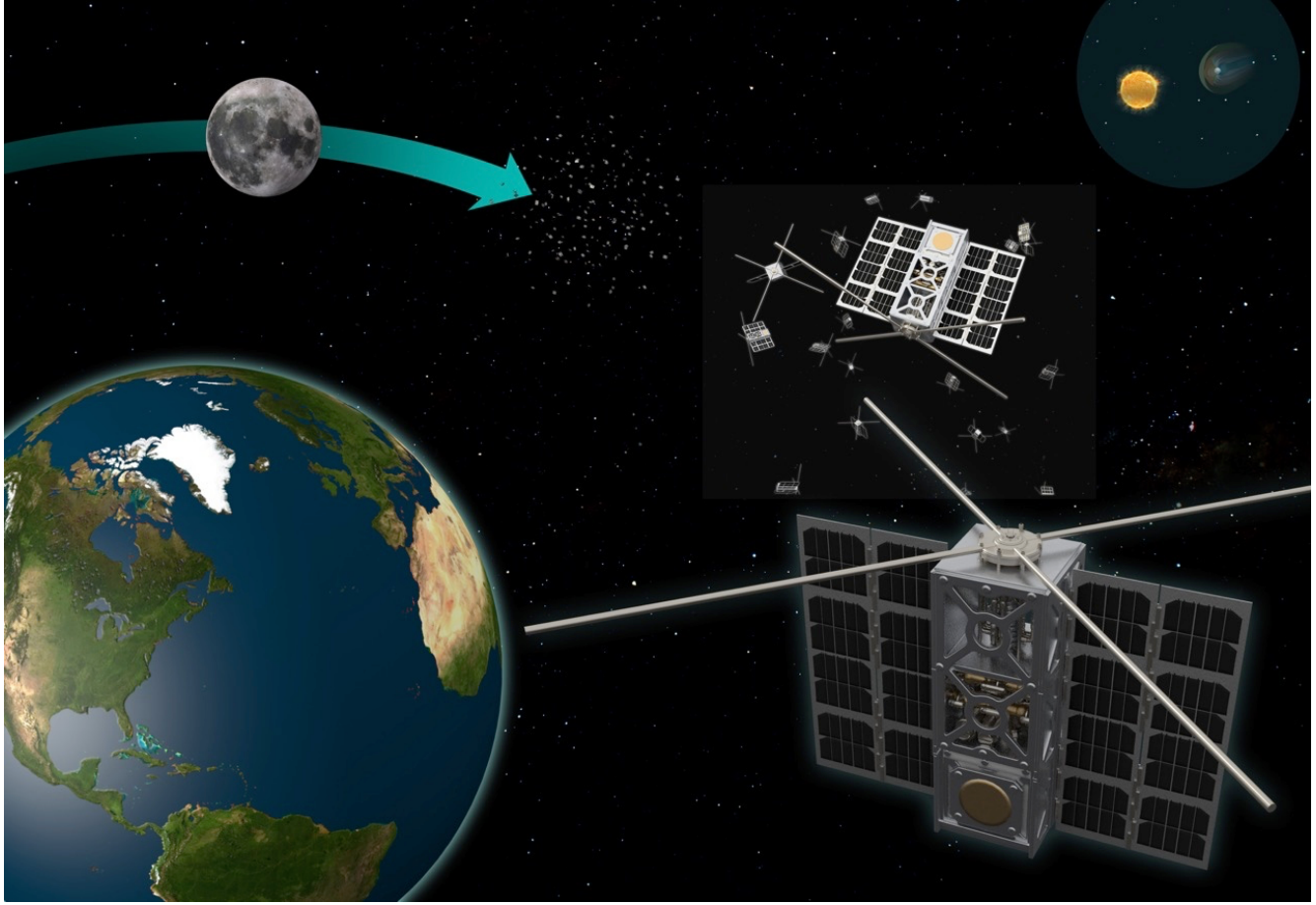


Constellations of Cubesats

T. Joseph W. Lazio

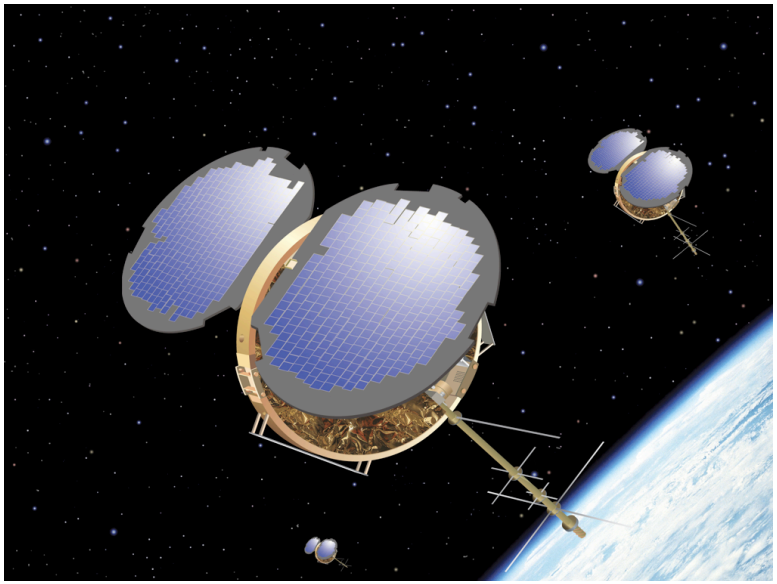
J. Castillo-Rogez, K. Belov, S. Broschart, N. Chahat, S. Chien, L. Clare,
C. Duncan, J. Sauder, T. Sweetser, M. Thomson, & Jay Wyatt

Jet Propulsion Laboratory
California Institute of Technology

Interplanetary Small Satellite Conference

© 2016. All rights reserved.

Terrestrial Constellations



GPS radio occultation constellations
(Image credit: Orbital Sciences Corp.)

Radio astronomy arrays

LOCUST (Image credit: U.S. Navy)

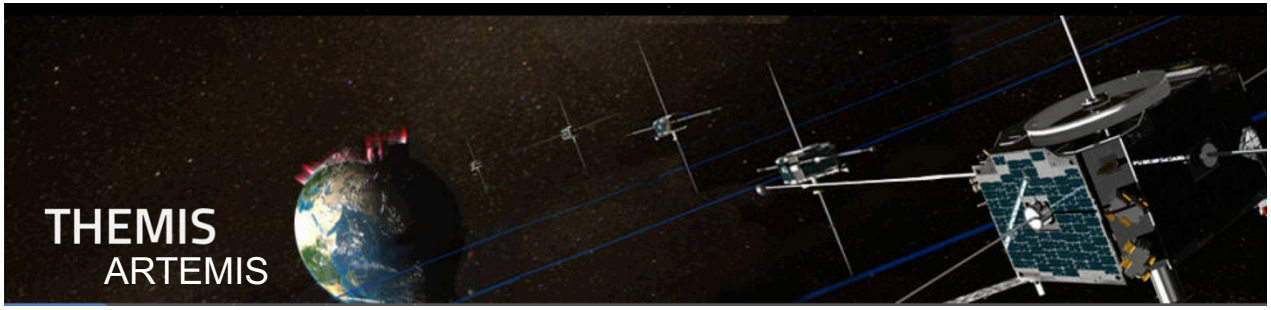
Constellations

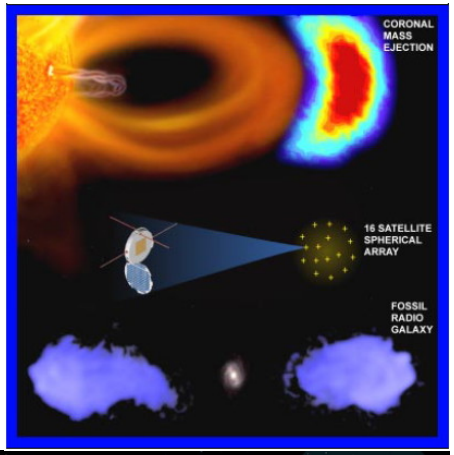
Raison d'etre

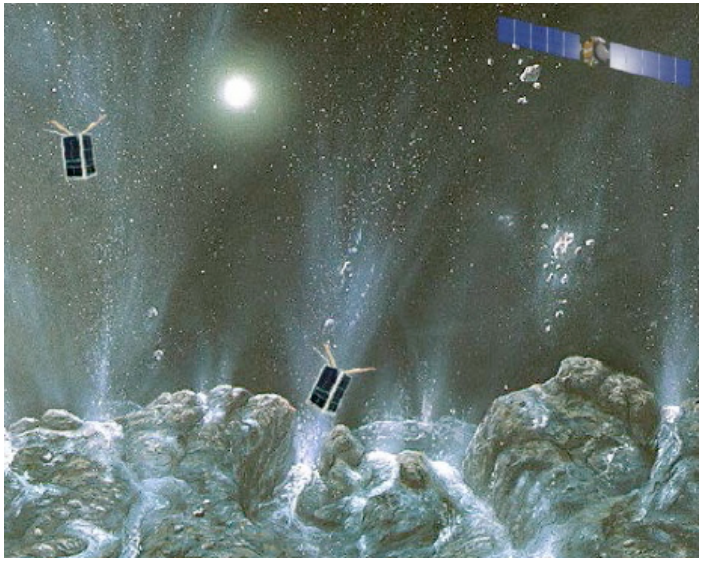
- **Track dynamics of distributed, evolving systems**
- **Single sensor implausible**
- **Redundancy and/or resistance to failure**

Planetary and Space Science Constellations

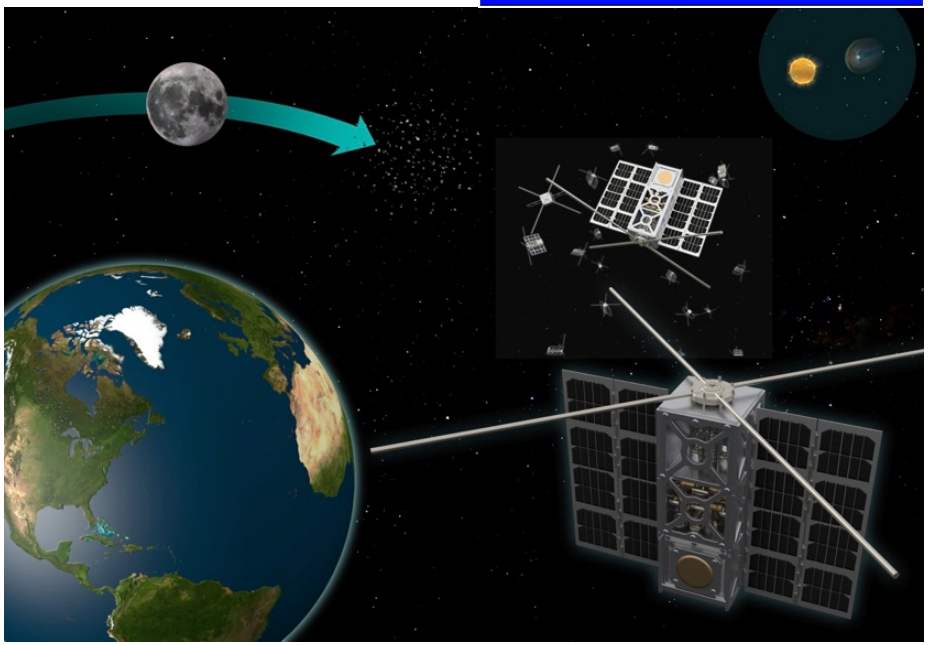
An Incomplete List …







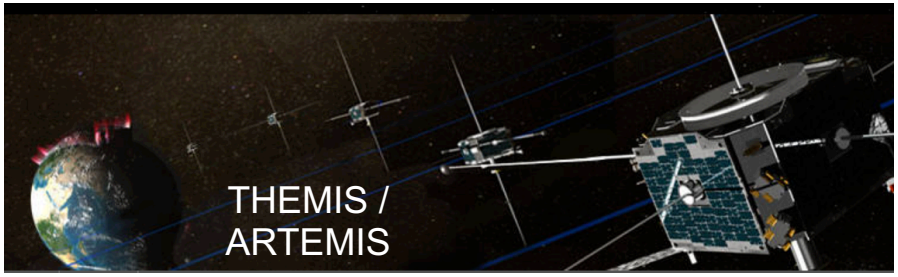
cf. *lunar laser retroreflectors*, Lunar Geophysical Network, Mars Geophysical Network



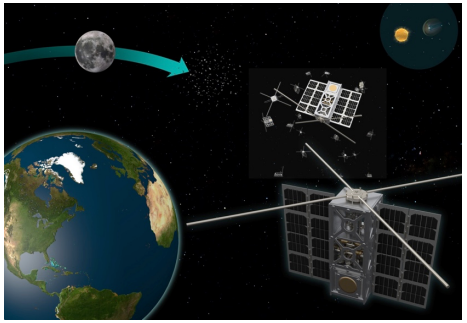
Planetary and Space Science Constellations

Sensor Web Architectures

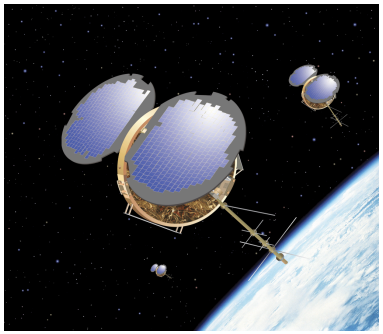
Pixelization/Voxellation



Beamforming



Tomography



(seismic networks)

Technical Challenges

In no priority order …

- **Communication**
- **Guidance, navigation, and control**
- **Miniaturization and robustness of components**
- **Propulsion**
- **Thermal control**
- **Data storage**
- **Optimization of design**
- **Mission operations**
- **…**

➢ **Smallsats have potential to be mission enabling!**

Technical Challenges

In no priority order …

- **Communication**
- **Guidance, navigation, and control**
- **Miniaturization and robustness of components**
- **Propulsion**
- **Thermal control**
- **Data storage**
- **Optimization of design**
- **Mission operations**
- **…**

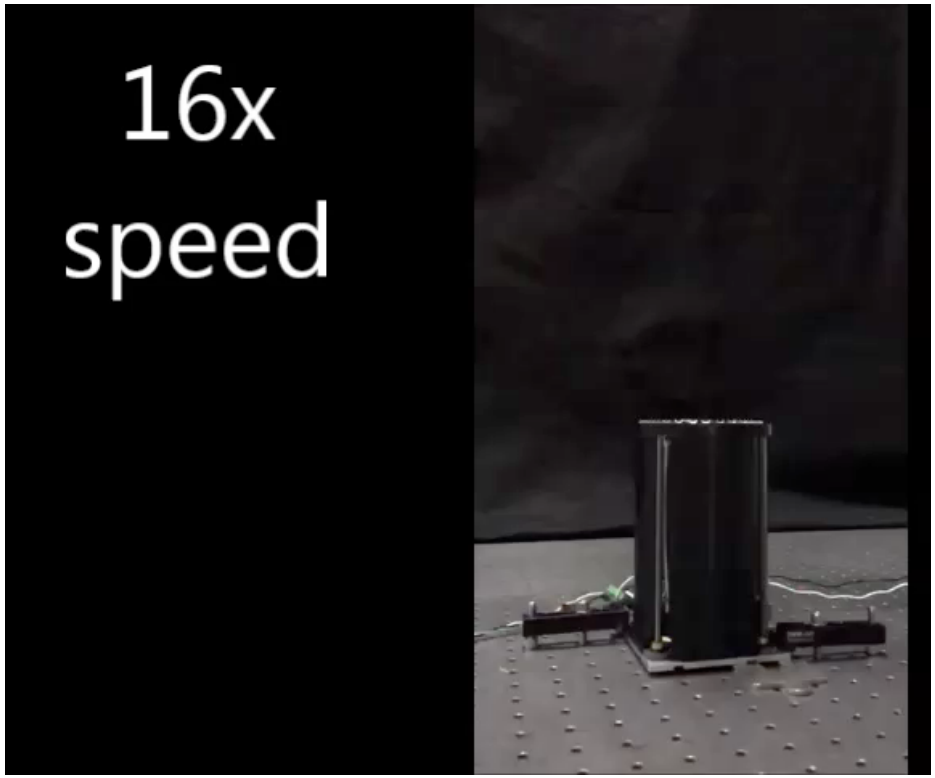
➢ **Smallsats have potential to be mission enabling!**

Communication Technologies

… and Navigation!

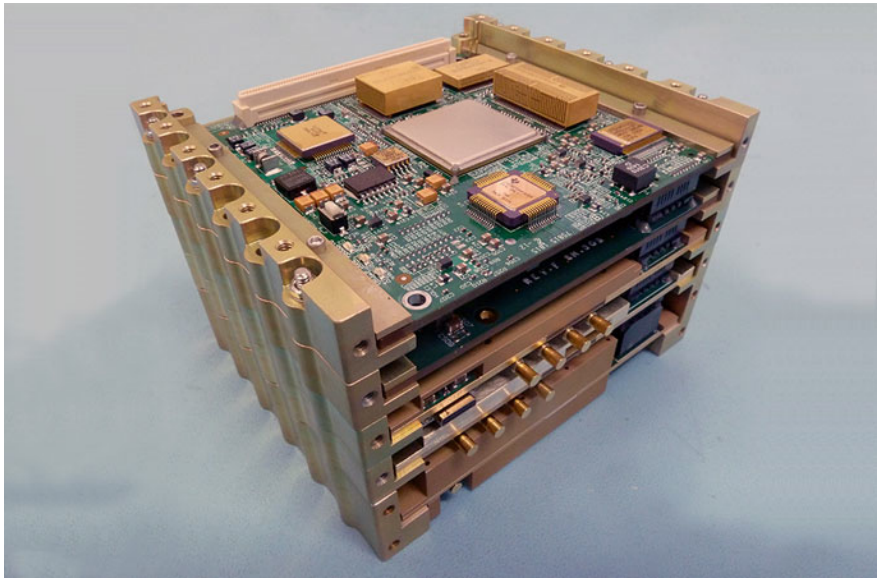
KaPDA

Ka-band Parabolic Deployable Antenna



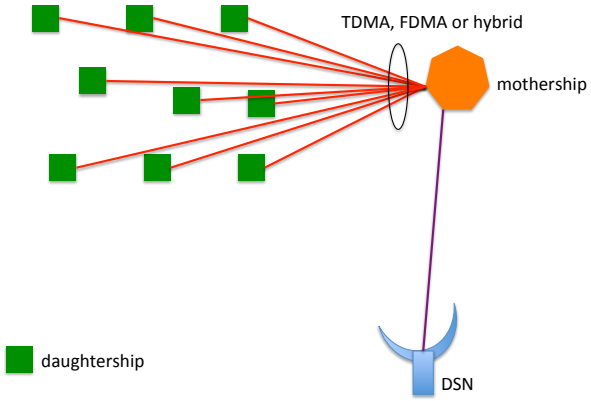
Iris

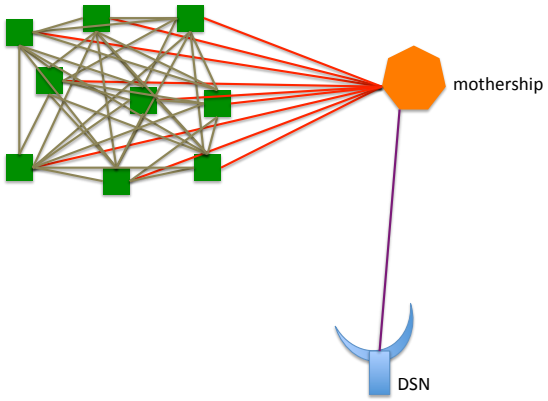
DSN-compatible FPGA Transponder for cubesats

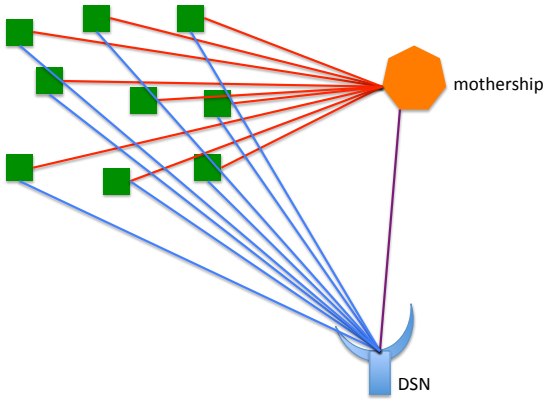


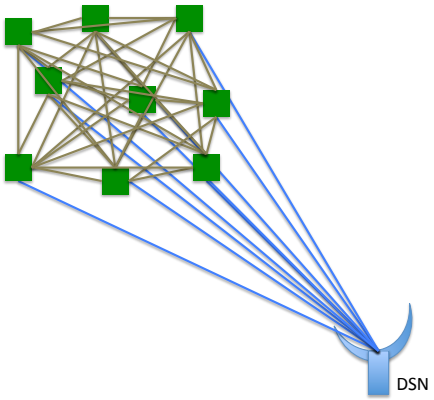
Networked Constellation Communications Technologies

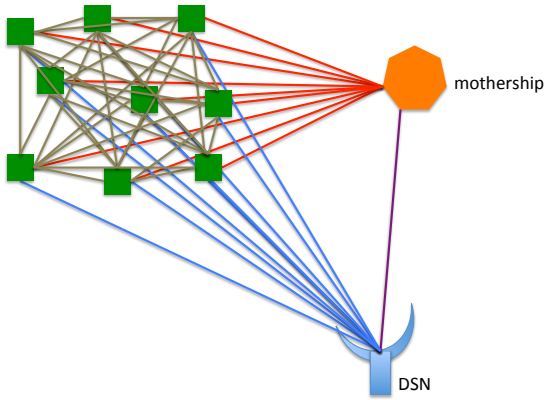
High-level alternative physical communications architectures

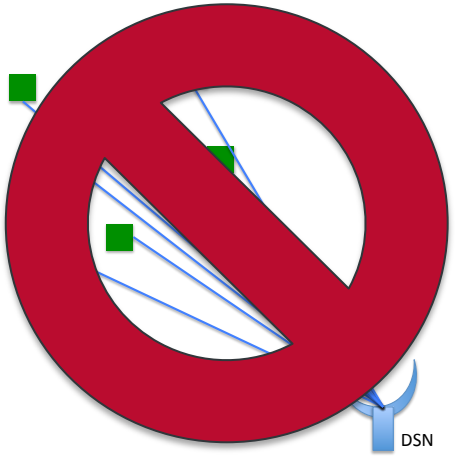








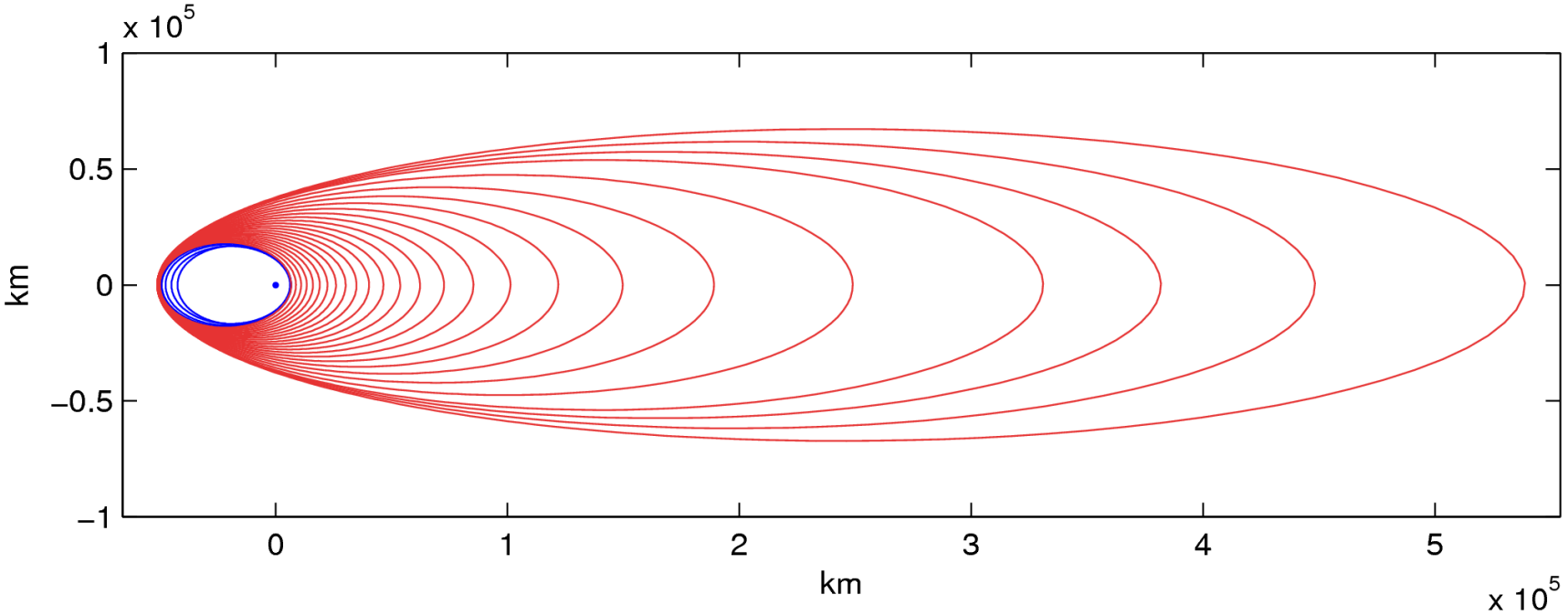




Navigation


2000-Jan-01 12:00:00 UTC
1x time (paused)
Time Control
2000 Jan 01 12: 00: 00 UTC
Now
Rate: 1x (paused)
Real rate
Adhara
Wezen
Canopus
Pallas
ZET Pup
GAM Vel
Miaplacidus
LAM Vel
IOT Car

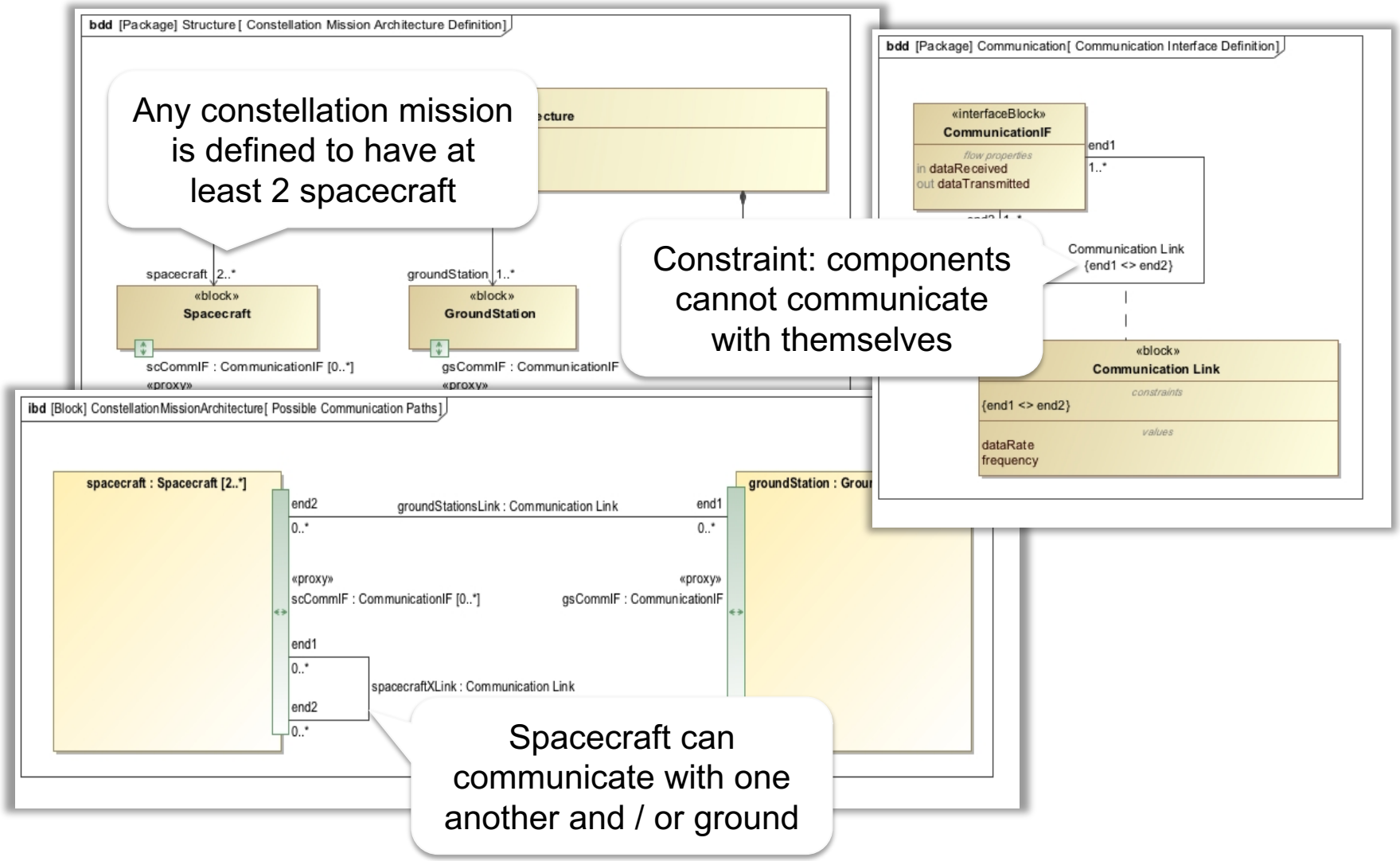
Families of Orbits



Originally developed in context of planetary departure

… also relevant for swarms around a planet

Networked Constellation Optimization



Summary

- Smallsats/cubesats offer plausible means of implementing *affordable deep space* constellations
  - a.k.a. “sensor webs,” swarms, fleets, …
- Many technologies starting to mature
  - e.g., Telecommunications
- Operations and optimization likely to remain (*or appear to remain*) significant challenge