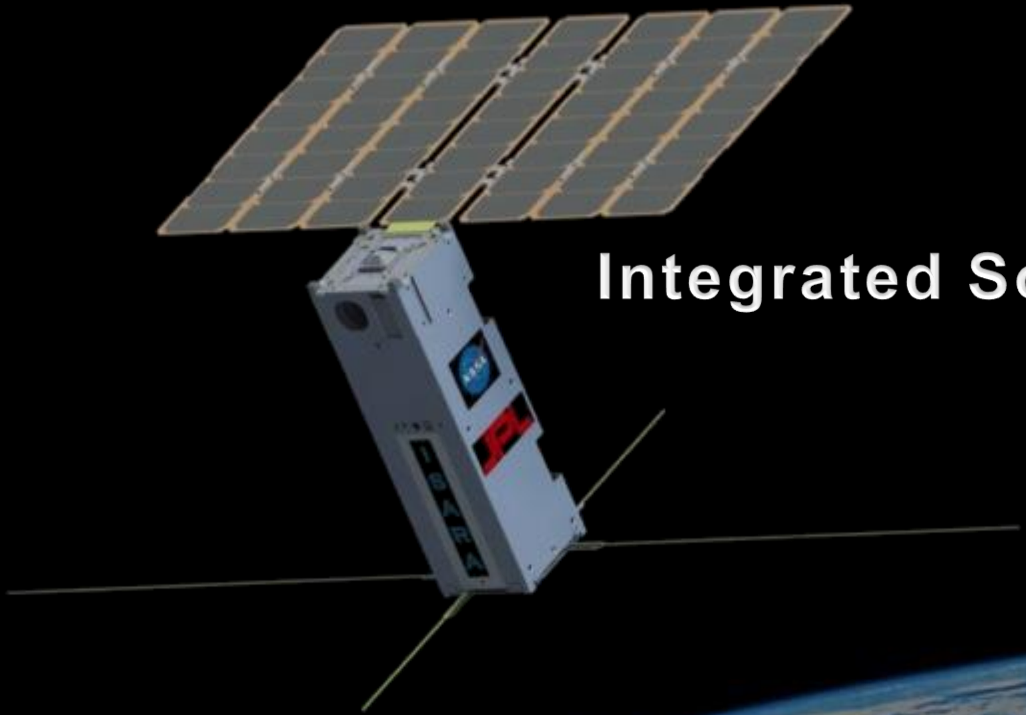


ISARA

Integrated Solar Array Reflectarray

Mission Overview

August 10, 2013

Dr. Richard E. Hodges – PI
Biren Shah – PM
Dhack Muthulingham – co-I, PSE
Tony Freeman – collaborator

Jet Propulsion Laboratory
California Institute of Technology

Overview

- ISARA Mission Summary
- Payload Description
- Experimental Design

ISARA Mission

I SARA

Objectives:

- Demonstrate a practical, low cost Ka-band High Gain Antenna (HGA) on a 3U CubeSat
- Increase downlink data rate capability to over 100 Mbps with minimal impact on spacecraft mass, volume, cost and power requirements.

Technology Payload:

- HGA integrated into a commercially available deployable solar array panel design.

Benefit to NASA:

- Enabling technology as high bandwidth comm is required for high resolution sensors.
- Foundational technology for low cost, highly versatile fractionated spacecraft and satellites in space-based networks.
- Technology can be used for sensors such as Radars & Radiometers.

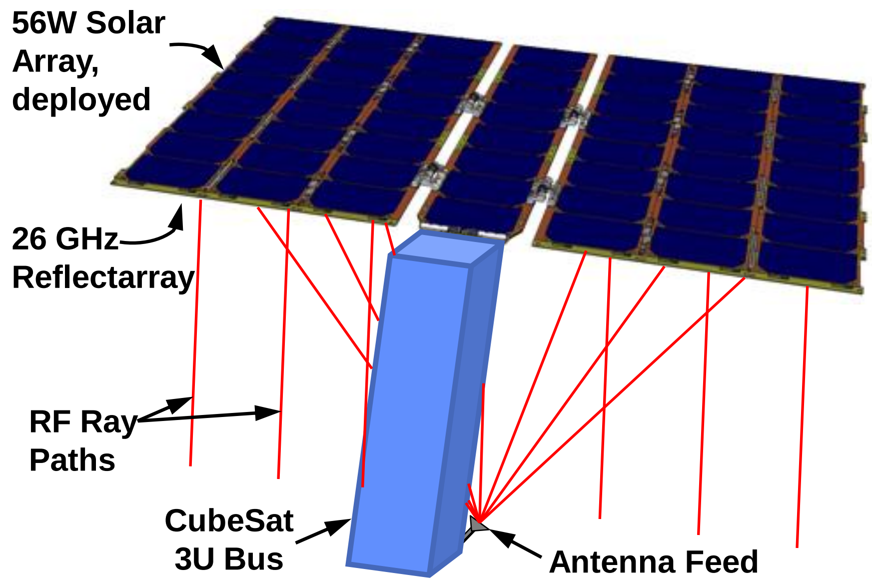


Illustration of Reflectarray mounted on CubeSat solar panels

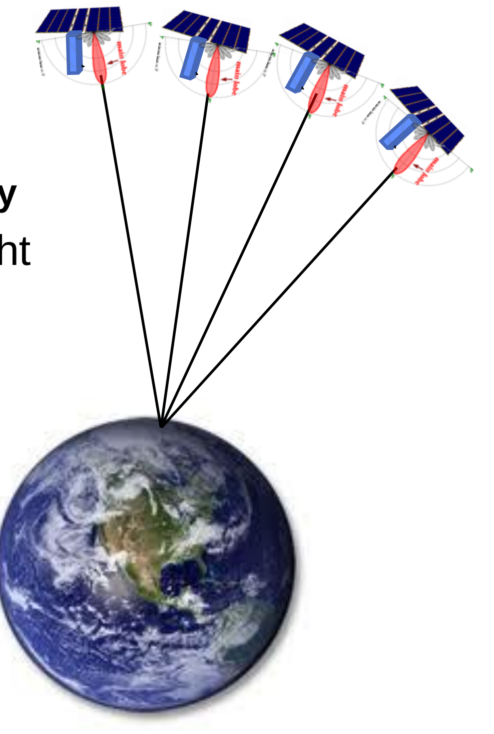
Team Members/Partners

Role	Name	Org
PI	Richard Hodges	JPL
PM	Biren Shah	JPL
Co-I	Dhack Muthulingam Tony Freeman	JPL
Collab	L. Jones, M. Zawadzki, A. Tourian, F. Aguirre,	JPL
Collab	Andrew Kalman	Pumpkin
Collab	Mark Johnson / Brian Davis	NRL/SGSS

On-Orbit Experiment Overview

- **Experimental Objectives**
  - Measure antenna gain to verify performance
    - **Compare with ground antenna measurements to demonstrate TRL 7**

- **Experimental Design**
  - Satellite in LEO orbit flies over ground station
    - **90 minute orbit – up to 7 minute observation time per pass**
    - **At least two usable passes per day**
  - ADCS system used to point antenna in nominal direction
    - **BCT star tracker ADCS maintains ~0.02º (3σ) pointing accuracy**
  - Stretch goal: measure antenna pattern during satellite over flight



- **Ground Station**
  - Ka-band receiver with medium gain antenna
  - UHF telecom system
  - Data recording system

Mission Features and Description

- **Key Mission Features**
  - Components at TRL 5 or higher
  - 2 years to Flight Readiness Review
  - Selected by CubeSat Launch Initiative (CLI)
  - Class D mission. Developed using tailored NASA 7520.5E standard.

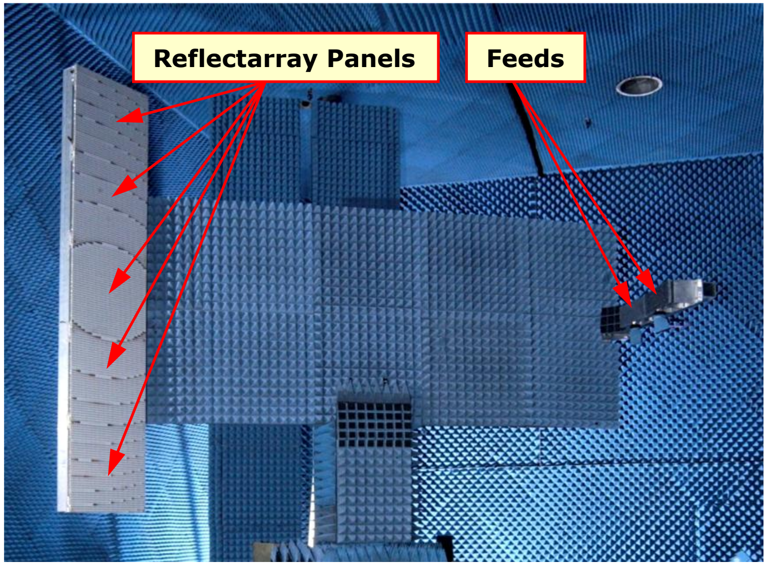
- **ISARA System Description**
  - S/C Configuration
    - S/C Bus – Pumpkin "MISC 3" 3U bus with "Turkey Tail" deployable solar array
  - Key Subsystems
    - Ka-band Payload – Reflectarray High Gain Antenna (HGA), Standard Gain Antenna (SGA), transmitter & switch
    - ADACS (Attitude Determination and Control System) – BCT XACT
    - UHF Communications – AstroDev Carbon 2 for s/c control and operations
    - C&DH (Command & Data Handling) – Pumpkin motherboard for computer control of s/c
    - EPS (Electrical Power System) – Pumpkin solar array, batteries, control module
    - Flight S/W – Naval Research Labs / SGSS: adapting Qbx S/W

HGA Antenna Technology Selection

- Table compares the most common types of HGA technologies when applied to a CubeSat

	Gain and Efficiency	Stowed volume	Mass	Cost	Deployment Mechanism
Reflector	Very High	Very Large	Medium	High	Antenna
Patch array	Medium	Medium	Medium	Med-High	Antenna
Active array	High	Large	Heavy	Very high	Antenna
Reflectarray	High	Small	Very light	Low	Solar Array

- Reflectarray technology was recently matured to TRL 5, funded by a NASA ESTO IIP for the SWOT mission
- Leveraged previous NASA investments such as the Wide Swath Ocean Altimeter (see figure at right).
- ISARA will demonstrate TRL 7 by performing a direct, on-orbit measurement of antenna gain



Reflectarray Antenna Developed for NASA's Wide Swath Ocean Altemeter

HGA Antenna S/C Integration

HGA – Reflector Characteristics

- Reflectarray antenna
- Flat and thin form factor.
- Capable of pencil beam, shaped beam, etc.
- Good efficiency (>50% demonstrated)

Solar Panel Mounting

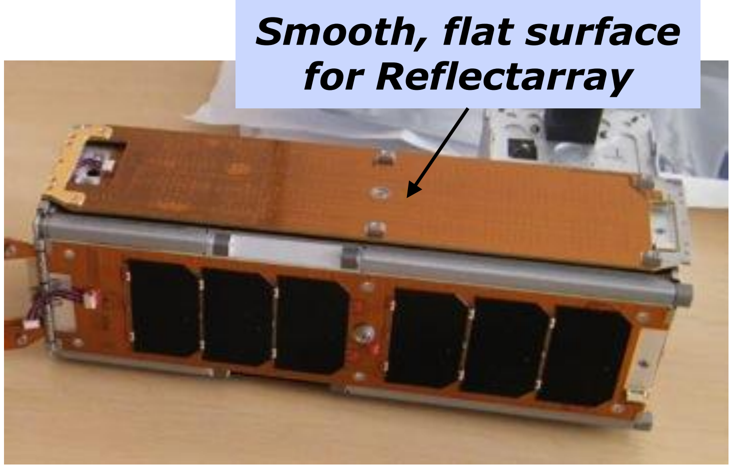
- Use "Turkey Tail" solar panel configuration
- Reflectarray panels mounted on back side of solar array panels
- Fits within the available space for solar panel
- Flatness is sufficient for antenna
- Hinges may need better positioning tolerance

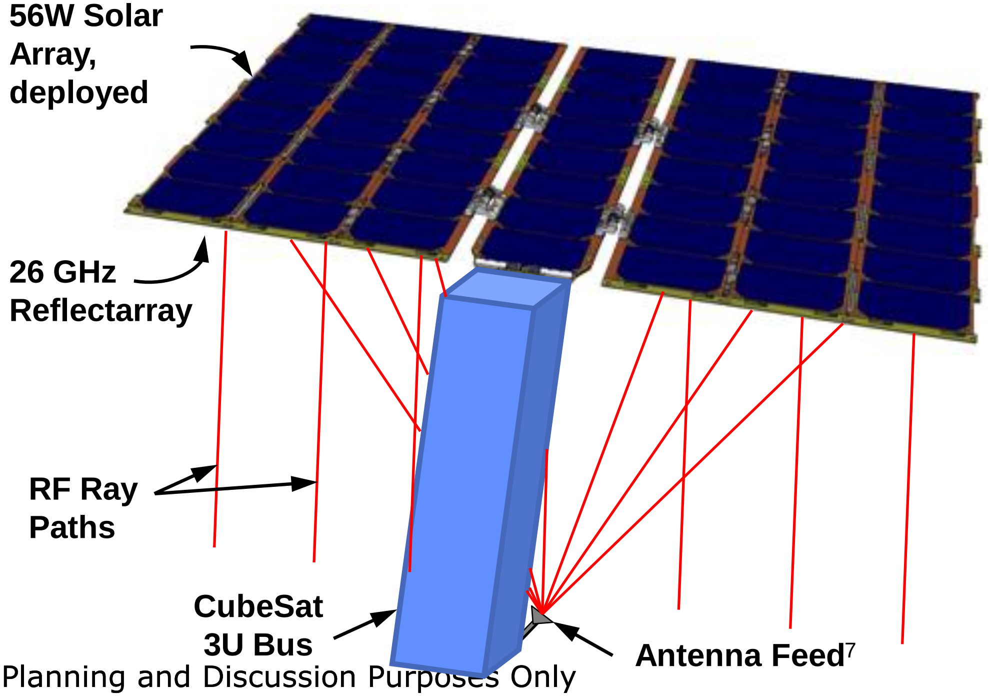
Feed

- Mounted on S/C bus
- "Flip Out" Deployment

Key S/C Requirements

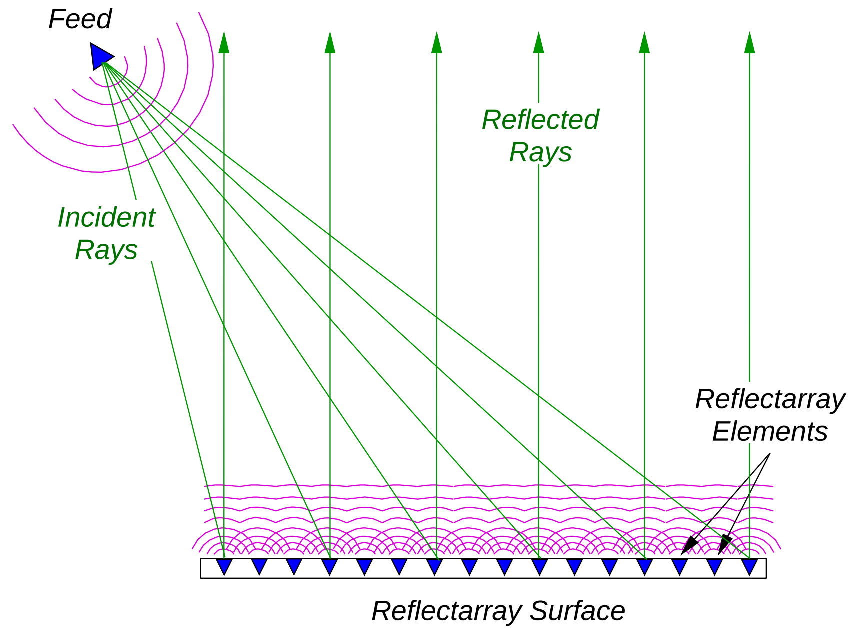
- Pointing accuracy – use reaction wheels
- Solar panel deployment accuracy – hinges

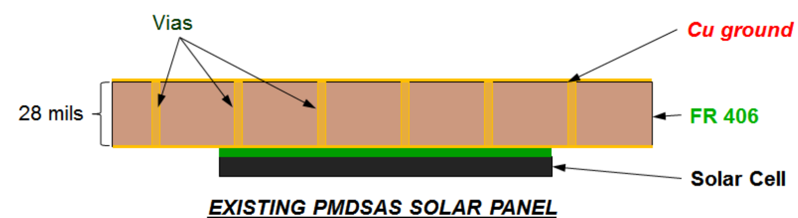


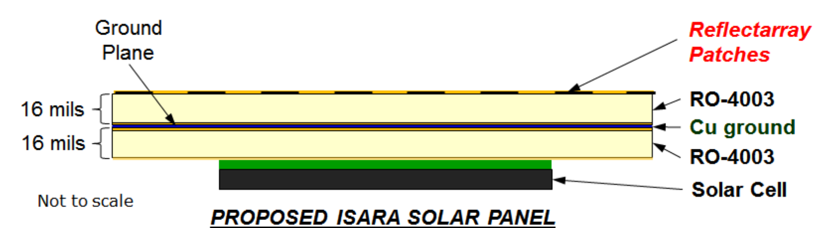


Reflectarray/Solar Array Integration

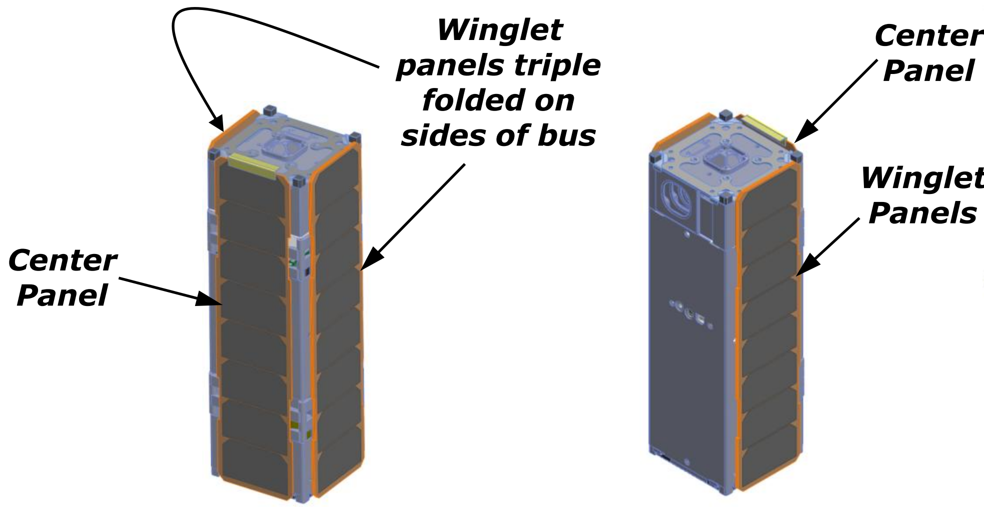
- **Solar Array**
  - Pumpkin Modular Deployable Solar Array System (PMDSAS™)
  - Standard solar cells mounted on a printed circuit board (PCB)
- **Reflectarray Antenna**
  - Collimate beam with a flat reflector
  - Copper patches etched on 15-20 mil PCB
  - Feed is a microstrip patch antenna
- **Solar Array/Reflectarray Integration**
  - Solar array and reflectarray integrated into a single circuit board
    - PCB material changed to multilayer configuration with Rogers dielectric
    - Vias changed to accommodate solar cells
- **Minimal overall impact on mass & volume**





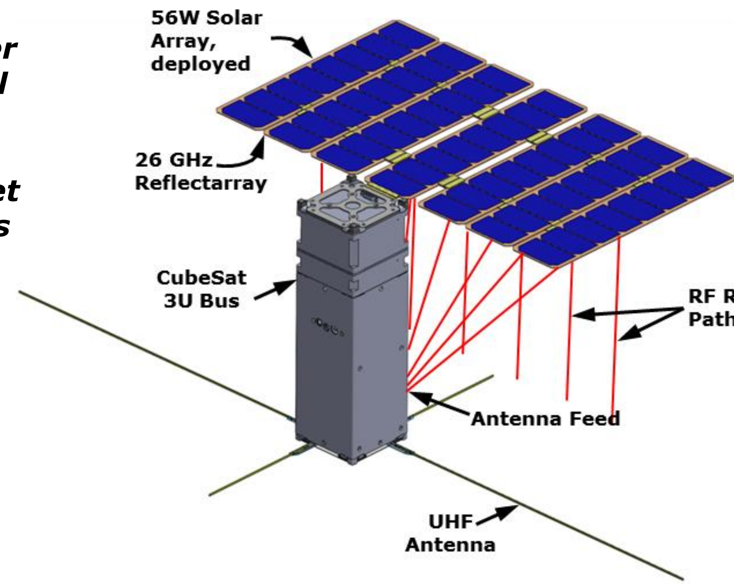


Reflectarray Deployment

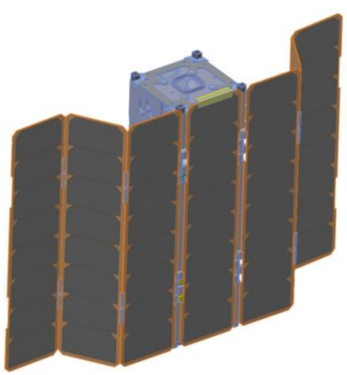


Front View *Back View*

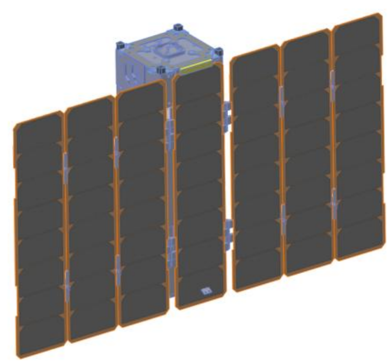
Stowed Configuration



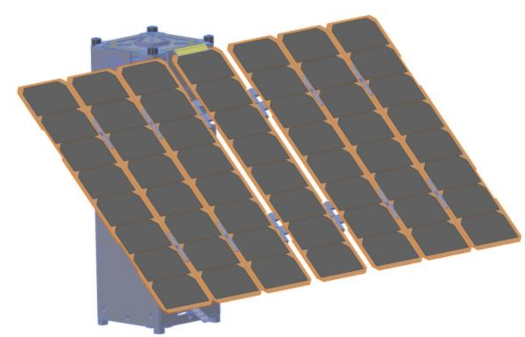
Deployed Configuration



Triple folded side panels flip out



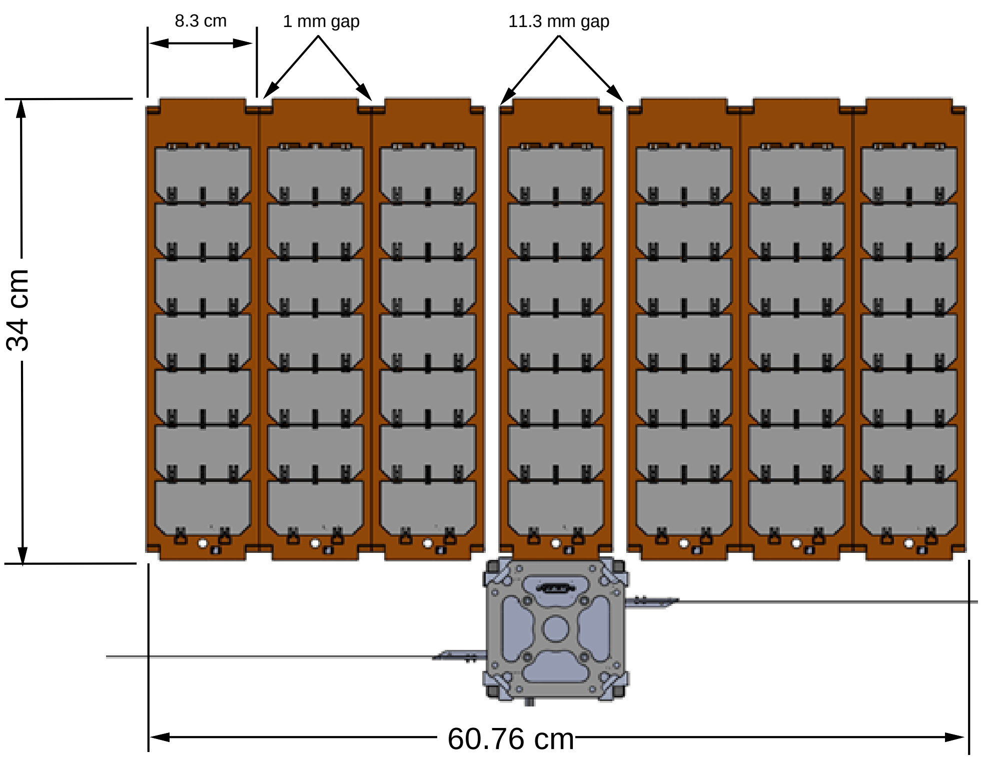
Panels fully unfolded

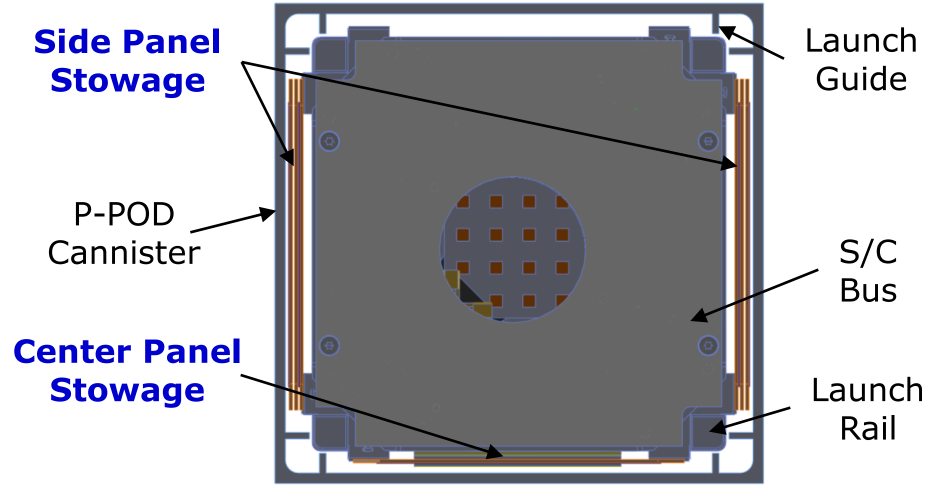


Solar Array Flips up

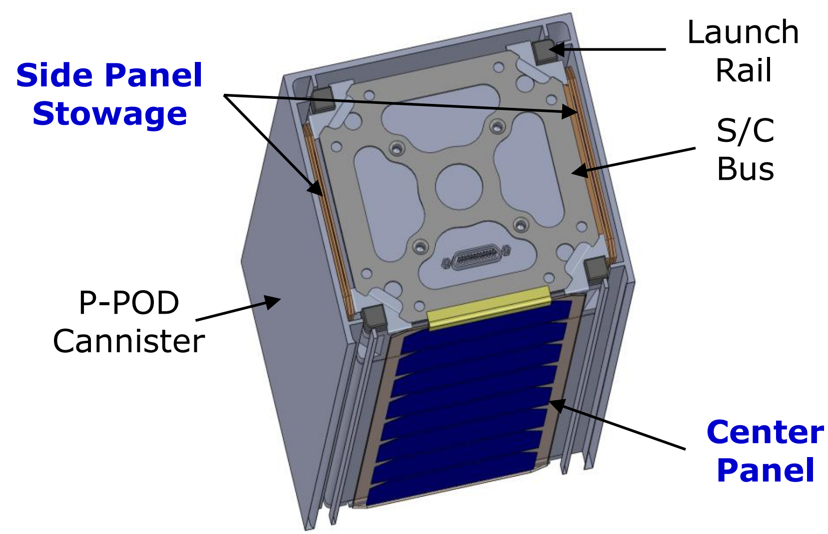
Panels Stow Between P-POD and S/C Bus

- **Available space for panels**
  - 8.3 cm space is available to stow panels between the bus and the P-POD (10cm – 2*0.85 cm)
  - Central hinge gap = 1.13 cm
- **Available Reflectarray Aperture**
  - Azimuth aperture length is 60.7 cm overall
  - Elevation aperture length is 34 cm



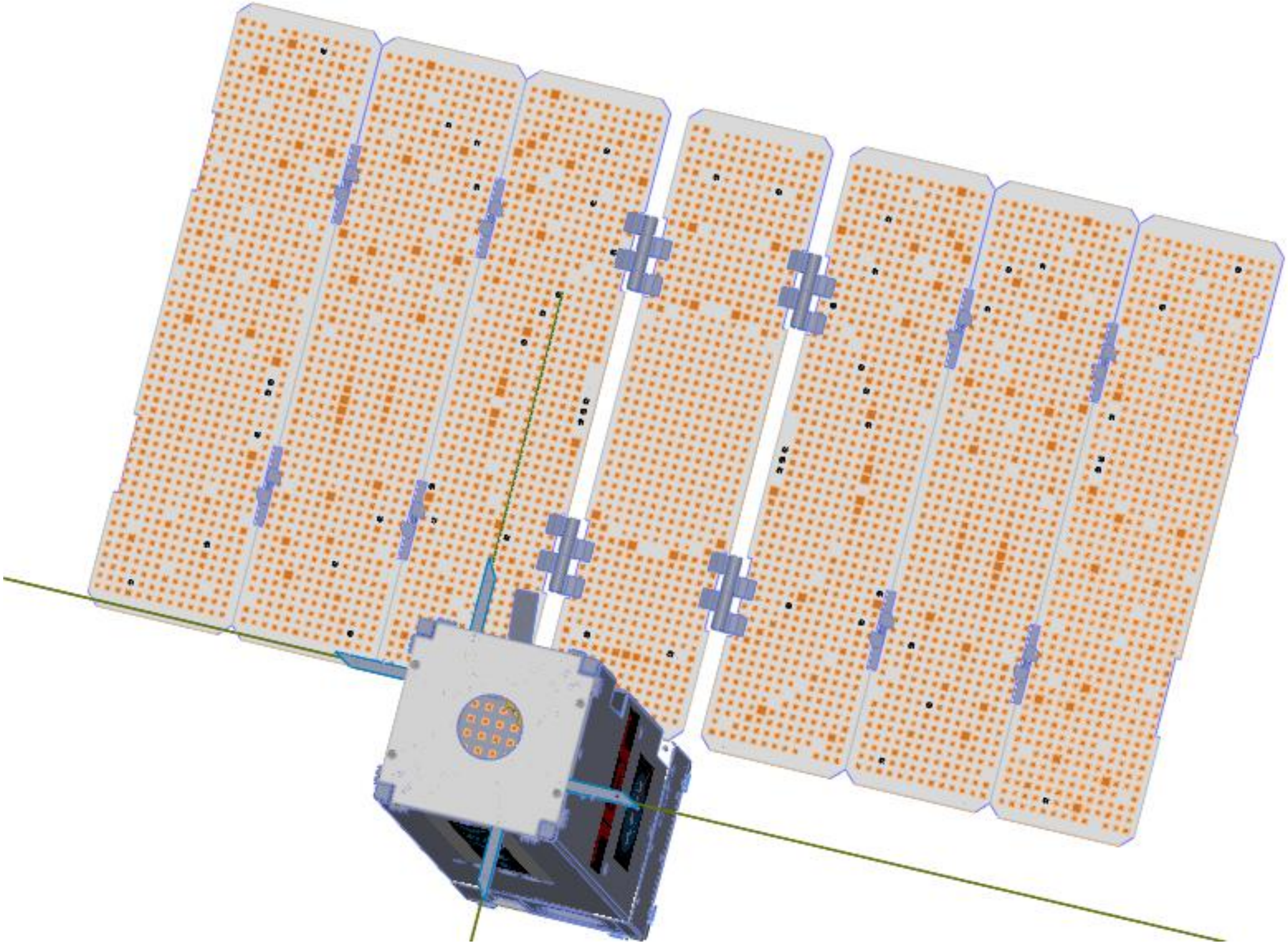


Bottom View

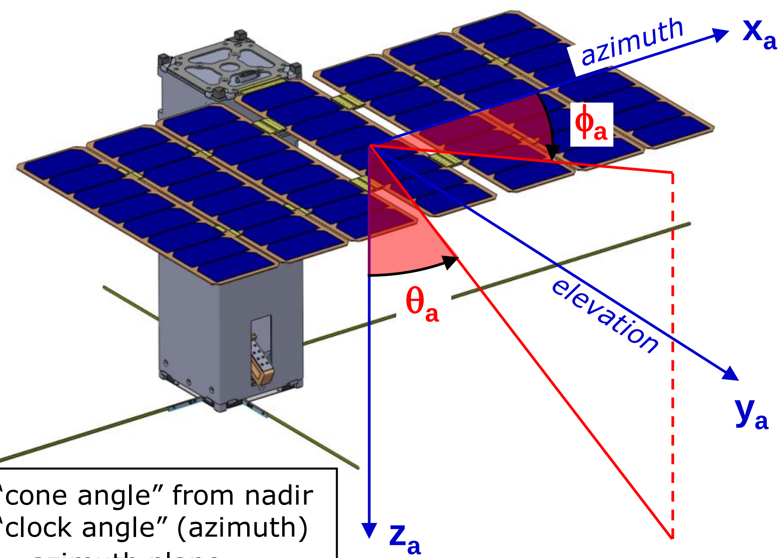


Top: Cut-Away View

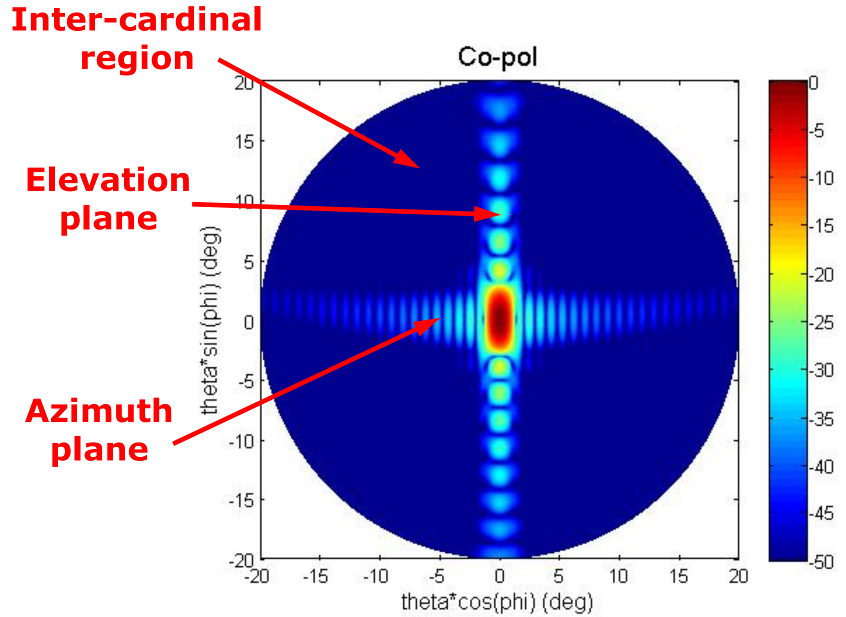
ISARA Reflectarray Spacecraft Assembly



Antenna Characteristics

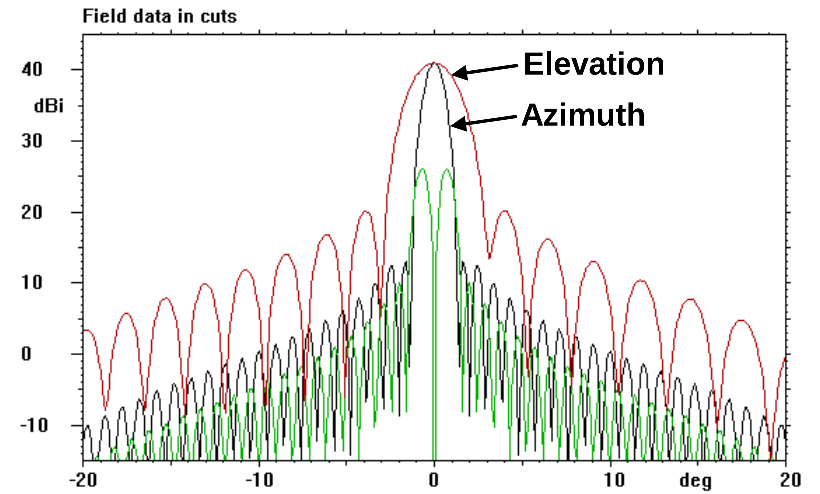


θ_a = "cone angle" from nadir
ϕ_a = "clock angle" (azimuth)
x_a-z_a = azimuth plane
y_a-z_a = elevation plane



Key Antenna Characteristics:

- Gain (~35 dB)
- Principal plane pattern parameters
  - Beamwidth (~ 1° x 2°)
  - Sidelobes (~ 20 dB first sidelobe)
  - Cross-pol (~15 dB relative to main beam)



Principal Plane Patterns

Antenna Gain Measurement

Ka-Band Payload

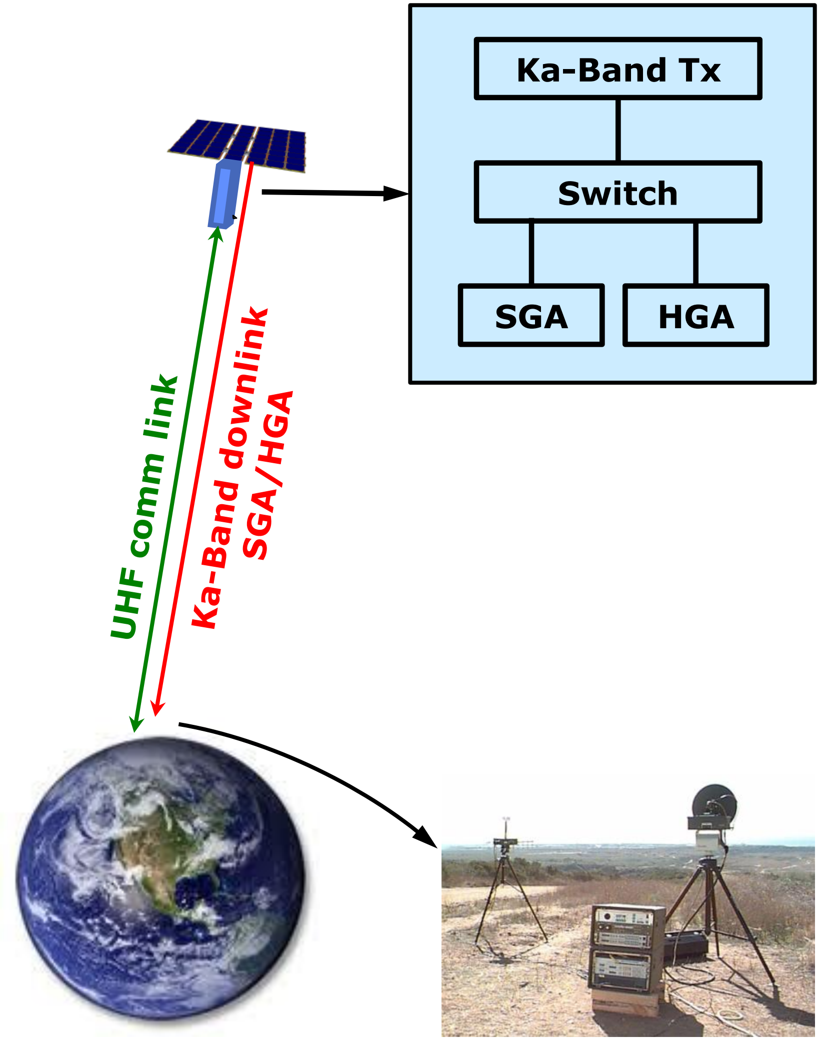
- 35 dB Reflectarray High Gain Antenna (HGA)
- 16 dB Standard Gain Antenna (SGA)
- Ka-band CW transmitter switches rapidly between SGA and HGA
  - Normalize space loss, atmospheric attenuation

On Orbit Gain Measurement

- Command s/c to aim HGA beam peak at ground station
- Transmit Ka-band tone while slowly switching between HGA and Standard Gain Antenna (SGA)
- Monitor and record Ka-band received signal
- Record s/c location and orientation
- Method simulates key features of radio transmission

Ground processing

- Record received power P_{HGA}, P_{SGA}
- Convert observation angles to antenna C.S.
- Use HGA and SGH data to determine HGA gain
  - Gain = meas HGA – meas SGA + known SGA Gain
- Compare measured data to calculated gain



Concluding Points

- **ISARA would provide practical HGA option for 3U and larger class CubeSats**
- **Key advantages compared to deployable parabolic reflector**
  - Very Low Cost
  - Minimal impact on stowed volume (compared to > 1U stowage for parabolic reflector)
  - Minimal mass impact
- **Enables 100 Mbps telecom data rate**
- **Potential application to CubeSat instruments**

Backup Slides

ISARA Configuration (TBR)

I SARA