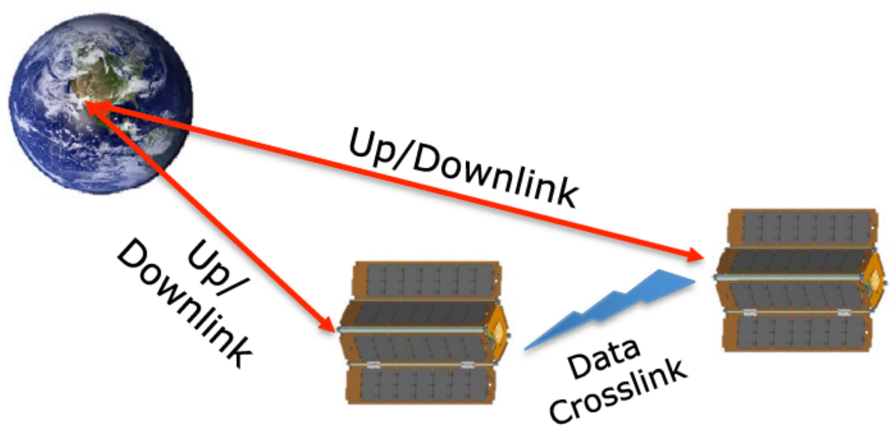
2 • Demonstrate science utility with compact science payload

5 1/2U Helium Magnetometer and combination Star-Tracker/Imager

• Demonstrate ability to monitor and power cycle COTS/university processing systems

Mission Concept

• JPL-built spacecraft; collaborative partnerships with Michigan, Texas, and CalPoly/Tyvak for COTS processing systems. Ground stations at U. Michigan and Goldstone with DSN compatibility



- C&DH monitor hosted payloads – autonomously resetting components in event of upset
- Spacecraft demo relay communications from other spacecraft back to ground stations

Pre-Decisional--For Planning and Discussion Purposes Only

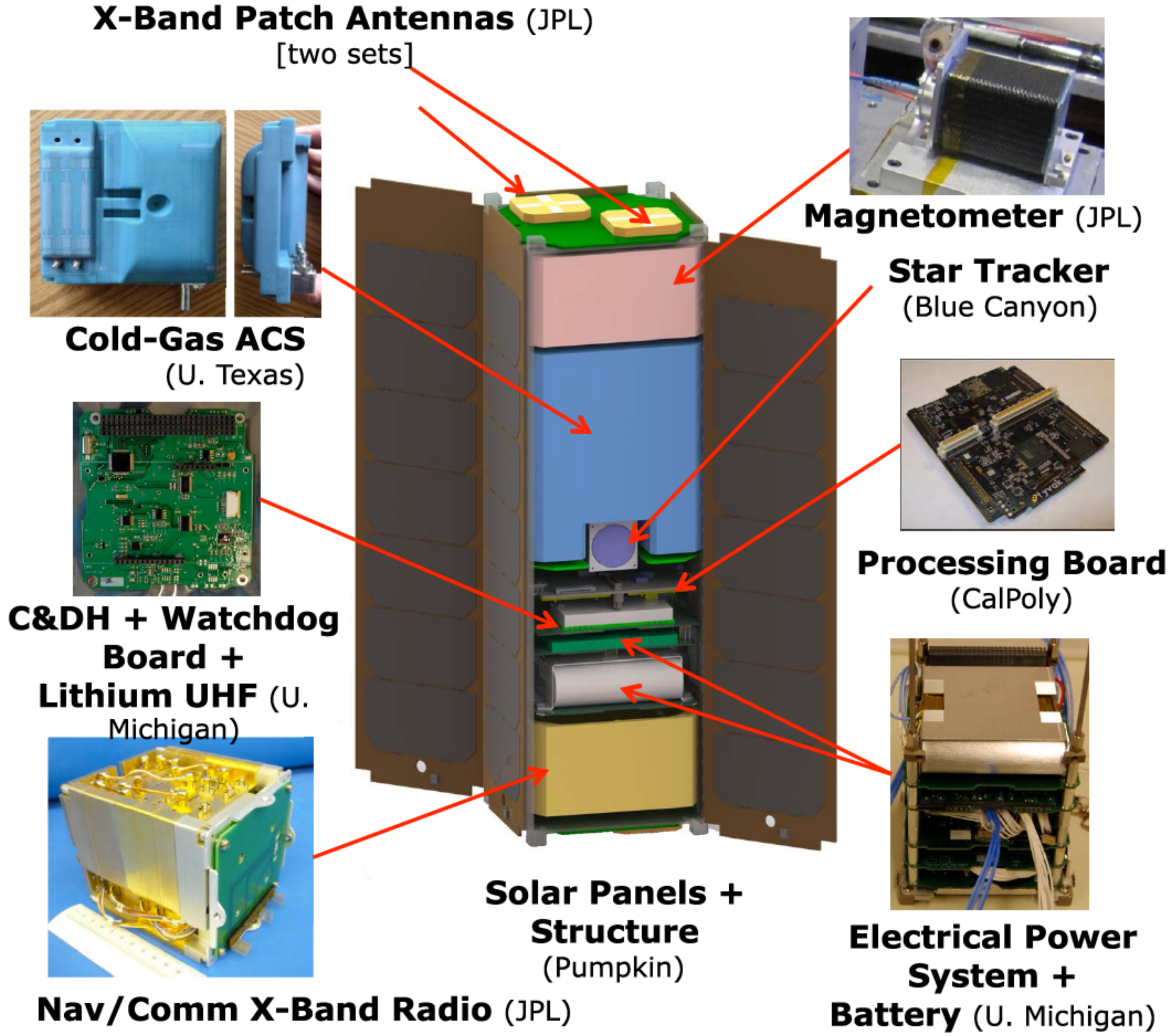
INSPIRE – *world's first deep-space CubeSats*

Overview:

Volume: 3U (10x10x30cm)
Mass: 3.8 kg
Power Generation: 17 W
Data Rate: 100-1200 bps

Operations:
DSN, Peach Mountain (U. Michigan) & DSS-13 (JPL)

S/C components will provide ***the basis for future high-capability, lower-cost-risk missions*** beyond Earth expanding and ***enabling NASA capabilities in an emergent domain.***



Sword: UHECR Pulse Detection From Space

Deployable antenna array

Orbit altitude: 800 km

Horizon: 3000 km away

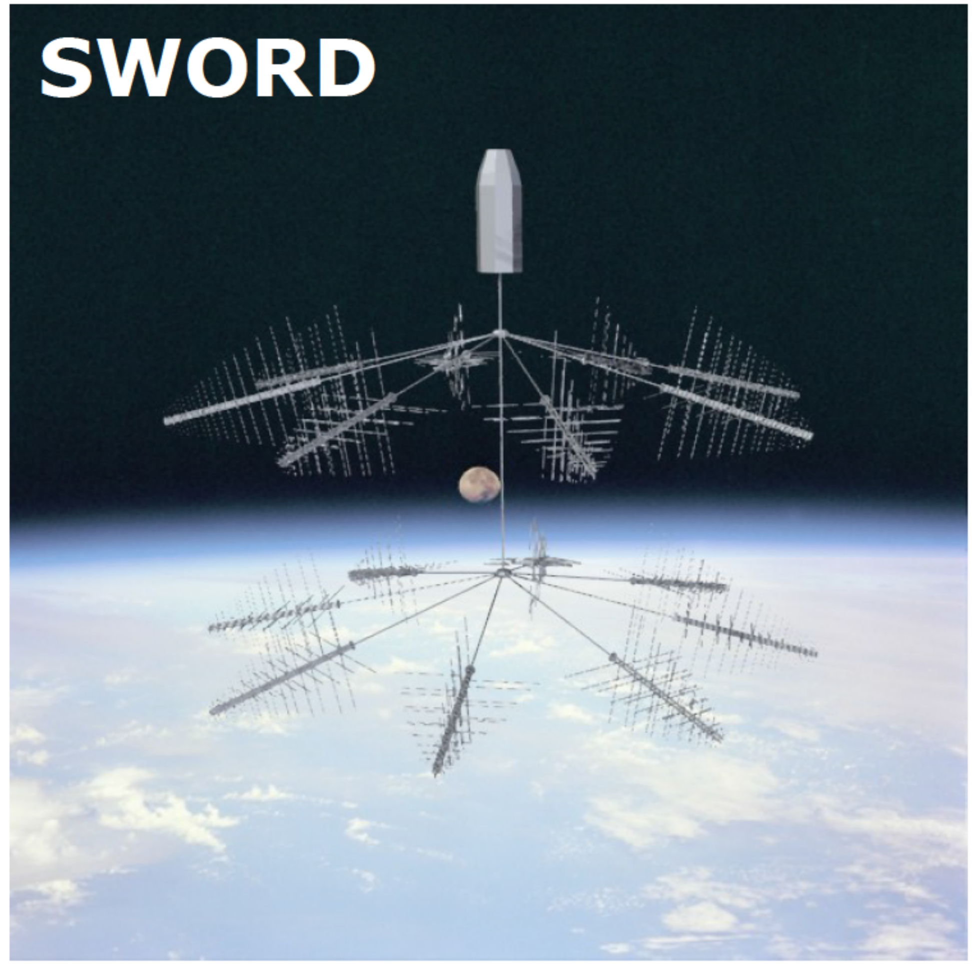
Visible area: 117×10^6 km^2

Band: 30-300 MHz

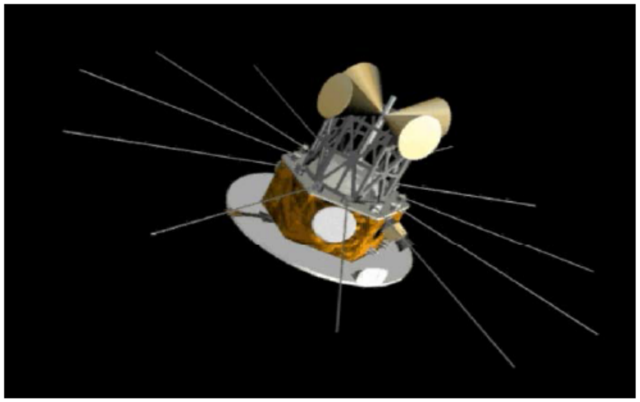
Radio pulses expected to be stronger at lower frequencies

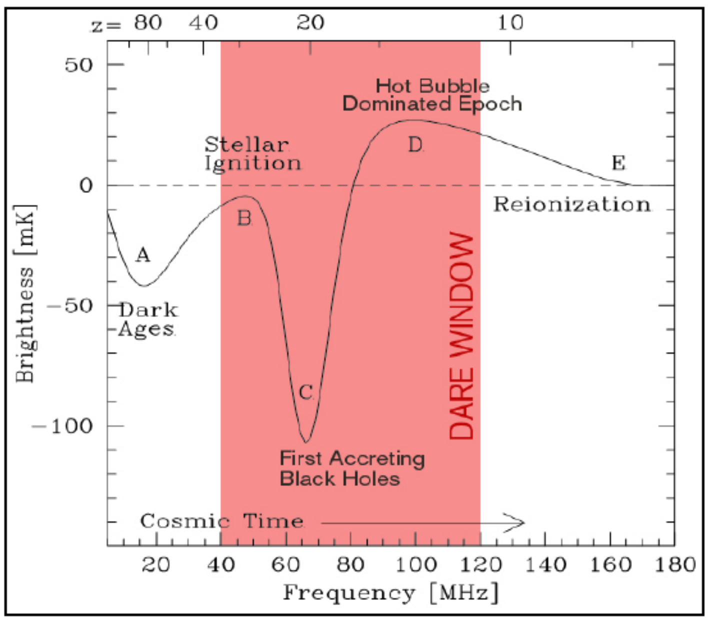
30MHz cutoff is where ionosphere effects begin to dominate.

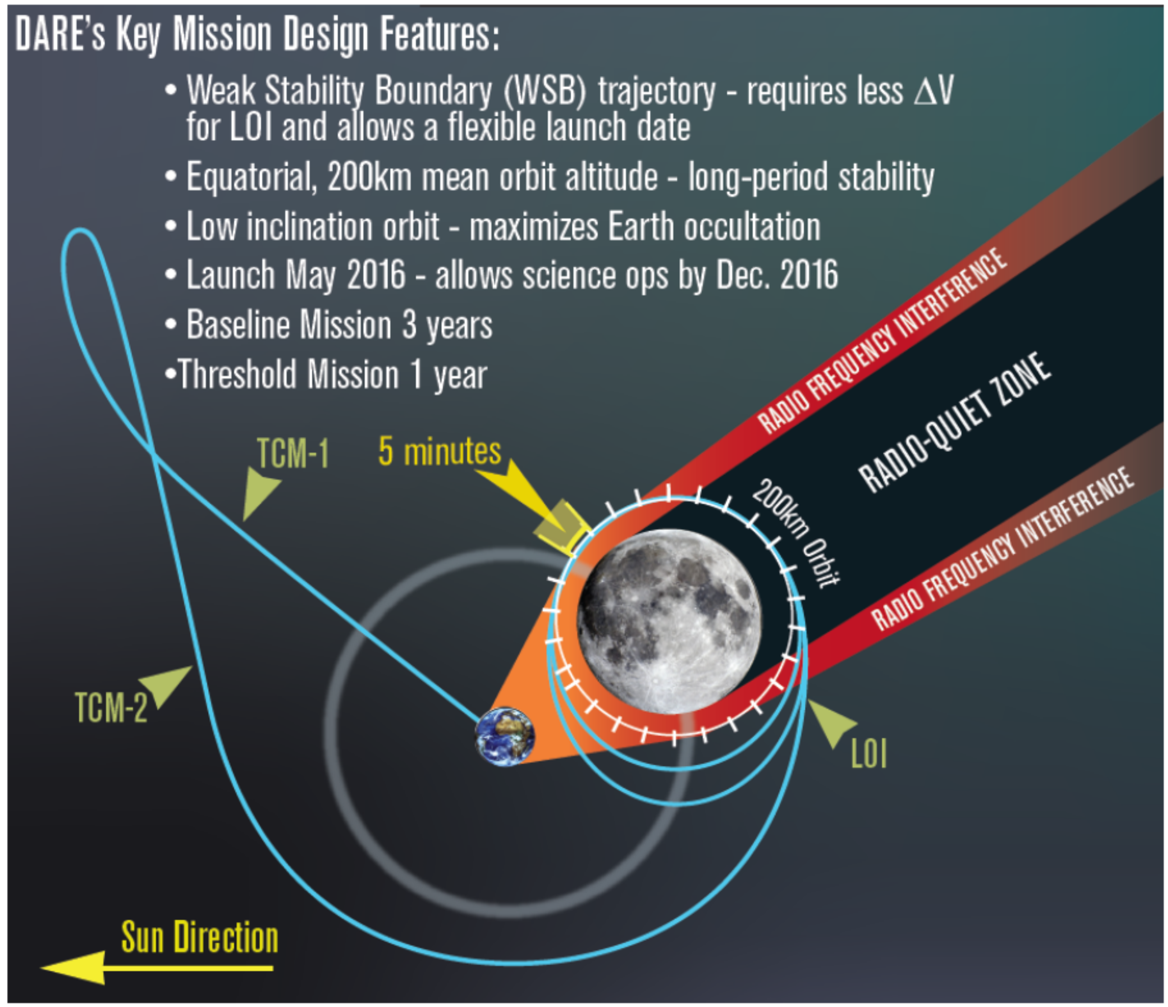
High band costs more in data rate and signal is weaker above 300 MHz.



Dark Ages Radio Explorer







Workable Interplanetary CubeSat System Architecture emerges from the maturation of six key technologies

LightSail 1^{tm}: Planetary Society, Stellar Exploration, CalPoly-SLO

RAX-2: University of Michigan