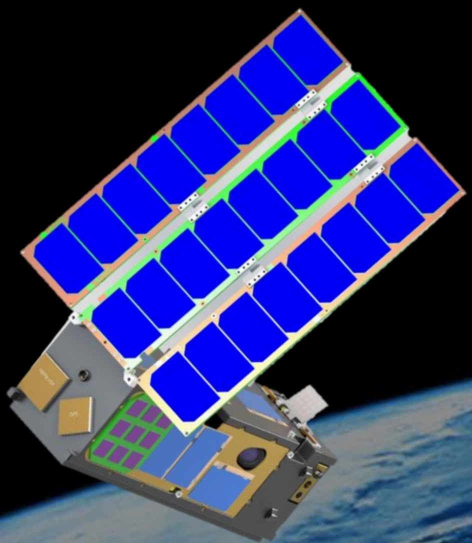
ISARA Lessons Learned



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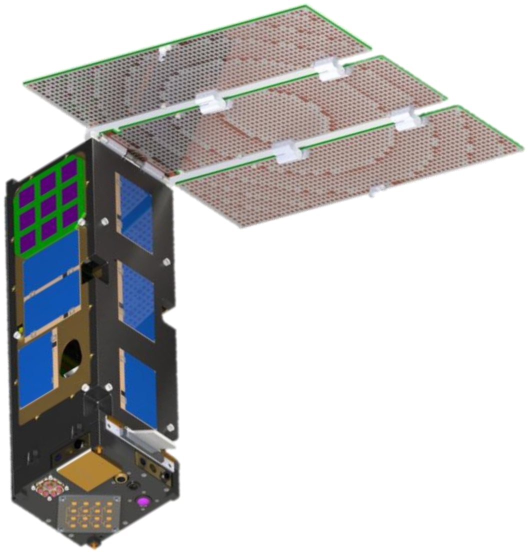
Project Overview

Objectives:

- Demonstrate a practical, low cost Ka-band High Gain Antenna (KBA) on a 3U CubeSat to enable increasing downlink data rates from 9.6 kbps to over 100 Mbps with minimal impact on spacecraft mass, volume, cost and power requirements.

Enabling Technology:

- Integrated Solar Array Reflectarray Antenna (ISARA)



ISARA Reflectarray/Solar Array mounted on a 3U CubeSat

Subsystem Flight Validation Plan

- Measure KBA Gain from Low Earth Orbit and validate against antenna model
- Measure Carrier SNR to demonstrate application of KBA to high data rate links
- Flight System – CubeSat w/ ISARA antenna in LEO orbit
- Ground System – Ka Terminal for experiment, UHF for S/C communications and control

Role	Name	Org
PI	Richard Hodges	JPL
Proj Mgr	Dorothy Lewis / Richard Welle	JPL / TAC
Payload Manager	Dan Hoppe	JPL
Payload Partner	Andrew Kalman	Pumpkin
S/C Bus and ops	Darren Rowen	TAC

ISARA On-Orbit Gain Measurement

Ka-Band Payload

- >32 dB Reflectarray High Gain Antenna (HGA)
- 19 dB Standard Gain Antenna (SGA)
- Ka-band CW transmitter switches rapidly between SGA and HGA

Gain Measurement

- Record received power P_{HGA}, P_{SGA}
- Calculate HGA gain:
  - Gain = $P_{HGA} - P_{SGA}$ + known SGA Gain

Key Advantages

- ***Eliminates key uncertainty factors:***
  - Transmit / receive line power losses
  - Space loss
  - Atmospheric loss
  - Ground station antenna pointing error
  - Minimize polarization mismatch loss
- ***Residual error can be estimated***
  - Receiver noise, SGA knowledge, etc.
    - Receiver noise is the main source
  - S/C antenna pointing (cause gain underestimate)
  - Directly calculate mean and variance

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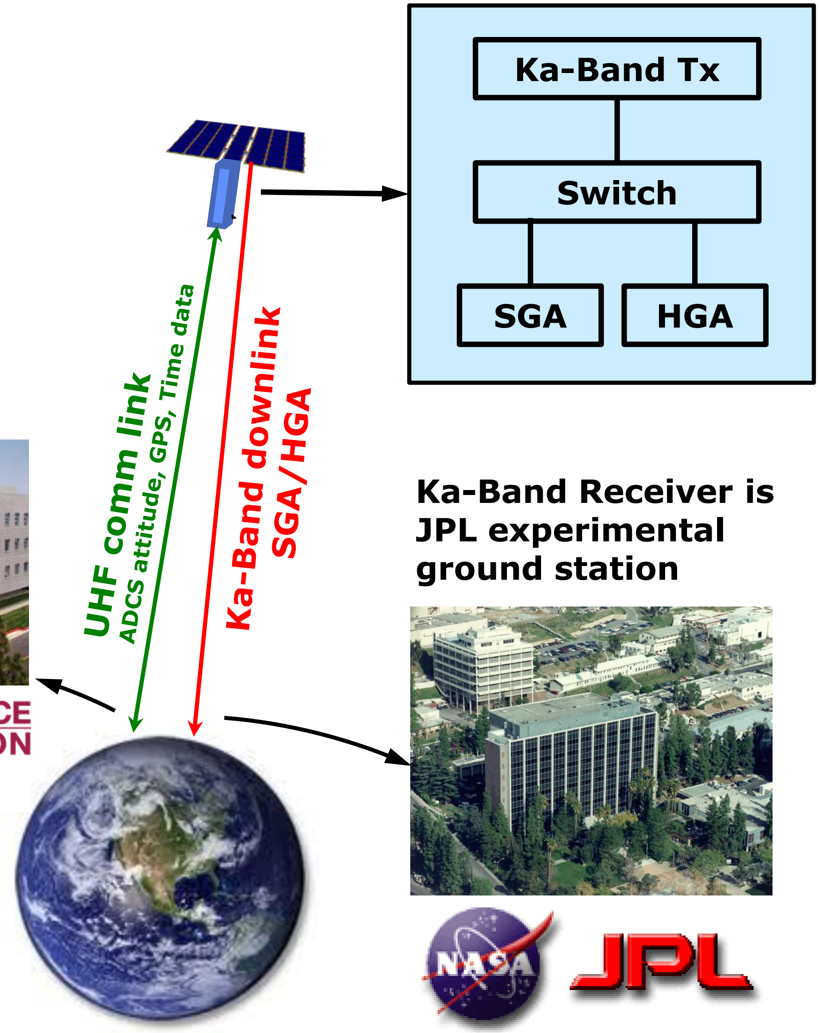


JPL

Lessons Learned (1 of 3)

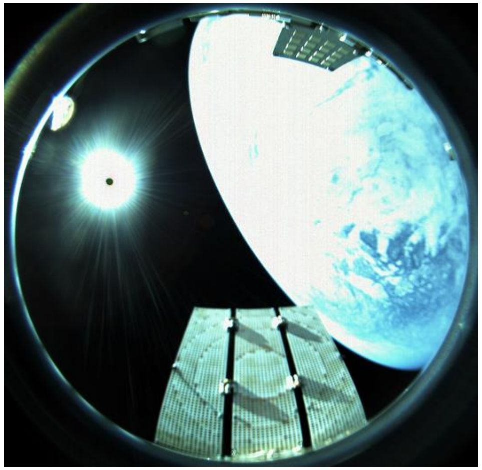
- **NTIA (or FCC) License**
  - Start early!
    - **FCC changed the rules & we got rejected for a FCC license at UHF.**
  - ISARA specific requirement for UHF signal to be present when operating Ka-band.
    - **Check available stations & verify same "footprint" for both, to ensure adequate coverage**
    - **Got lucky here. Our partner put a station at Vandenberg, which is close enough to JPL to have very similar coverage.**
- **Ground Station Development**
  - List all of the constraints of station (Location (FOV), placement of electronics, mission type considerations, noise at frequency of operation, etc)
    - **Write requirements to satisfy constraints**
  - Plan (far) Ahead!
    - **Length of time (Involving facilities, safety office, ordering material, etc)**
  - Station Calibration
    - **Do you have something to test this station against?**

- **Reevaluate Plans as Necessary to Keep Things Simple**
  - Initial proposal was to have JPL build & operate the entire satellite.
    - **Switched to Aerospace Corp for "Off-the-Shelf" bus & for UHF command and control.**
  - Antenna panels were initially proposed for 5-7 panels.
    - **Went with 3 panels in the end.**

Lessons Learned (2 of 3)

- **Holes drilled in the antenna PCB fab for solar cell installation**
  - Contractor assembling the antenna had concerns with trapping air bubbles under the cells
  - Contractor had us drill ~1000 holes in each PCB (between patches of the array) to mitigate "risk"
  - During satellite vibe, the conductive, PCB material blanketed the satellite body with a dot-pattern, matching the hole pattern of the array!
  - Resulted in consultation of material experts & rework to painstakingly fill all 6000 holes by hand! (3000 on EM unit and 3000 on FM unit)
  - Trust your gut! Don't give into un validated concerns
- **Identify, then Mitigate for Project Identified Potential Risks**
  - Held a project level risk of panel bowing over temp.
    - **Should have added a temp sensor on the antenna wing**
  - Add more telemetry!
    - **Cameras are great.**
    - **If you can add it with minimal effort- do it.**
    - **Success rates are improving on CubeSats…**

    but plan for the unexpected.



Lessons Learned (3 of 3)

- **Do your Homework up Front, Apply Resources Proportionally to Perceived Risk**
  - Not running enough/sufficient analysis up front resulted in technical problems down the road (Costing more $ to fix).
    - **Mechanical stresses (Failing Vibe- multiple times)**
    - **Release mechanism failure**
    - **EPS-H Board Failure**
    - **New Ground Station Development**
  - Beware of heritage arguments
- **Ensure you have an adequate APPROVED plan in place PRIOR to operations.**
  - This ensures everyone knows how to proceed as events occur.
  - Who gets informed of what and when?
  - How to deal with different classes of s/w changes in-flight.
    - **Level of review required. Internal only, or outside review?**
- **Other Bits of Wisdom**
  - Test As You Fly (TAYF)
  - Take quality photos along the way
  - Don’t skimp on reviews or round tables (Get others’ inputs)
  - Don’t be complacent or treat the hardware as second-class, because it’s a Cubesat.