CICERO – A Distributed Small Satellite Radio Occultation Pathfinder Mission

Community Initiative for Continuous Earth Remote Observation

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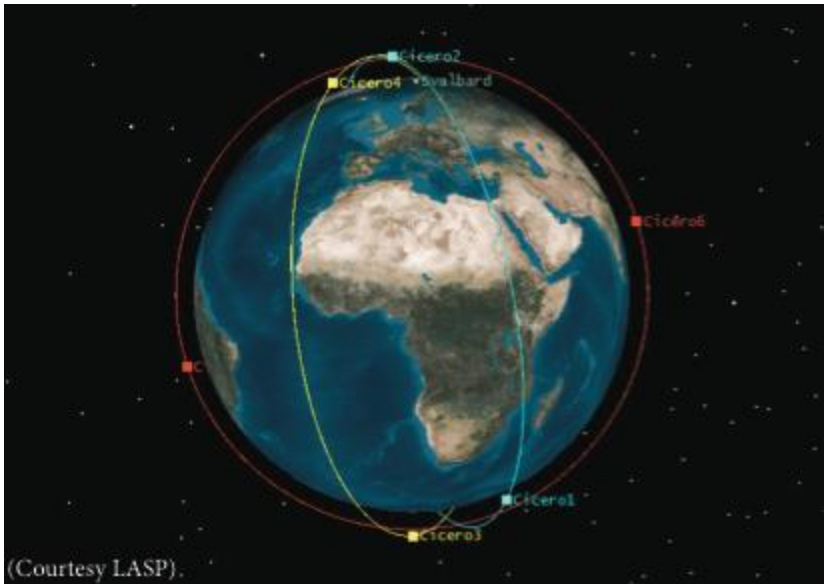
Motivation

Global problem that has yet to be adequately recognized:

Limited future spacecraft for weather/climate observation

- The CICERO Mission is designed to fill this void
  - Constellation of satellites providing GPS RO measurements
    - Global coverage
    - Accurate: 9% improvement
  - Pathfinder to fly 2 satellites
  - CICERO bus is a flexible SmallSat platform for constellation
  - Ample margins with minimal optimization = robust, lower cost!

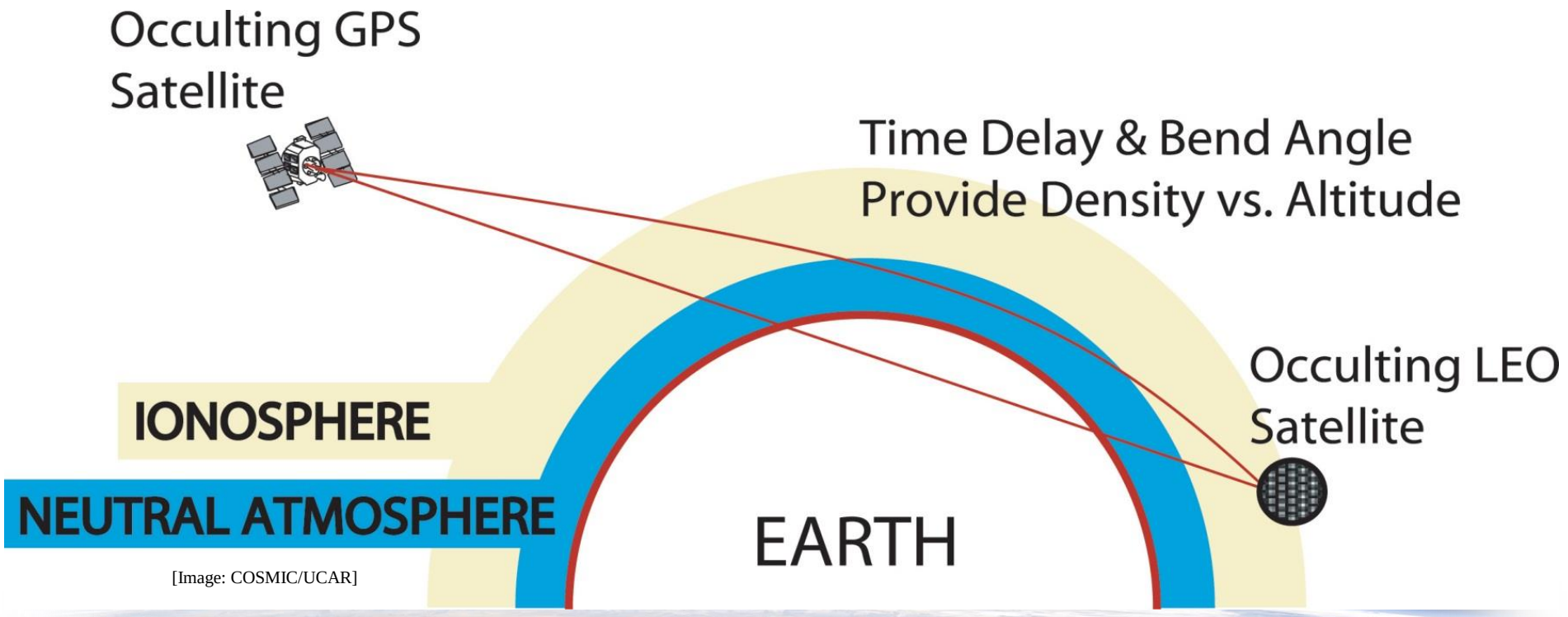


Paper describes RO mission and objectives in greater detail
Paper describes novel, highly capable ADCS & its performance

GPS Radio Occultation

What is GPS RO?

- Radio signals in atmosphere bend due to refractivity
- Bending shows up as excess range in GPS phase observable
- Invertible to get temperature, water vapor, and pressure profiles

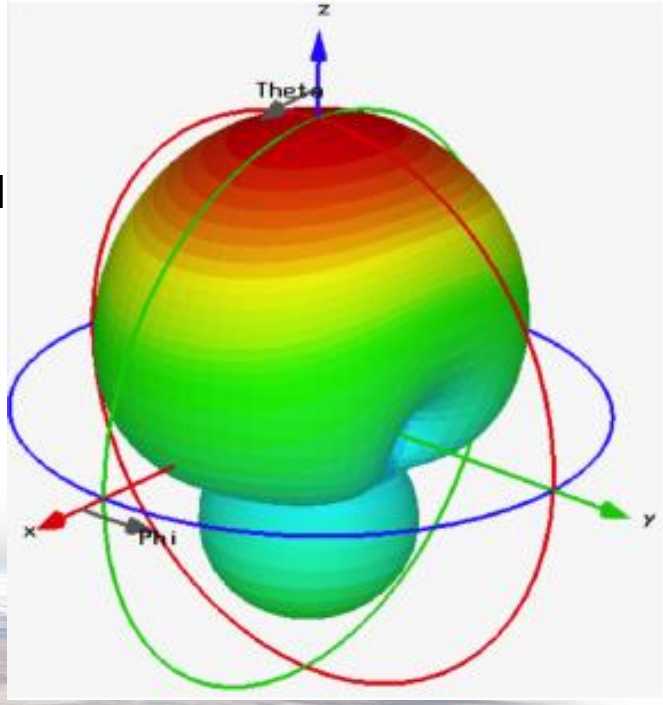


[Image: COSMIC/UCAR]

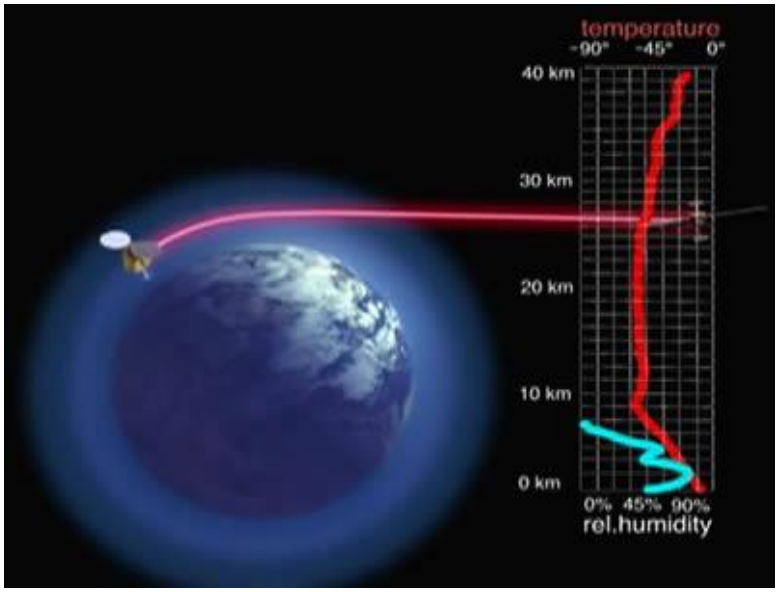
RO Mission Considerations

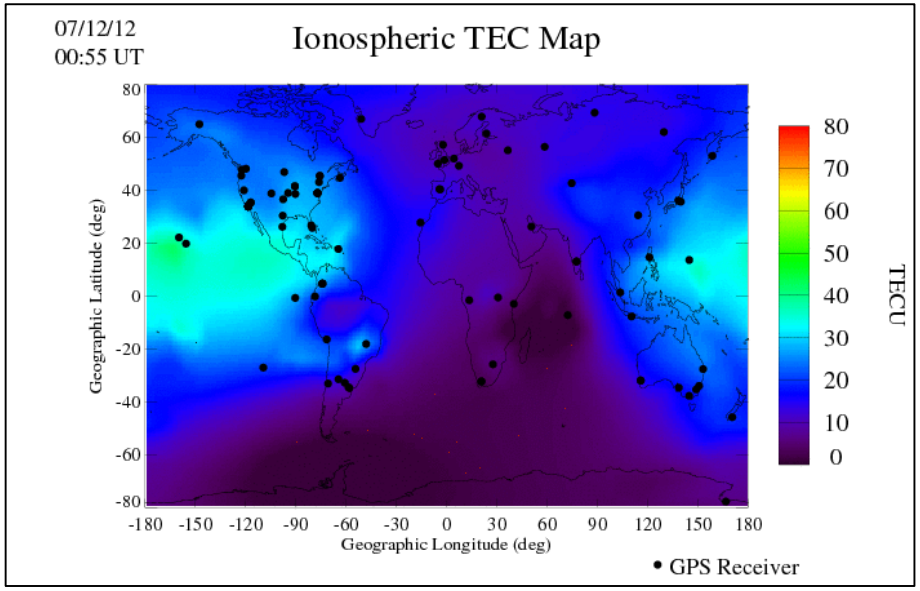
- Must receive occulting signals
  - Point high gain antennas at Earth's limb
  - RO antenna design
  - Important for attitude pointing, rates, knowledge
- Opportunistically collect signals
  - System capable of GLONASS, GPS, L1 – L5 signals
  - Drives selection of receiver
- Must deliver data in timely manner
  - Fast data-to-ground for weather prediction
  - Determines ground station location(s) and COMM bandwidth
- Low Cost
  - Small Satellite
  - Hardware Selection

RO antenna gain pattern



CICERO Science Data Products

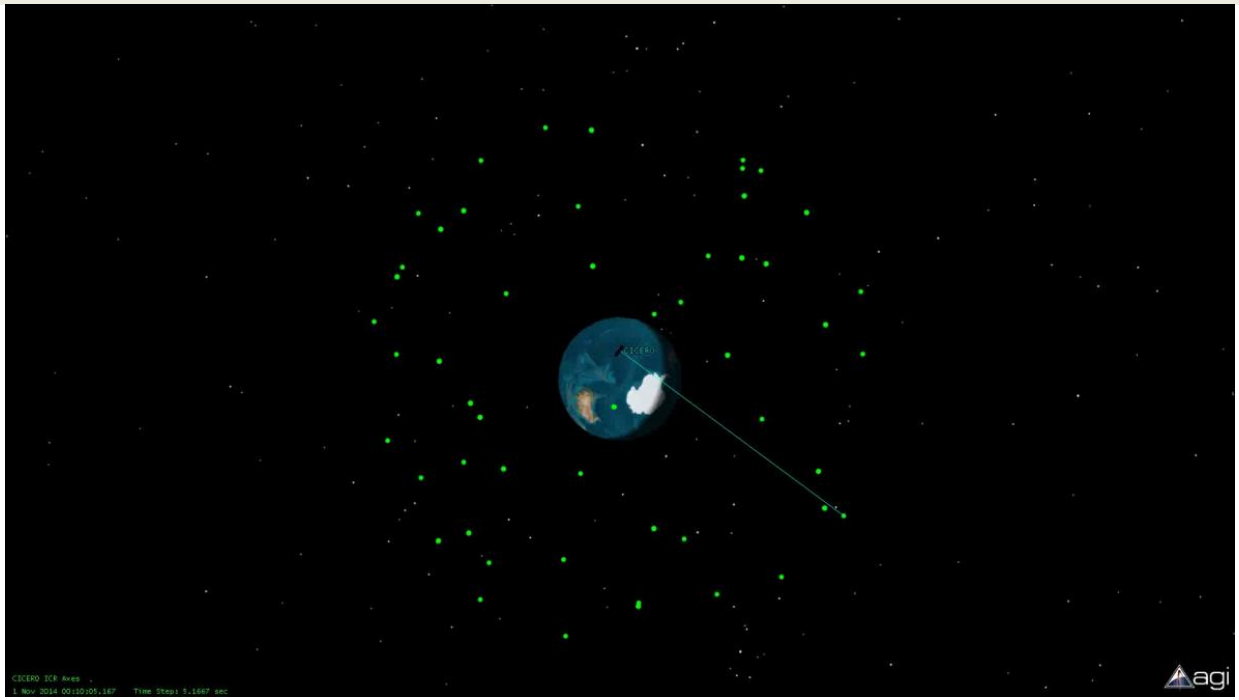




Data Type (Neutral Atmosphere)	Threshold
Number of Profiles per Day	565
Vertical Profile Range	2-60
Vertical Data Resolution a. Altitude Range 2-25 km b. Altitude Range 25-60 km	 0.1 1.0
Average Latency - minutes	90

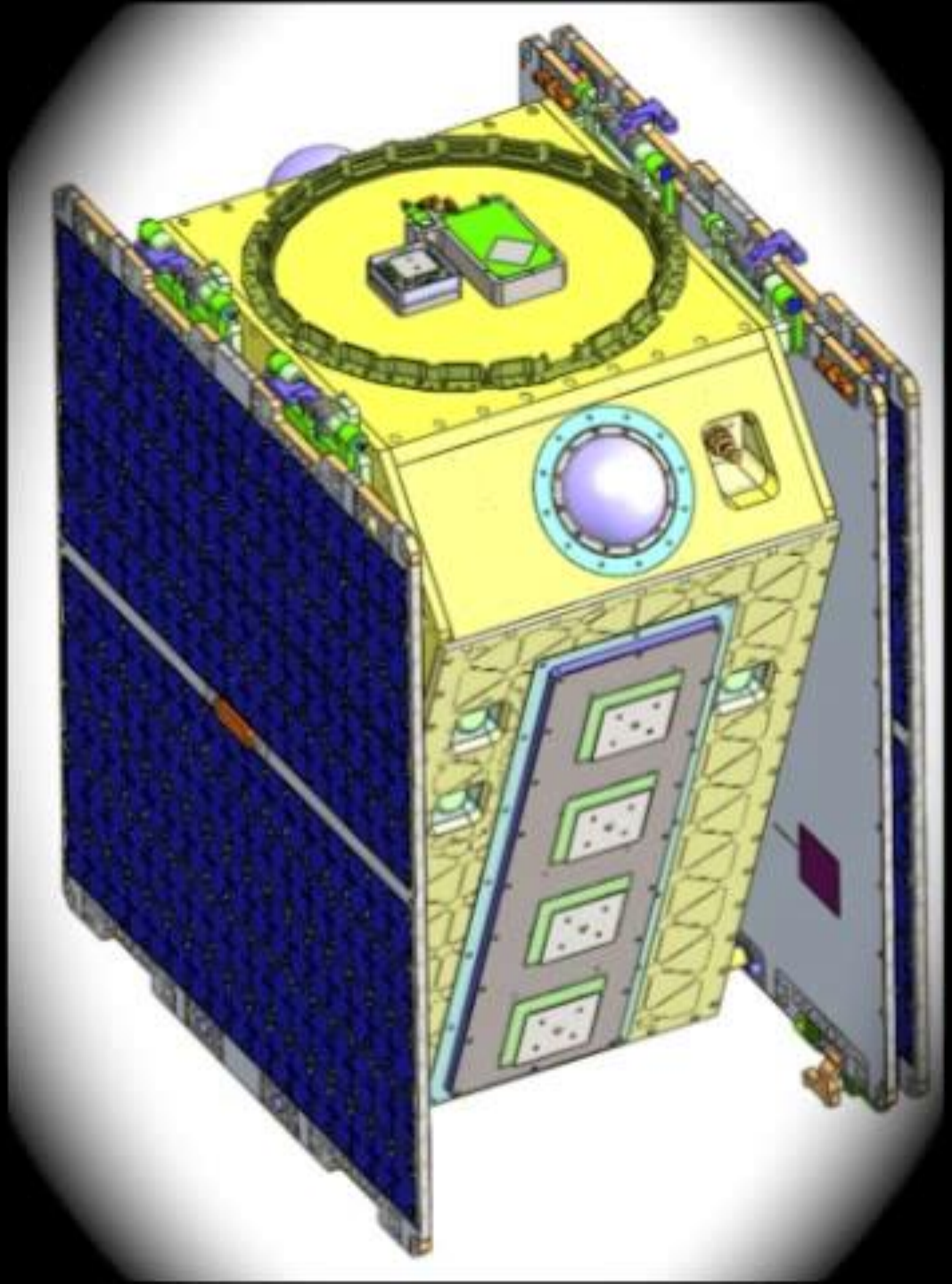
Data Type (Ionosphere)	Threshold
Altitude Range (km)	60-500
Vertical Resolution (km)	2
Measurement Range (TECU)	3-1000
TEC Observations per day	860,000
Average Latency - minutes	90
Scintillation Amplitude Index and Phase Sampling Rate (Hz)	50

Mission Overview

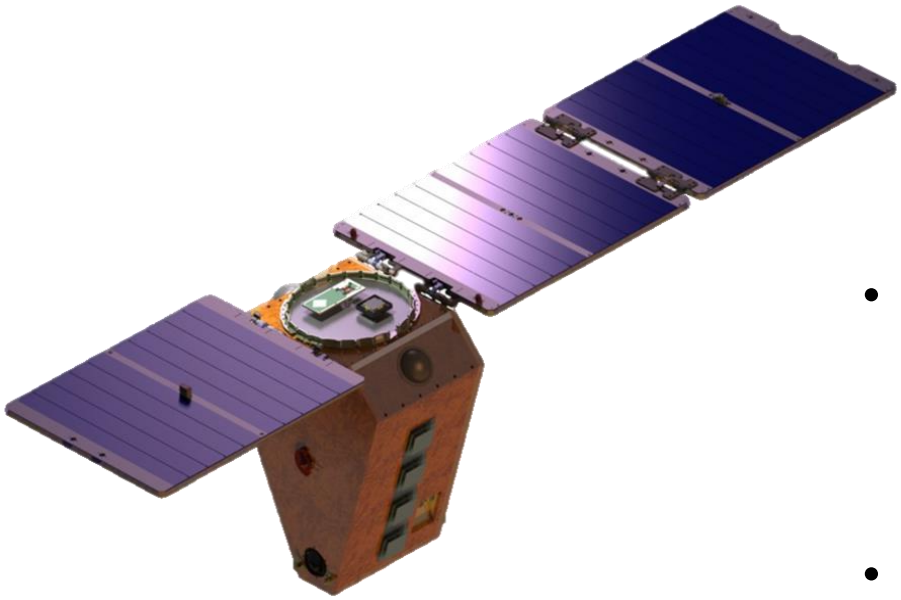


- 650 ± 50 km, sun-synchronous orbit
  - 1:30 a.m. descending node
- Nadir pointer, w/ sun pointing capability
- Single string, w/ selective redundancy
- X-band downlink, S-band uplink

Spacecraft Overview	
Mass	104 kg
Dimensions (Wingspan)	28 x 24 x 36 inches (120 inches)
Power	110 W, 28 V
Data Volume	35 MB/orbit



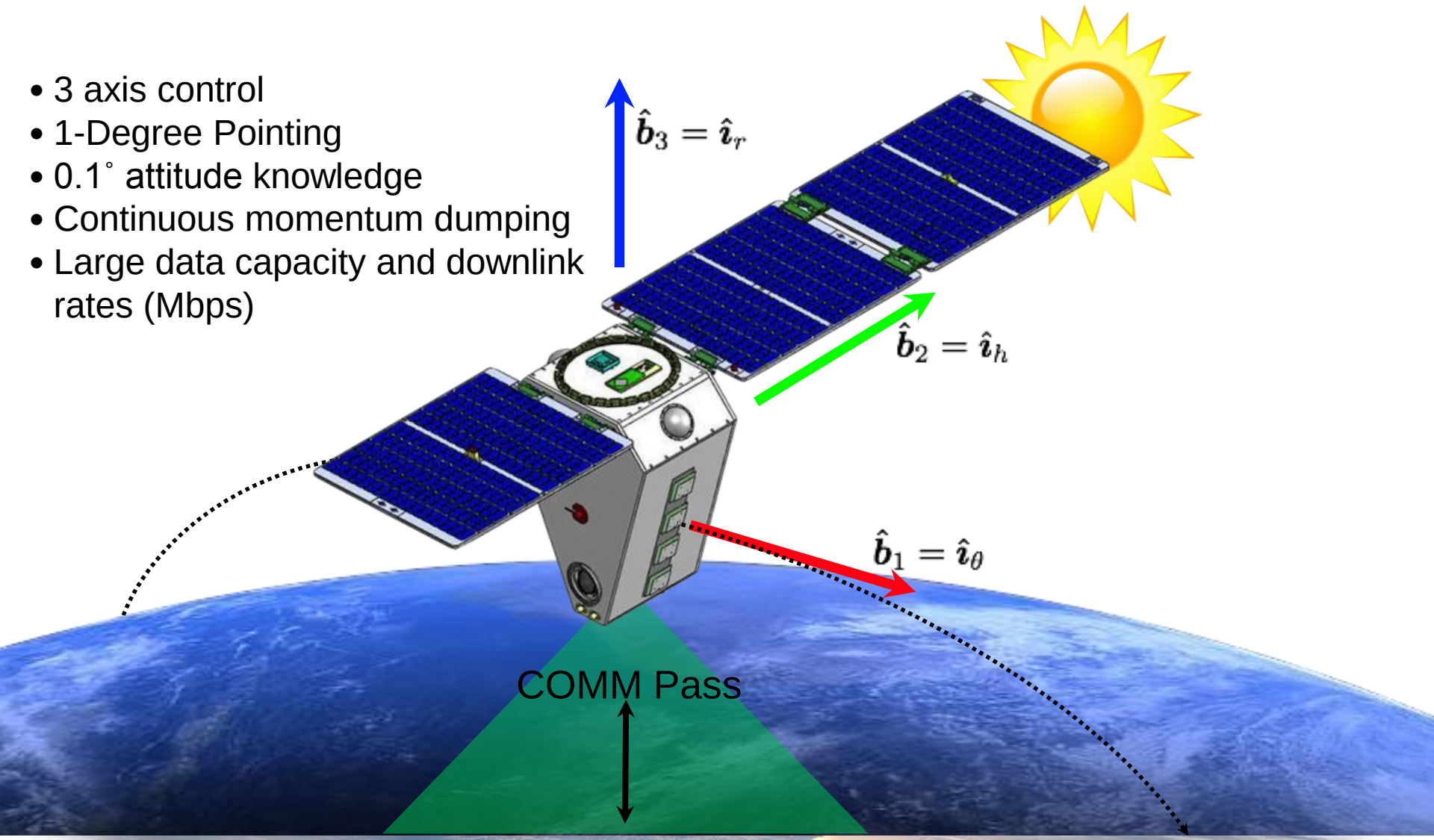
Design Philosophy



- Optimization: high programmatic costs
  - Purposely created robust design
  - Rapid development: FlatSat in 1yr. 3 mo.
  - Standardized bus for mission
- Ride share, reducing launch costs
  - U.S. and European vehicles considered
  - ESPA Rideshare (worst case vibe loads)
- Acquire EEE components w/o expensive lot tests
  - Well known candidate hardware
  - Avoid certification costs
- Use COTS when programmatically & technically advantageous
  - ST, RW, Batteries, Gyro, Radios, GPS
  - TRL – 9 components

Nominal Operations

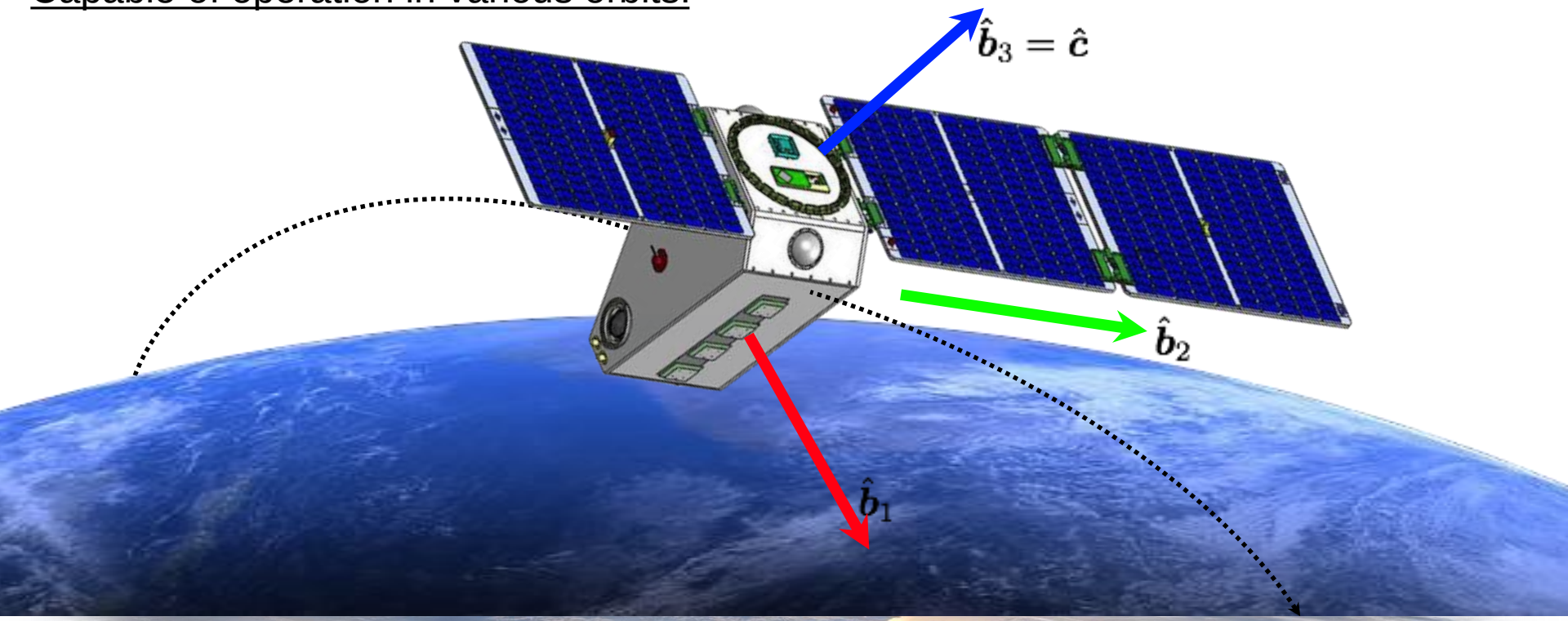
- 3 axis control
- 1-Degree Pointing
- 0.1˚ attitude knowledge
- Continuous momentum dumping
- Large data capacity and downlink rates (Mbps)



Sun-Pointing

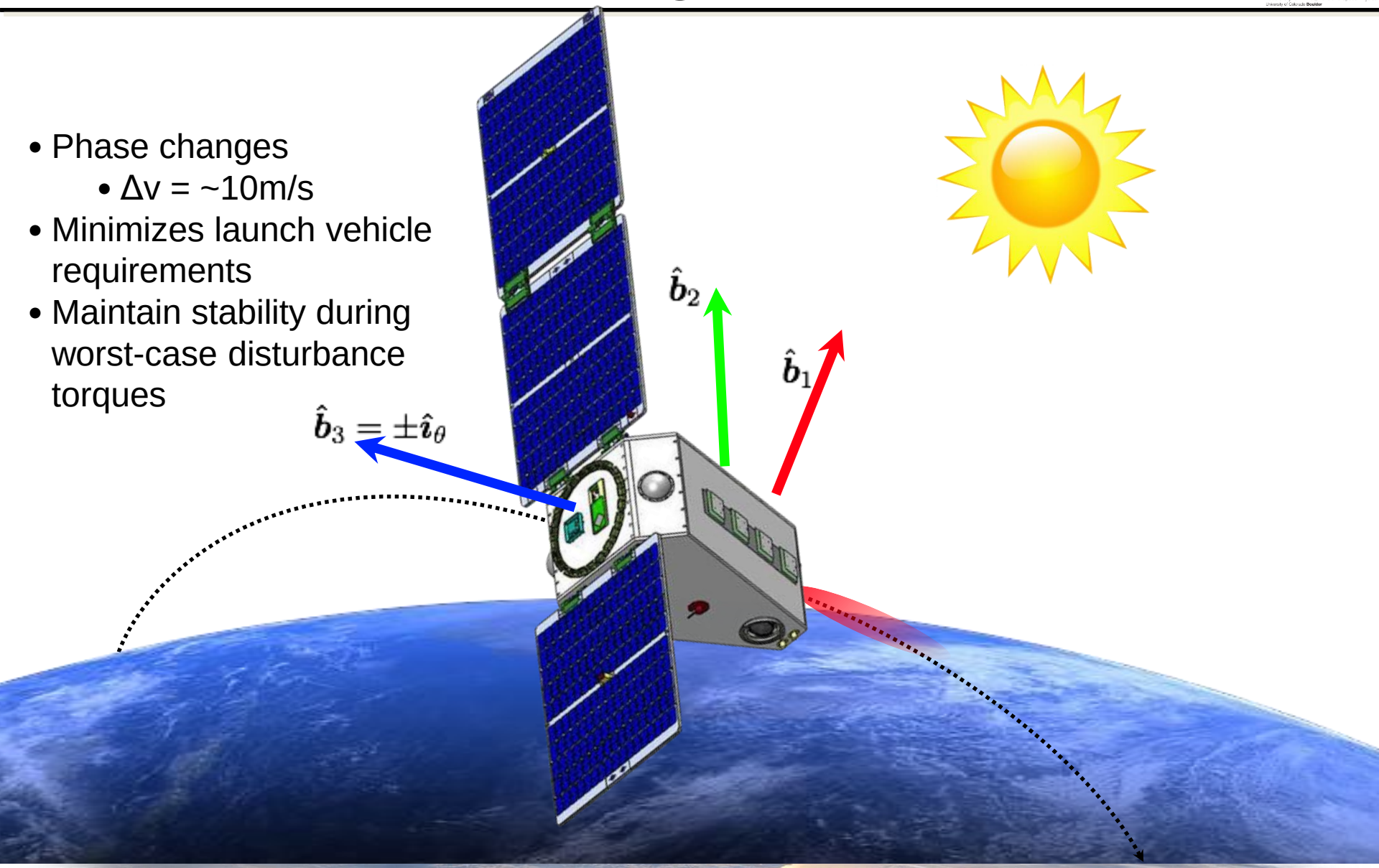
- Kick-off/safe mode
- Solar cells within 30˚ of sun
- Large margins on power production
- Large thermal margins

<u>Capable of operation in various orbits!</u>

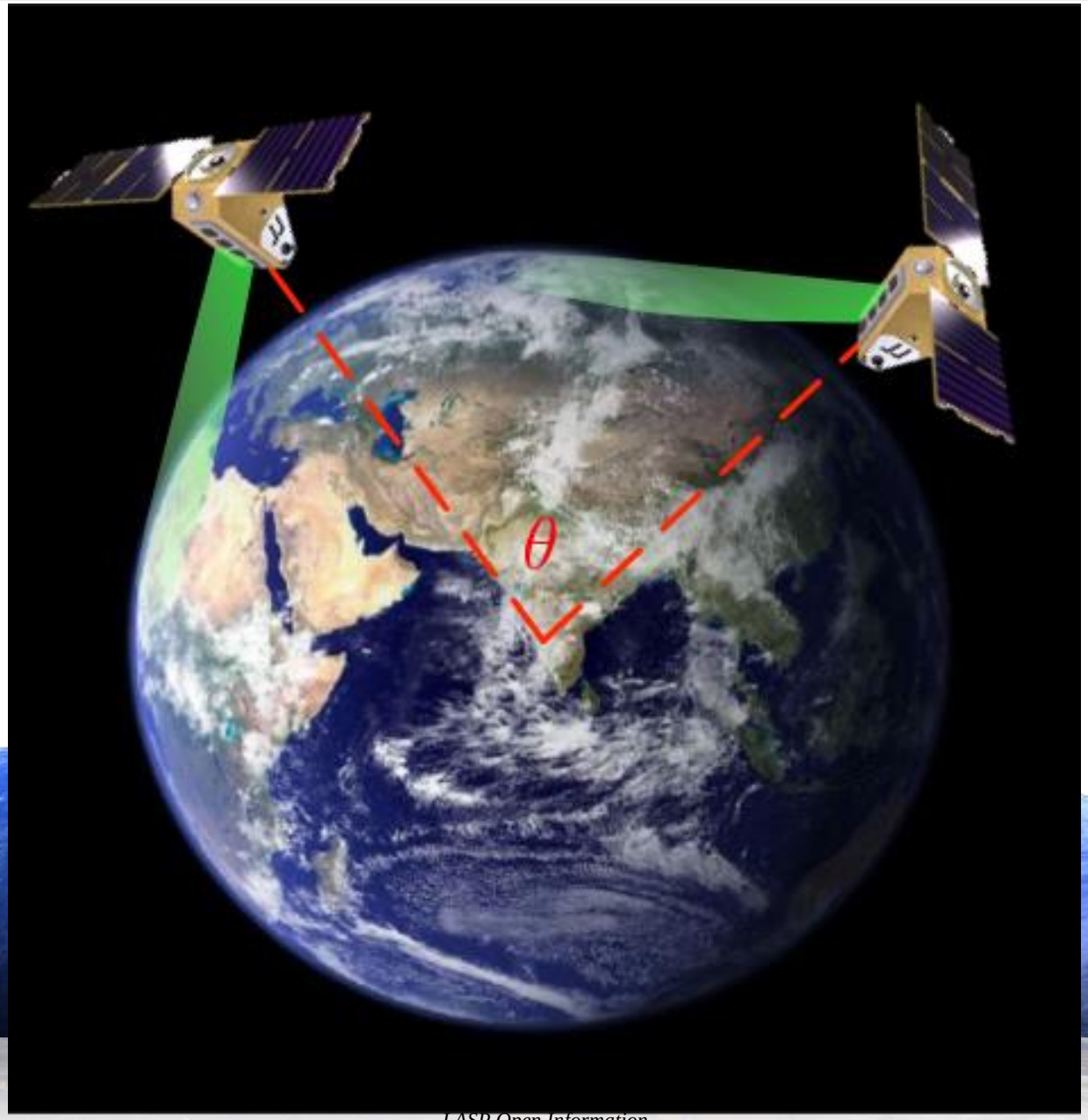


Thrusting State

- Phase changes
  - Δv = ~10m/s
- Minimizes launch vehicle requirements
- Maintain stability during worst-case disturbance torques



Thrusting State



Conclusions

- Constellation provides lower cost weather forecasting
- CICERO bus designed to perform RO mission
- High data output for forecasting
- Utilizes small satellite design philosophy
  - Low cost through minimal optimization, but high robustness
  - Small team = agile team

Acknowledgements

- CICERO design team
- Dr. Hanspeter Schaub
- Dr. Penina Axelrad
- Mike McGrath
- LASP
- GeoOptics

Back-up

Laboratory for Atmospheric and Space Physics
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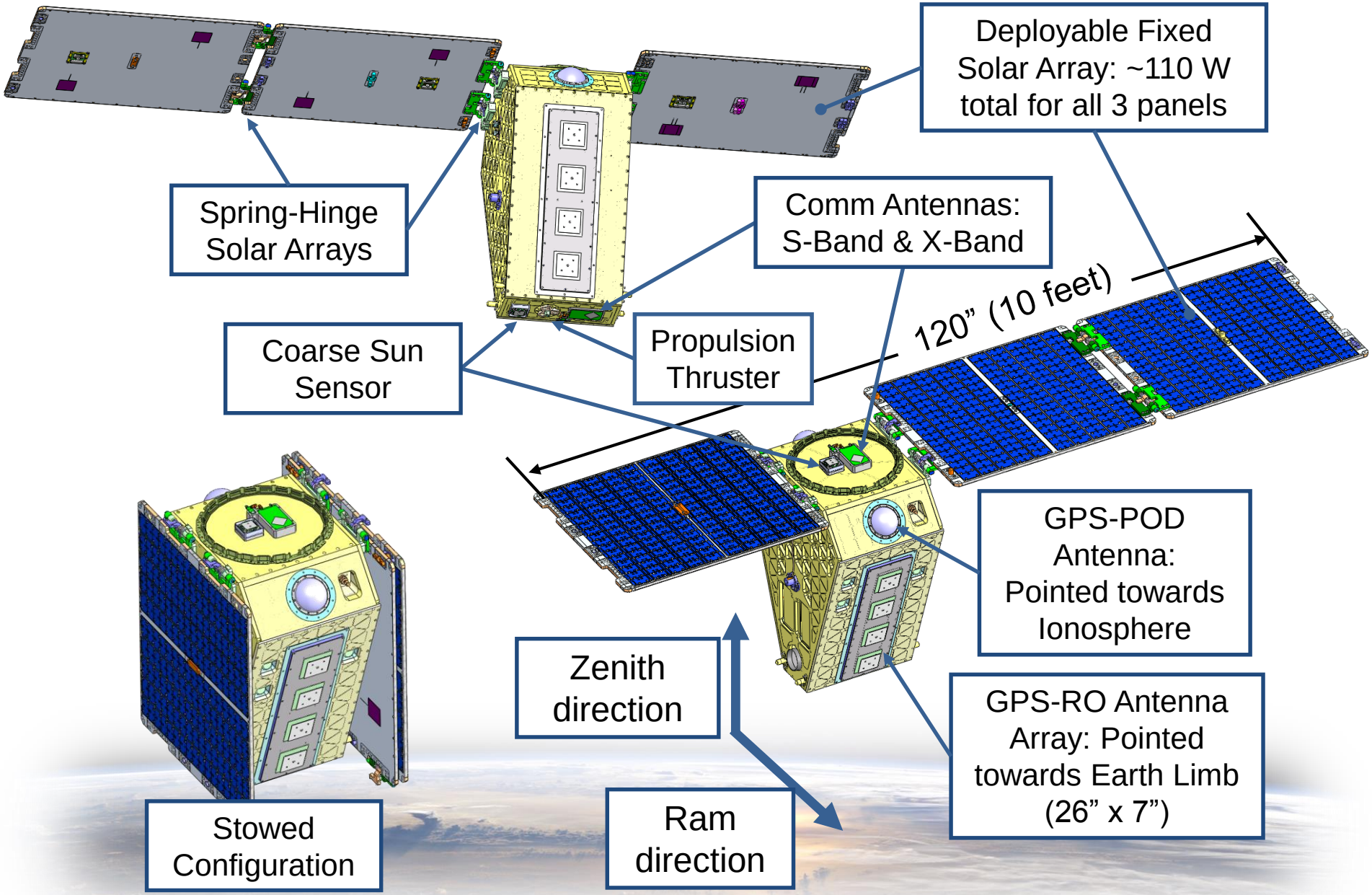
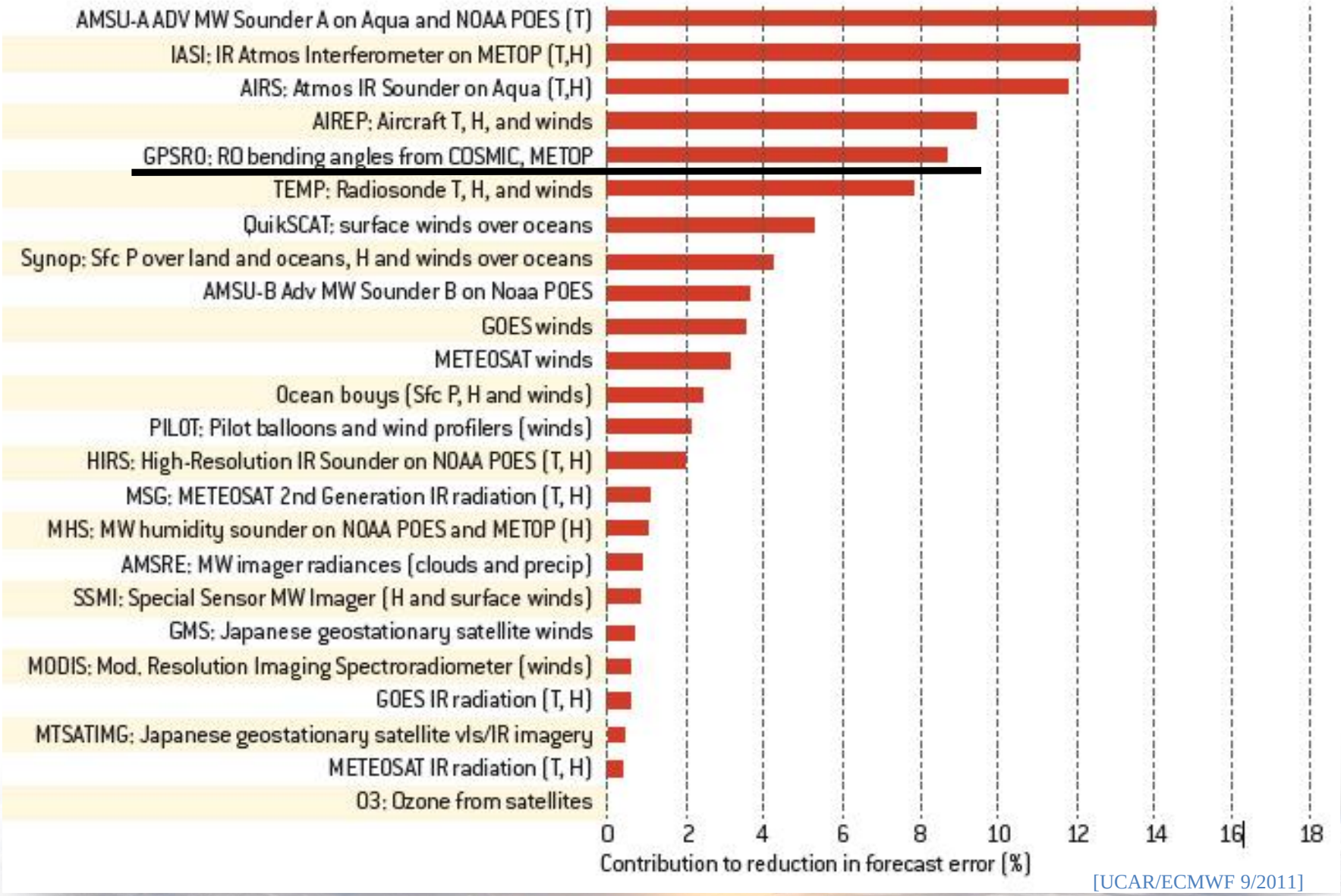
CICERO External Hardware



Impact of GPS RO on Forecasting



[UCAR/ECMWF 9/2011]