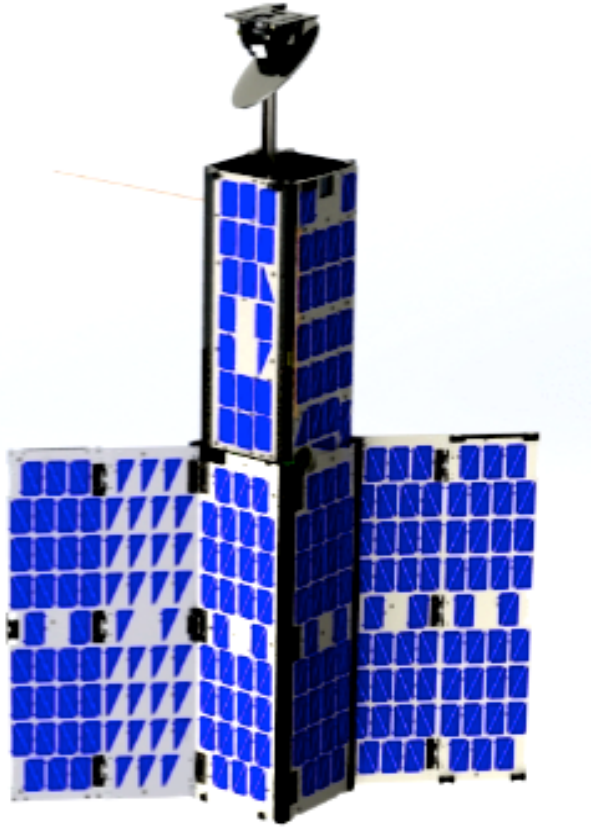


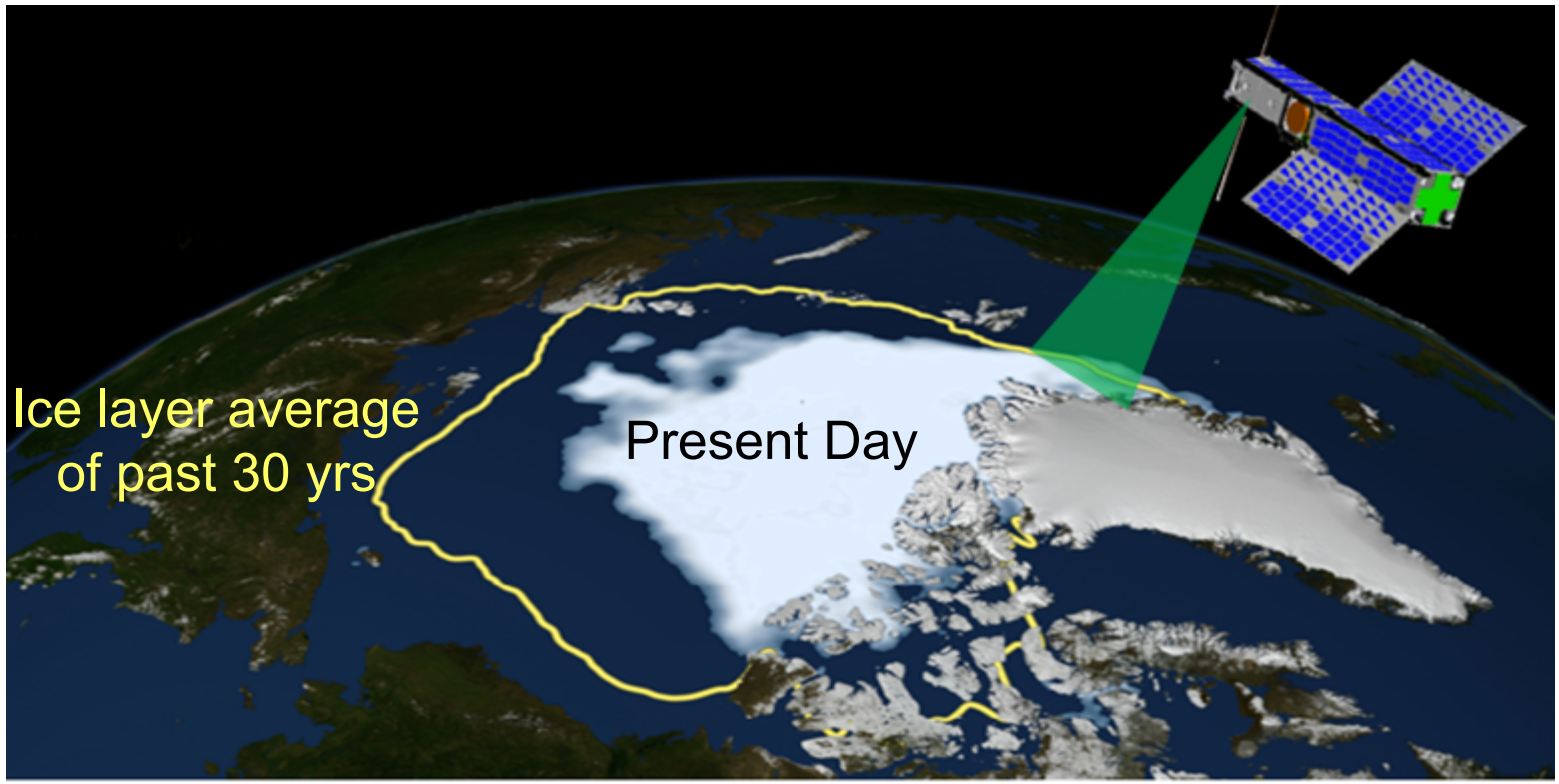
PolarCube

University of Colorado
Boulder

Colorado Space Grant
Research Symposium

April 19, 2014
Boulder, Colorado

Mission Overview



PolarCube will perform tropospheric temperature sounding using the 118 GHz O_2 resonance, by using a radiometer.

Mission Application

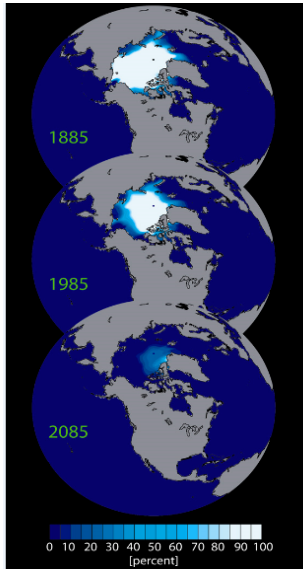
Polar

Perform observation of sea ice/open ocean boundaries.

Critical effect on troposphere in Polar regions.

Summer/Fall Arctic Ice Retreat

Moisture heat flux/storage

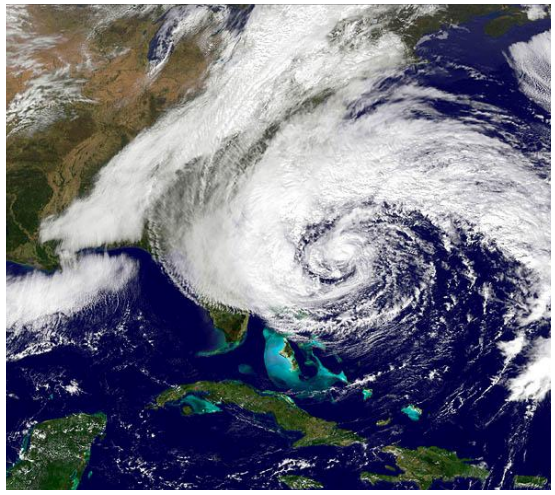


Aug Sept Oct Sea Ice Concentration Prediction

Weather

Providing representative data inputs to tropospheric weather models applicable to sever mesoscale weather phenomena.

High resolution/real-time warm core behavior of hurricanes/mesoscale weather.



Hurricane Sandy Image taken by NOAA (10-27-2012)

Heat Detection

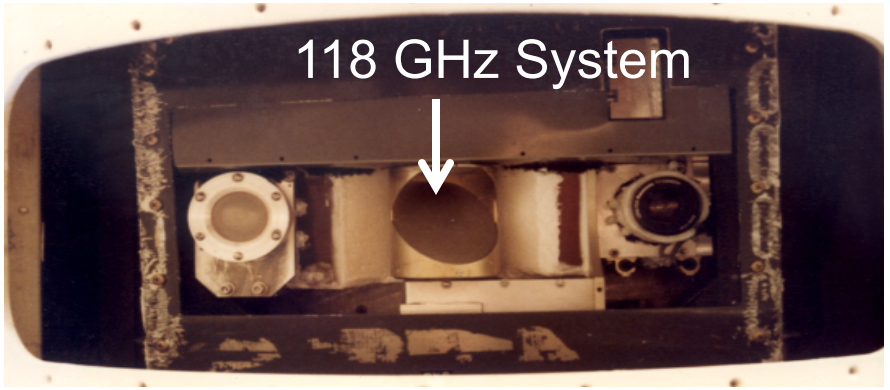
Cloud penetrating thermal imaging.

Heat detection through cloud Cover.

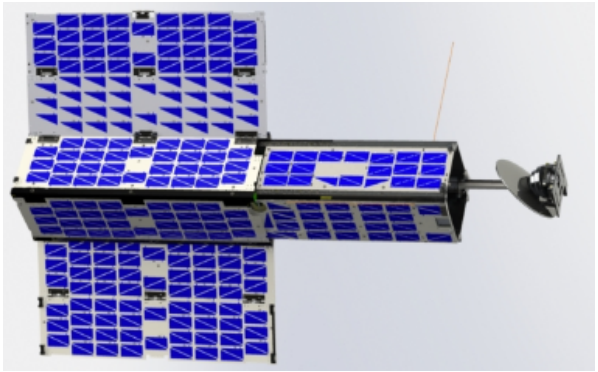
Can accomplish with a radiometer centered at 118.7503 GHz O_2 atmospheric temperature sounder.

Radiometer Technology

- Miniaturized past flown radiometer
  - NASA ER-2 Millimeter Wave Temperature Radiometer (MTS) 1986
  - ~600 lb.
- Temperature profiler
  - High resolution
  - ~2X Spatial res. Better than AMSU-AB
    - Currently used for weather predictions (temp. sound.)
  - Low cost alternative
- First to explore…
  - Passive Microwave sensing at 118 GHz small satellite (one of the first)
  - Observe Polar regions
  - Investigate Sea Ice/Water imaging
- Pathfinder
  - Constellation on staggered orbits
  - Near real time high resolution data at low cost

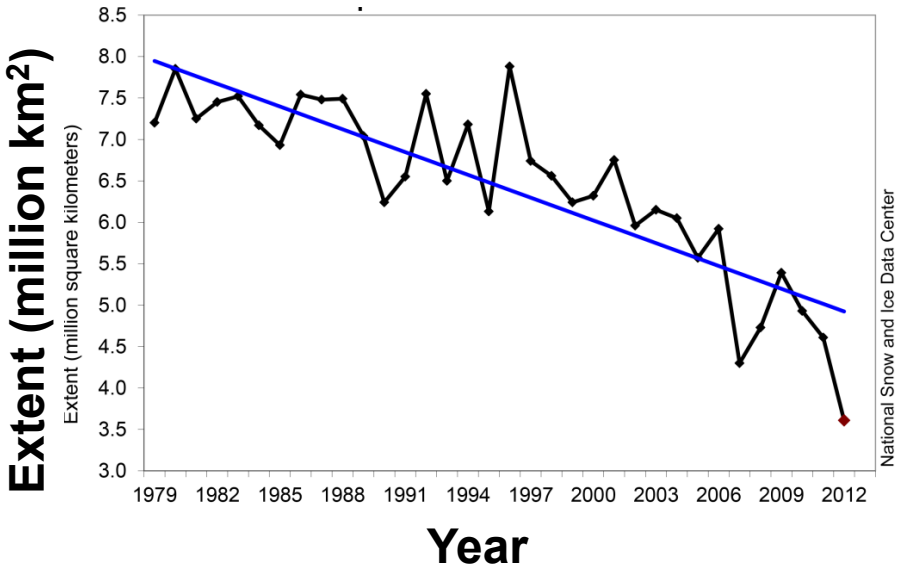


NASA ER-2 Aircraft & MTS Radiometer



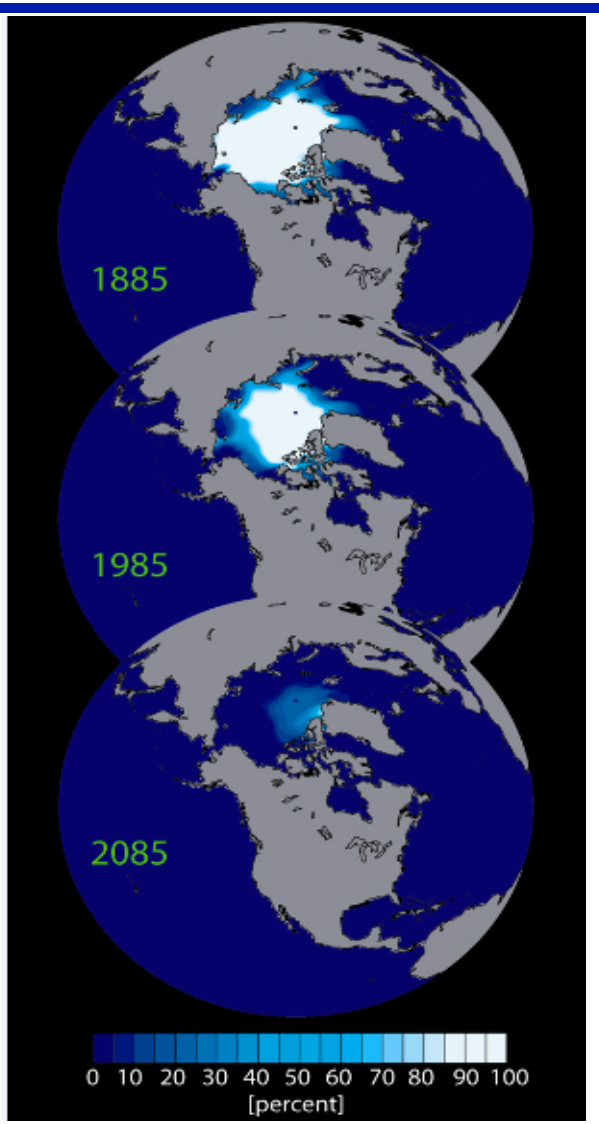
PolarCube Deployed spacecraft

Polar Science



Average Monthly Arctic Sea Ice Extent: September 1979 - 2012

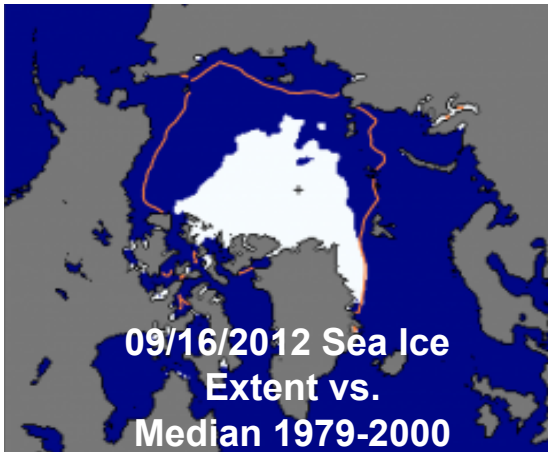
- Critical effects on troposphere
  - Summer/Fall Arctic ice retreat
  - Moisture heat flux
- Proper modeling
  - Response to global atmosphere
  - Radiative feedbacks to sea ice

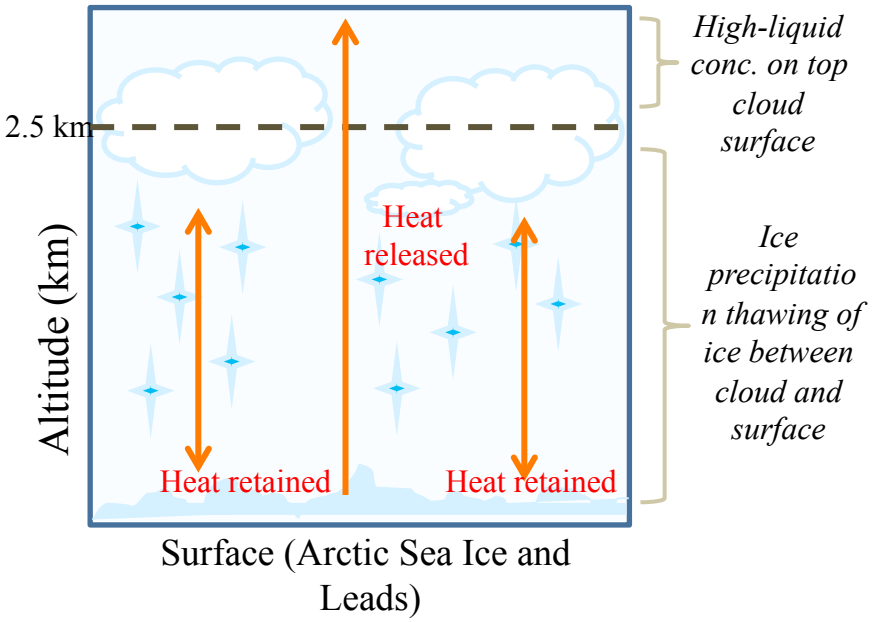


Average Fall Sea Ice Concentration Prediction

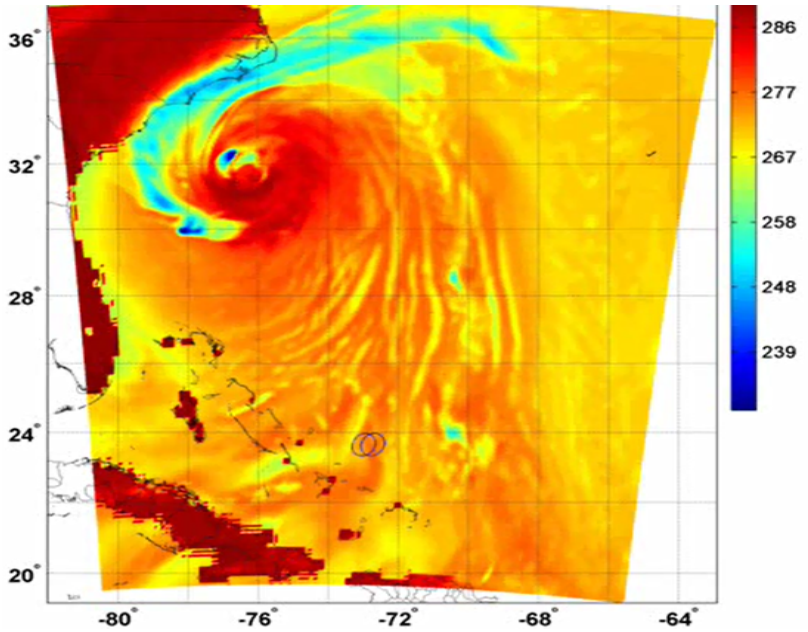
Polar Science

- Correlation: Sea ice & tropospheric arctic temp. variations
  - Cloud radiative feedback
    - Uncharacterized heat flux
  - Cloud cover change
    - Thinning sea ice
    - Biogenic impact
    - Ocean mixing
- Application: Arctic climate modeling
  - Radiative feedback models
- PolarCube
  - High-res. temp. profile needed for arctic climate modeling





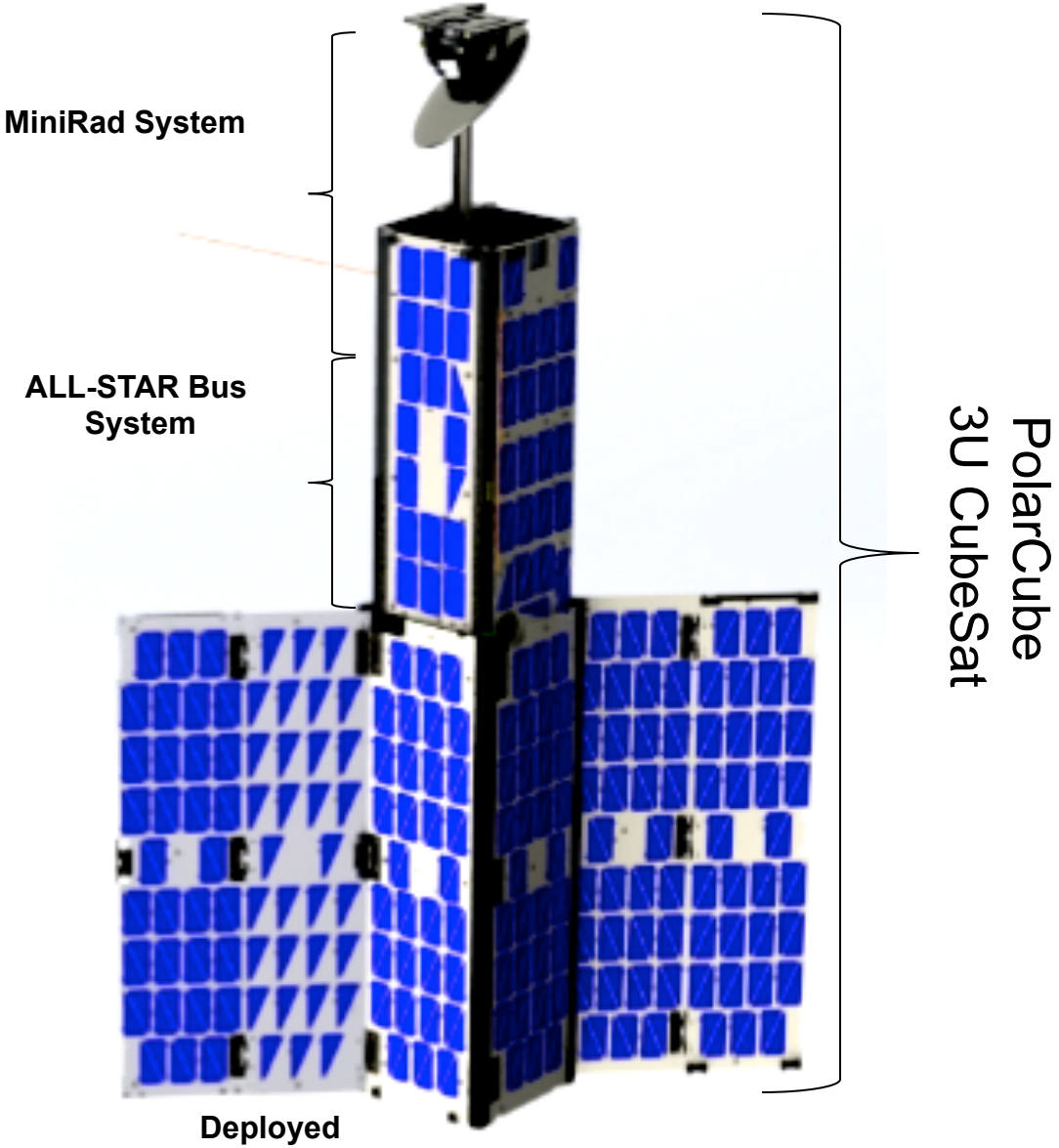
Numerical Weather Forecasting – PolarCube as a PATH demonstrator



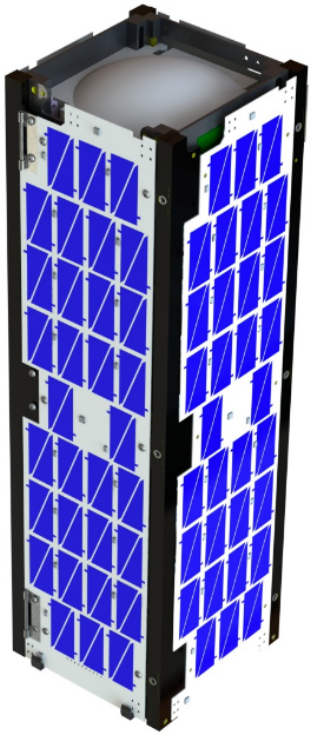
Hurricane Bonnie: Aug 1998 113.7503 GHz Brightness Temperature (top of atmosphere)

- PATH = Precipitation, Atmospheric Temperature and Humidity
  - PolarCube as a PATH array constellation satellite
  - Potential cost savings of a CubeSat-based satellite fleet
- Severe mesoscale weather
  - 15 minute time scales
  - 16.5 km resolution
- Hurricanes
  - Hurricane warm core behavior
  - Tropical cloud ice background measurements

PolarCube Spacecraft

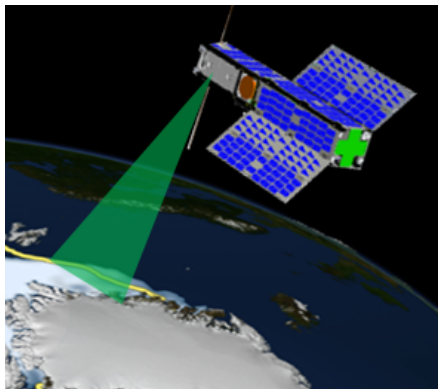


Deployed

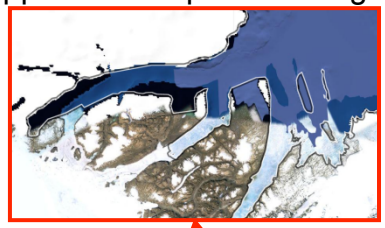


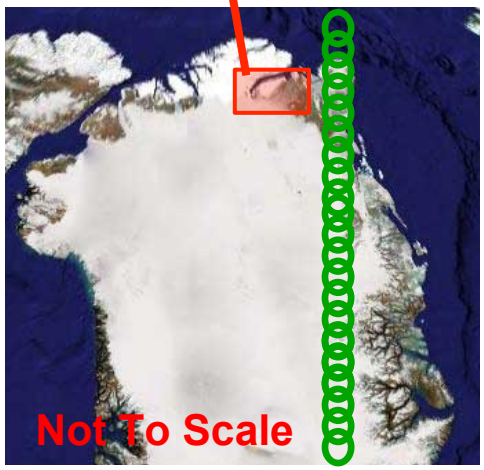
Stowed

MiniRad Data Collection



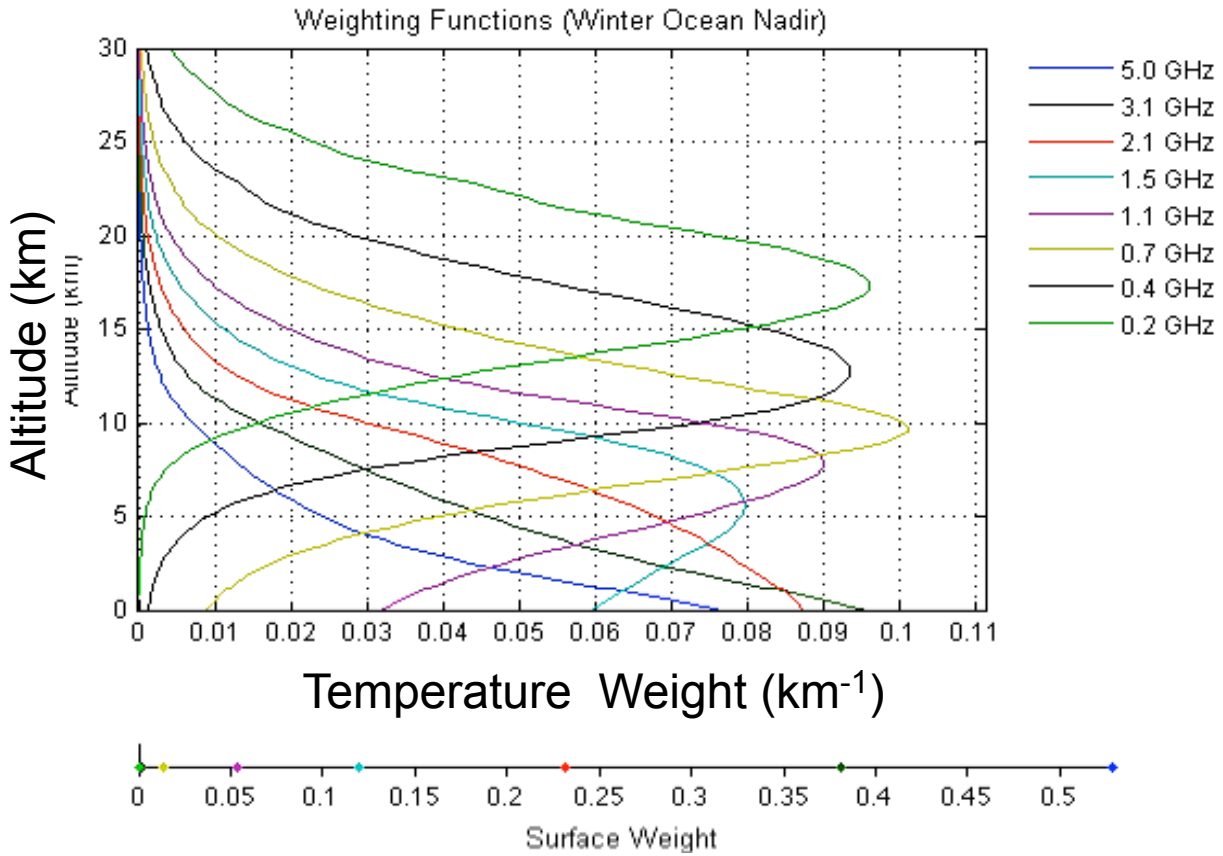
Approximate spot size on ground





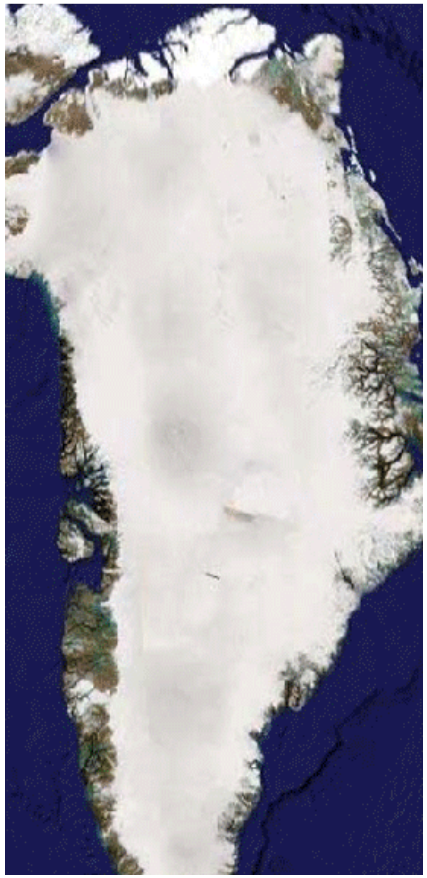
16.5 km Data Sample taken by PolarCube

- Sub-Track Data Sampling
  - Function of temperature & altitude
  - Each channel corresponds to different frequency
    - Centered at 118.7503 GHz



Data Collection: Operational Modes

Stabilized Instrument Demonstration (Minimum Success)



1.0 Hz MiniRad Sounding: Cold Calibration & Nyquist Sampling (map)

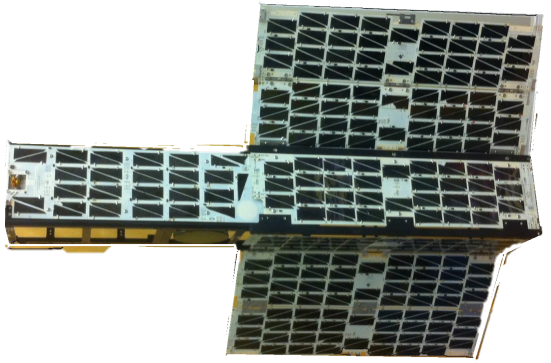
Temperature Profiling over Greenland (Not to Scale)

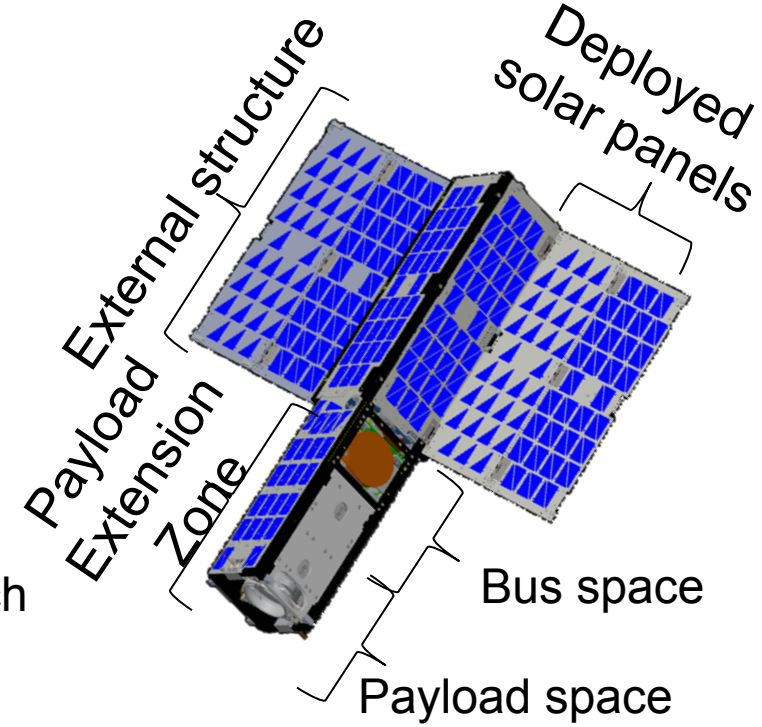
Science Data Collection

PolarCube using ALL-STAR

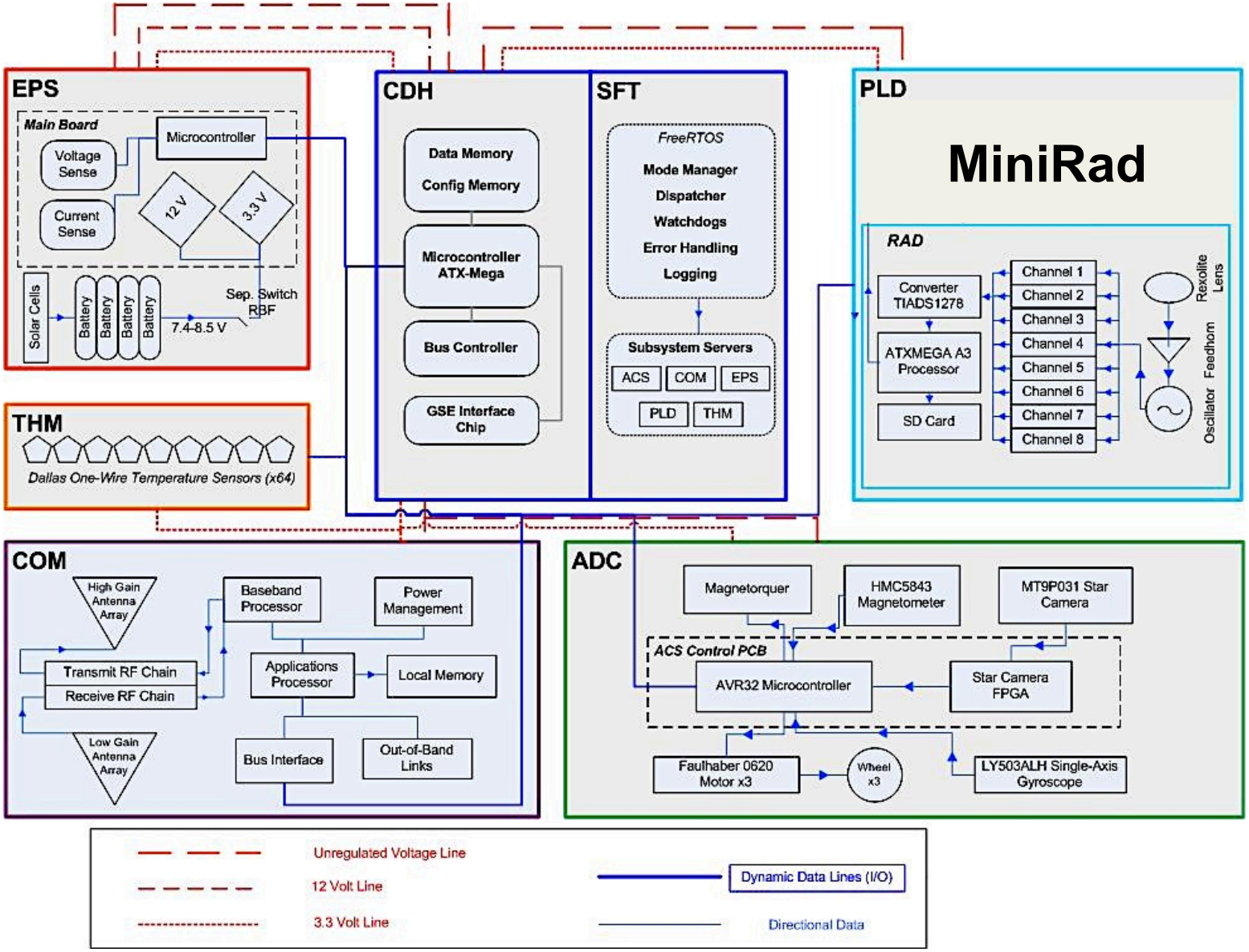
Agile
Low-cost
Laboratory
- for
Space
Technology
Acceleration
Research

- Purpose
  - Reproducible bus capable of flying variety of small payloads
  - Low cost
  - Support up to 1 year of research
- 3U CubeSat Bus
  - Bus components: 1.5U
  - Payload: 1.5 U
- Deployment
  - Payload extension
  - Solar panel wings
- Status
  - ALL-STAR-THEIA launch March 2014



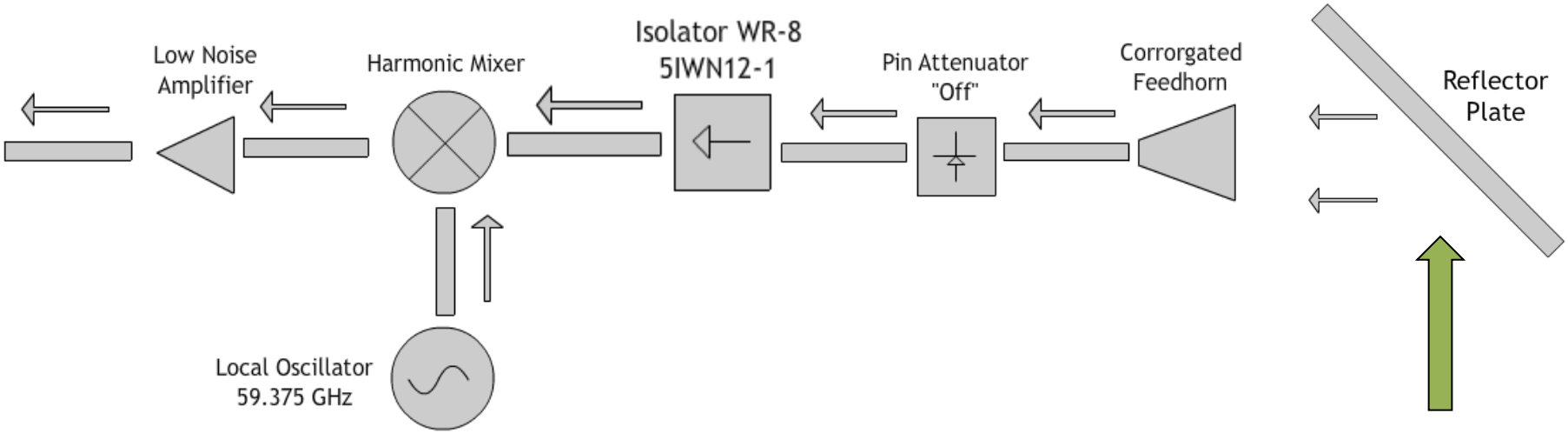


Functional Block Diagram



Radio Frequency (RF) Receiver

- Inputs
  - 118 GHz Radiation
    - Antenna temperature from environment
  - Thermal energy from environment
  - PIN diode control
  - Power rails: 6.5V (LO), 15V (LNA)
- Outputs
  - Intermediate frequency signal (150-6300 MHz)
- Function
  - Receive/down-convert 118 GHz radiation spectrum
    - Parabolic reflector and feed-horn
  - Mix signal down to intermediate frequency



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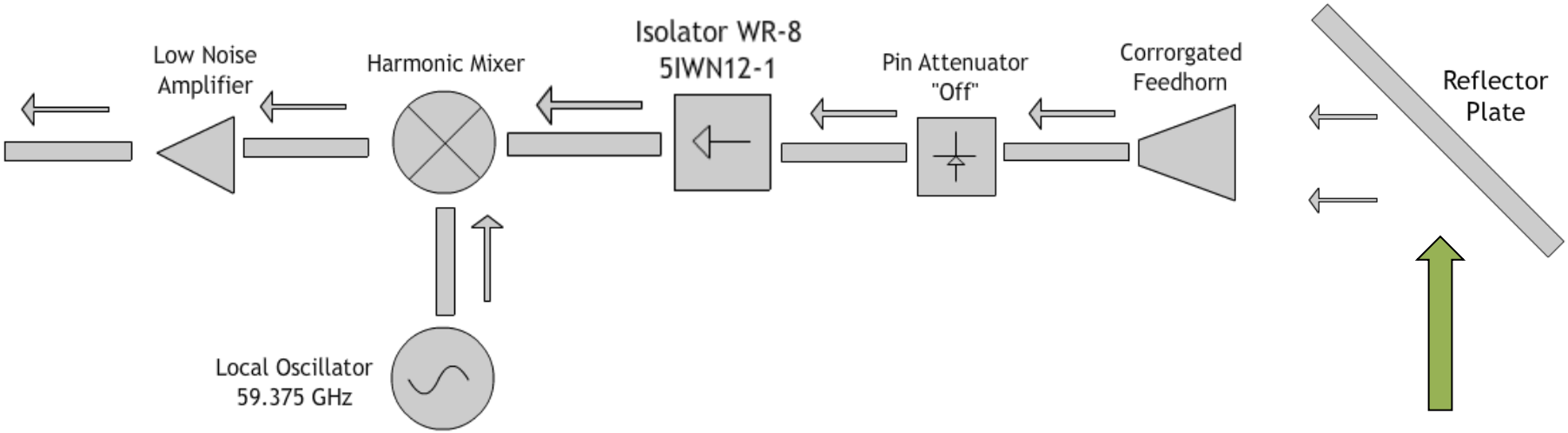

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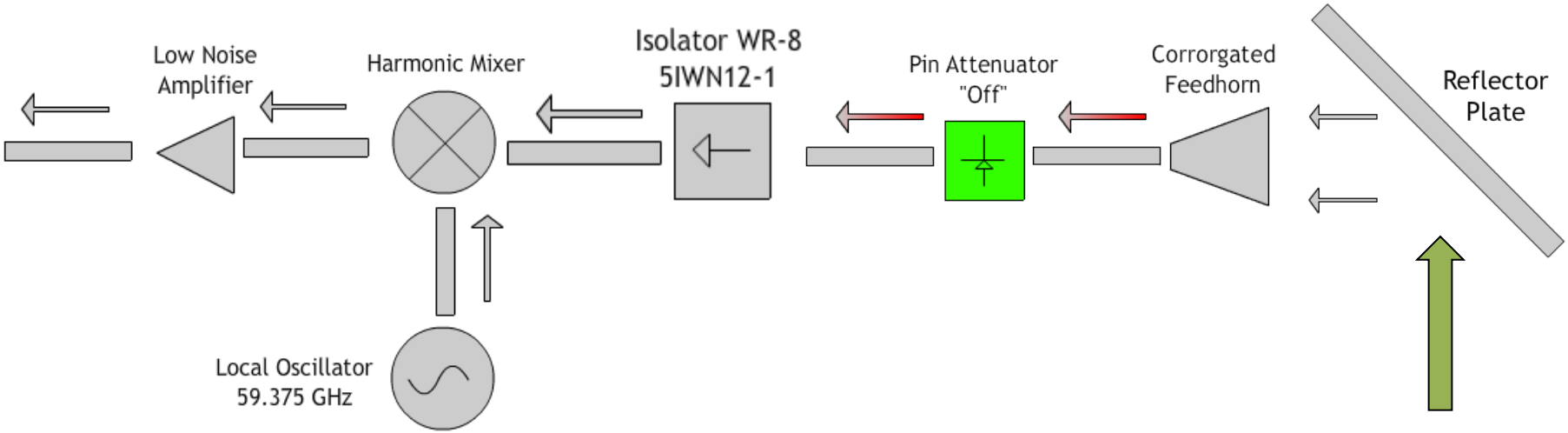

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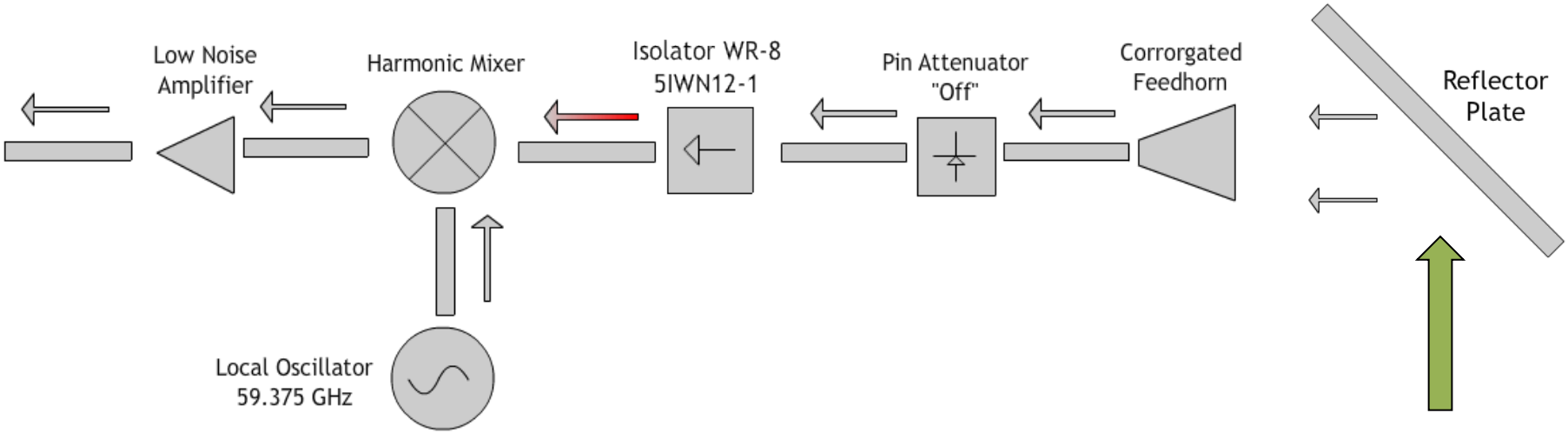

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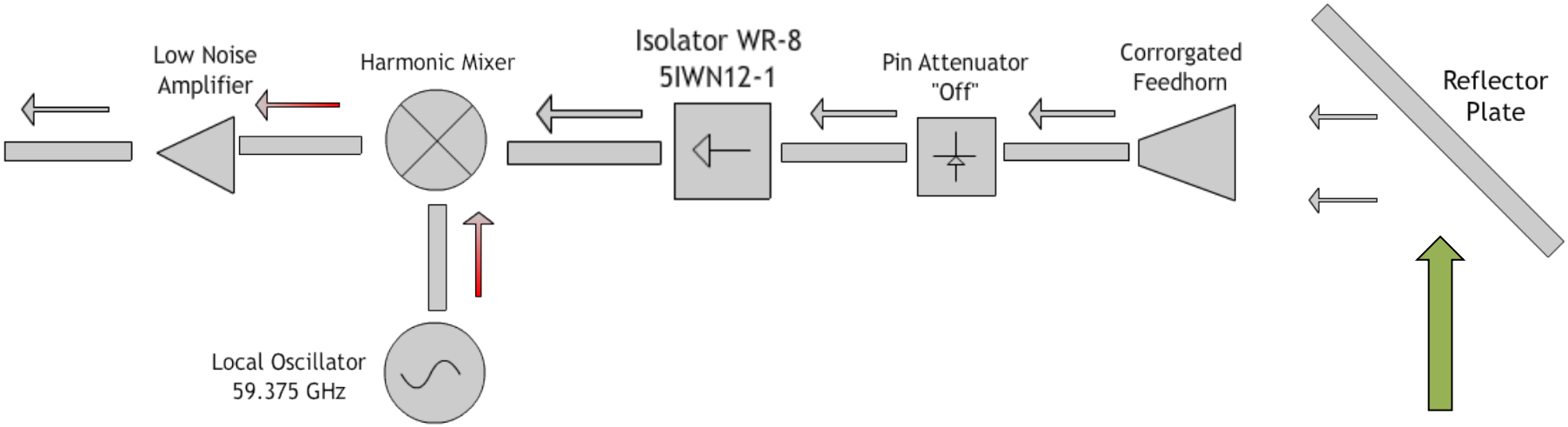

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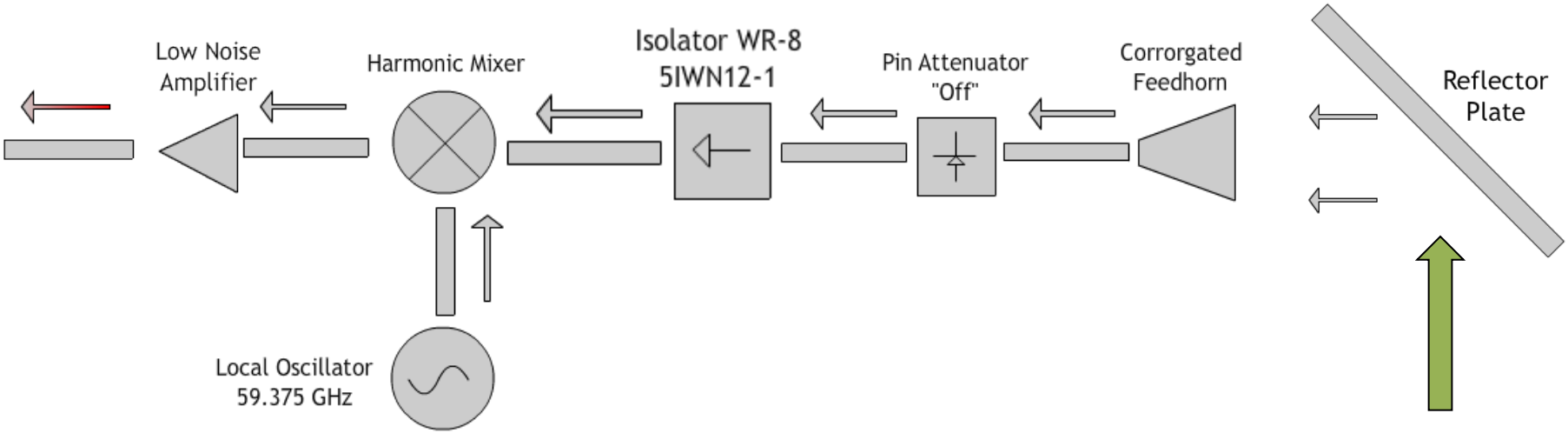

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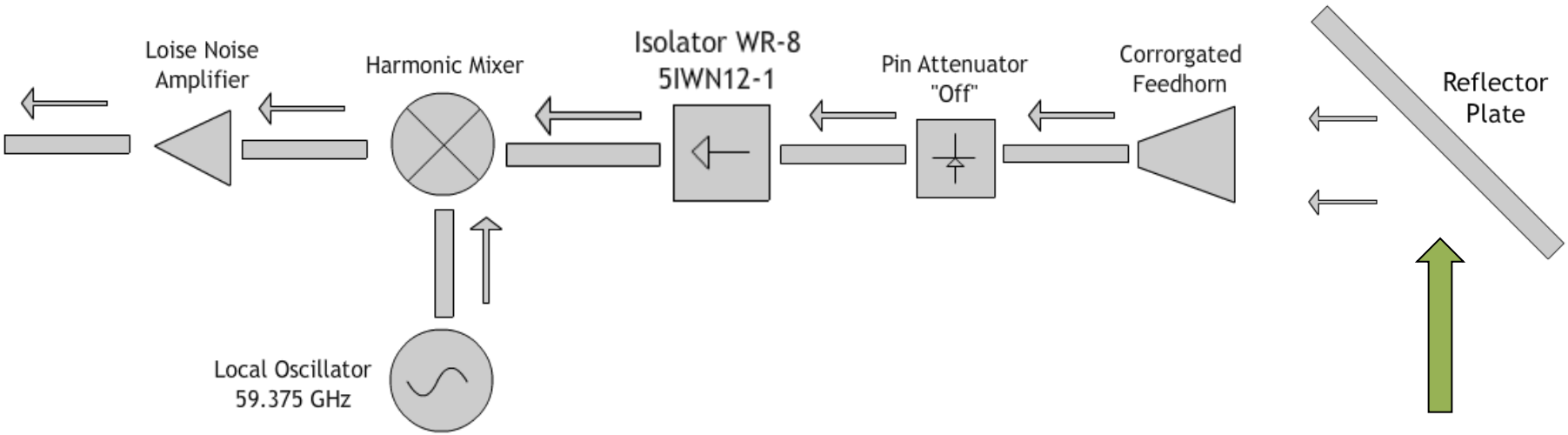

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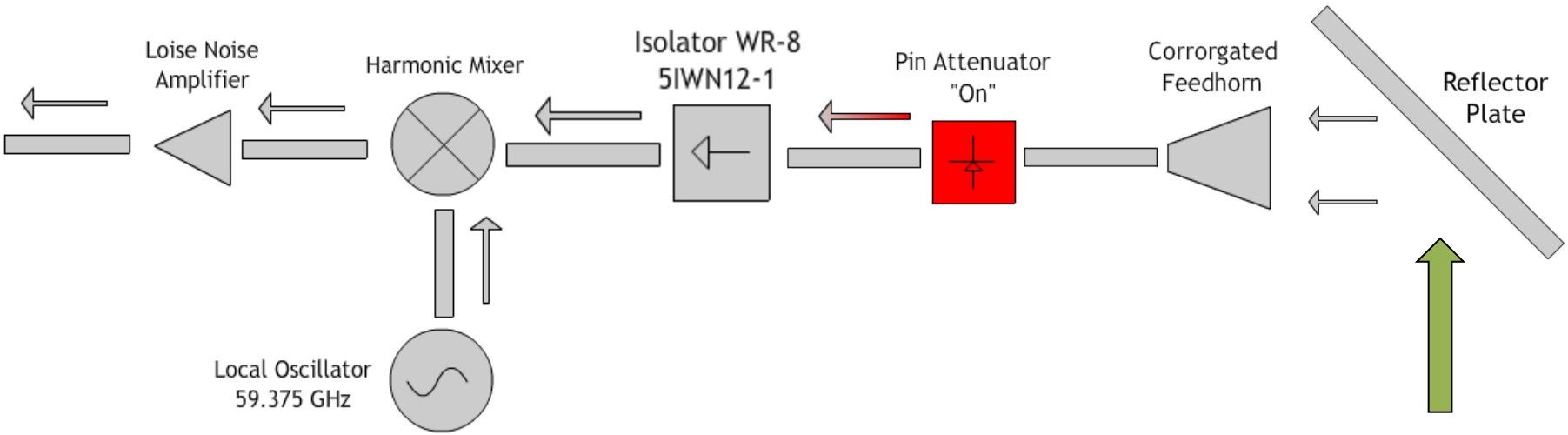
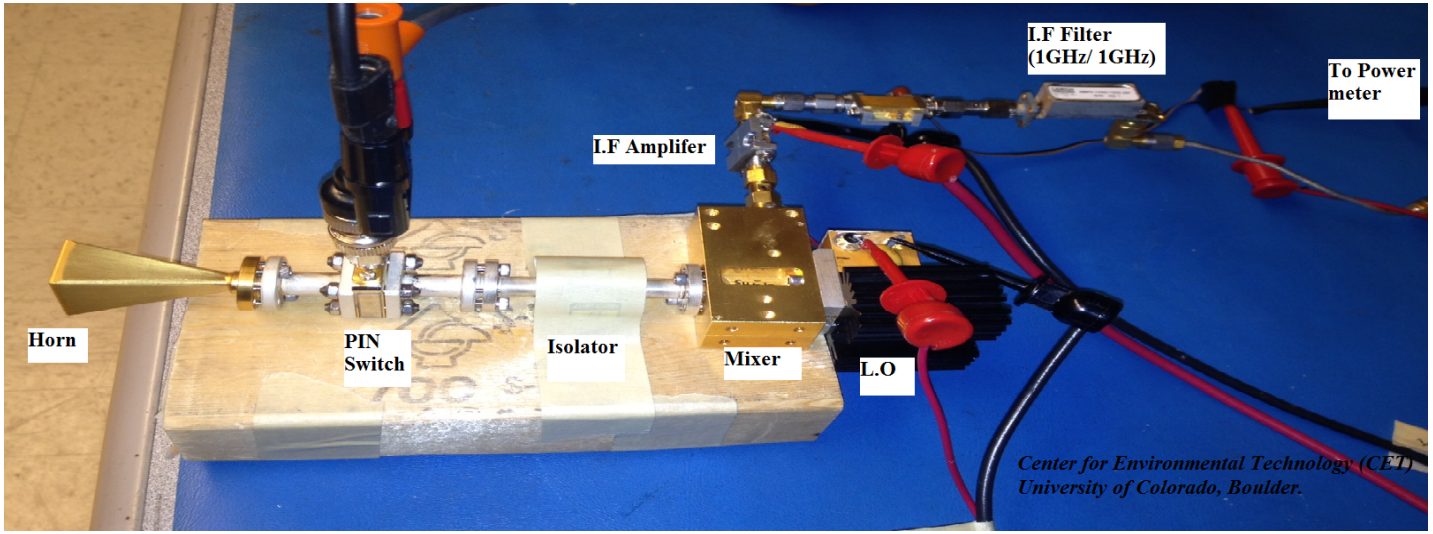


Verification & Testing

- **Y-Factor Test:**
  - Characterize system noise temperature of radiometer
  - Ratio of two noise power levels (or temp) on or off
    - Y = N(on)/N(off)
- **Experiment**
  - RF absorber
    - At room temperature (290 K)
    - Immersed in liquid nitrogen (LN2, ~77 K)
  - Measure power for both input temperatures, compute Y-factor and receiver noise temperature

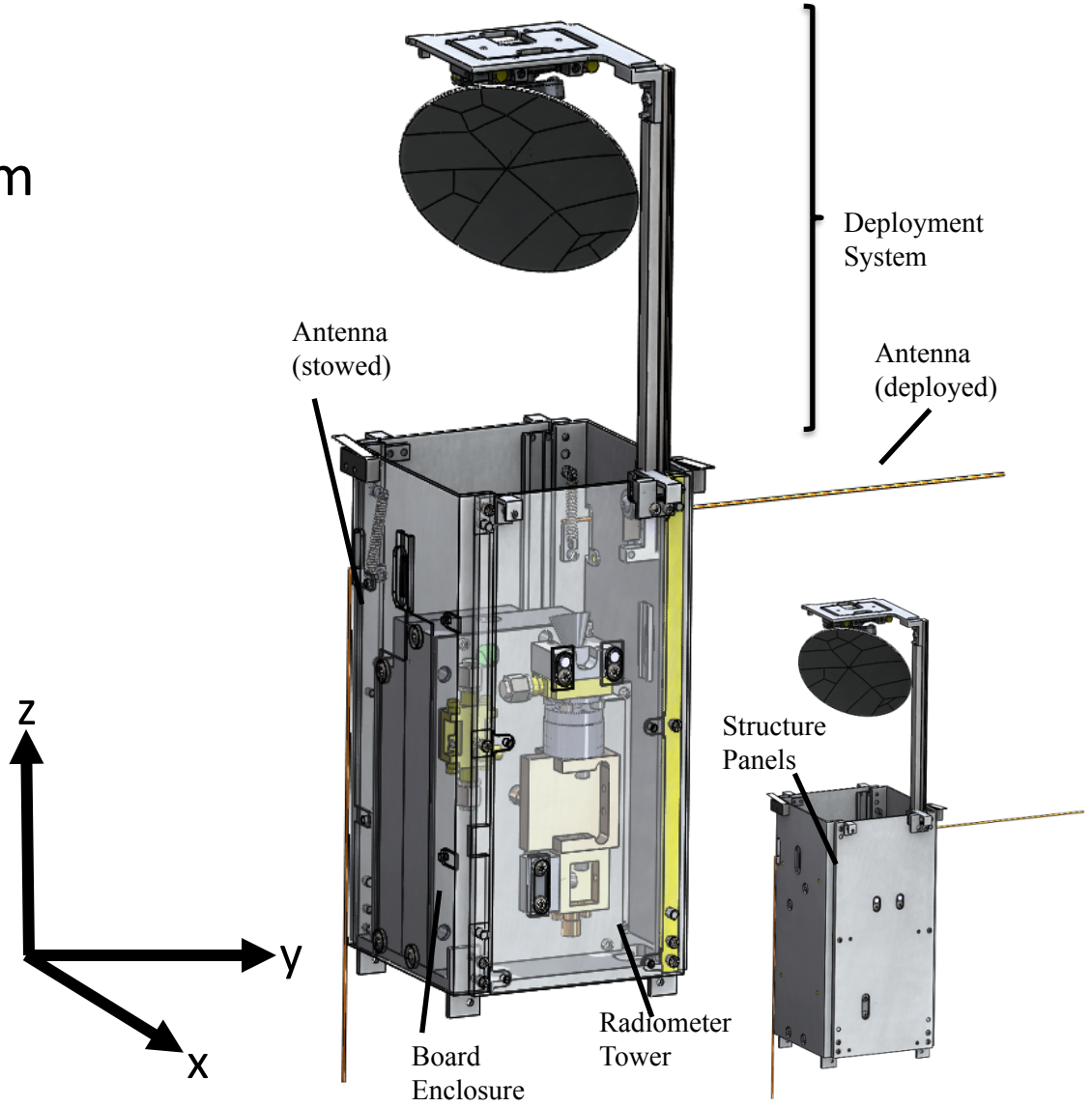


MiniRad Y-Factor Test Set-Up

Overview Structure MiniRad

Major Components:

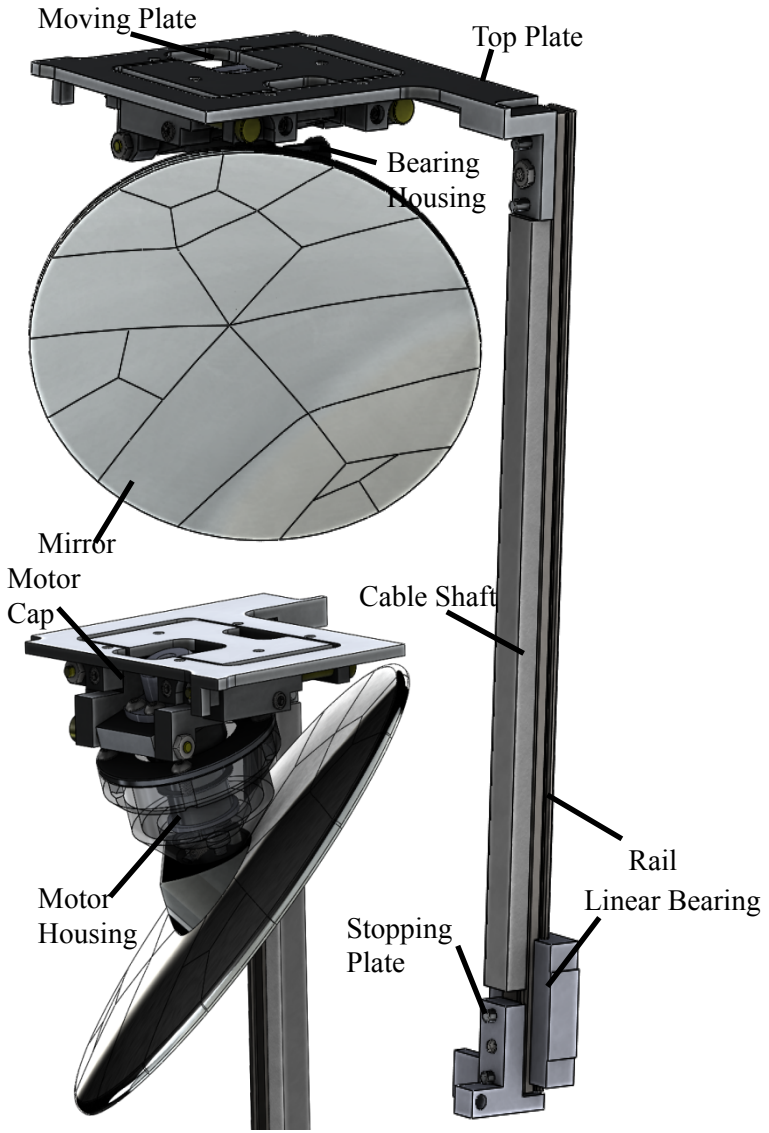
- Deployment System
- Outer Structure
- Board Enclosure
- Radiometer Tower
- Receive Antennas



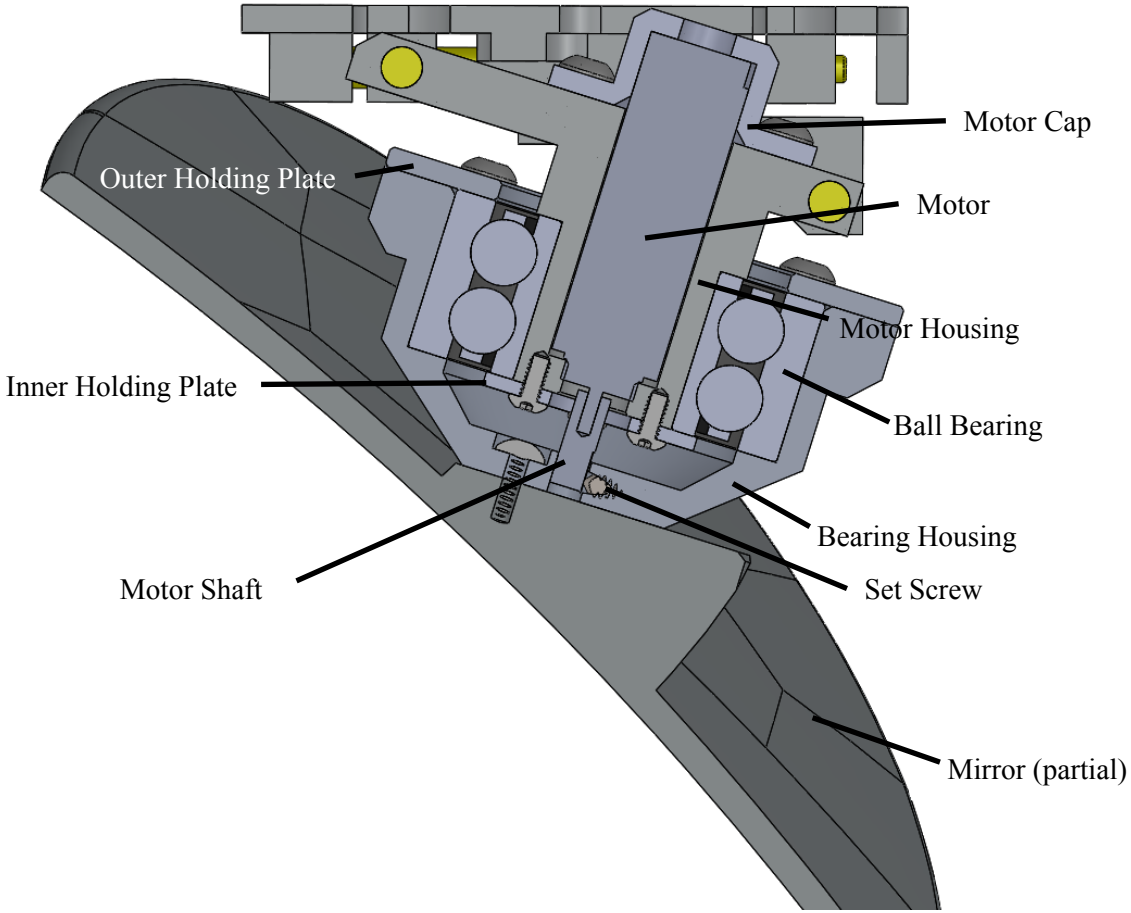
Deployment System

Major Components:

- Mirror
- Mirror Motor
- Rotation System
- Ball Bearings
- Adjustment Mechanism
- Linear Bearing

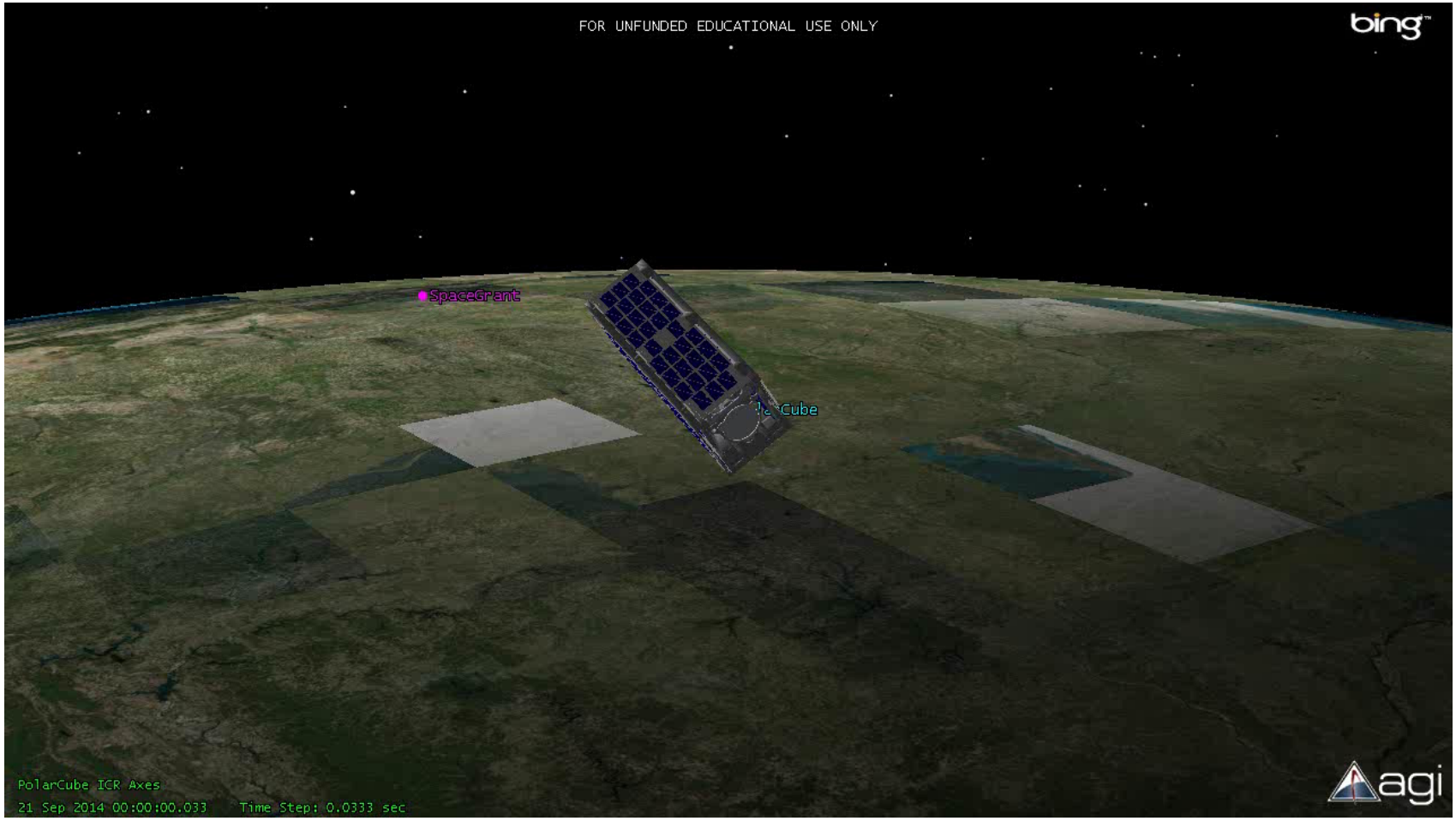


Rotation System



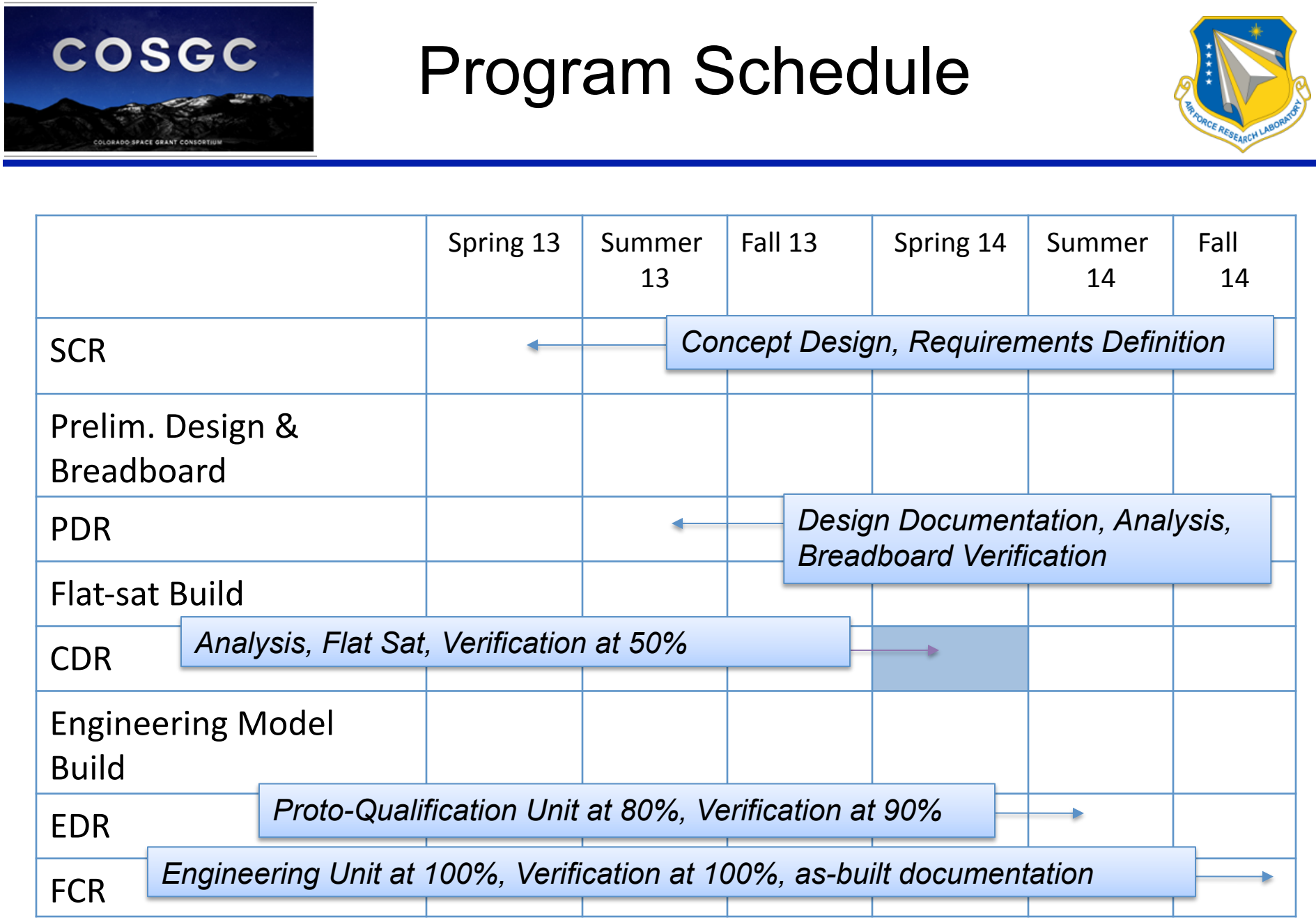
Cut through mirror rotation system

Deployment Visualization

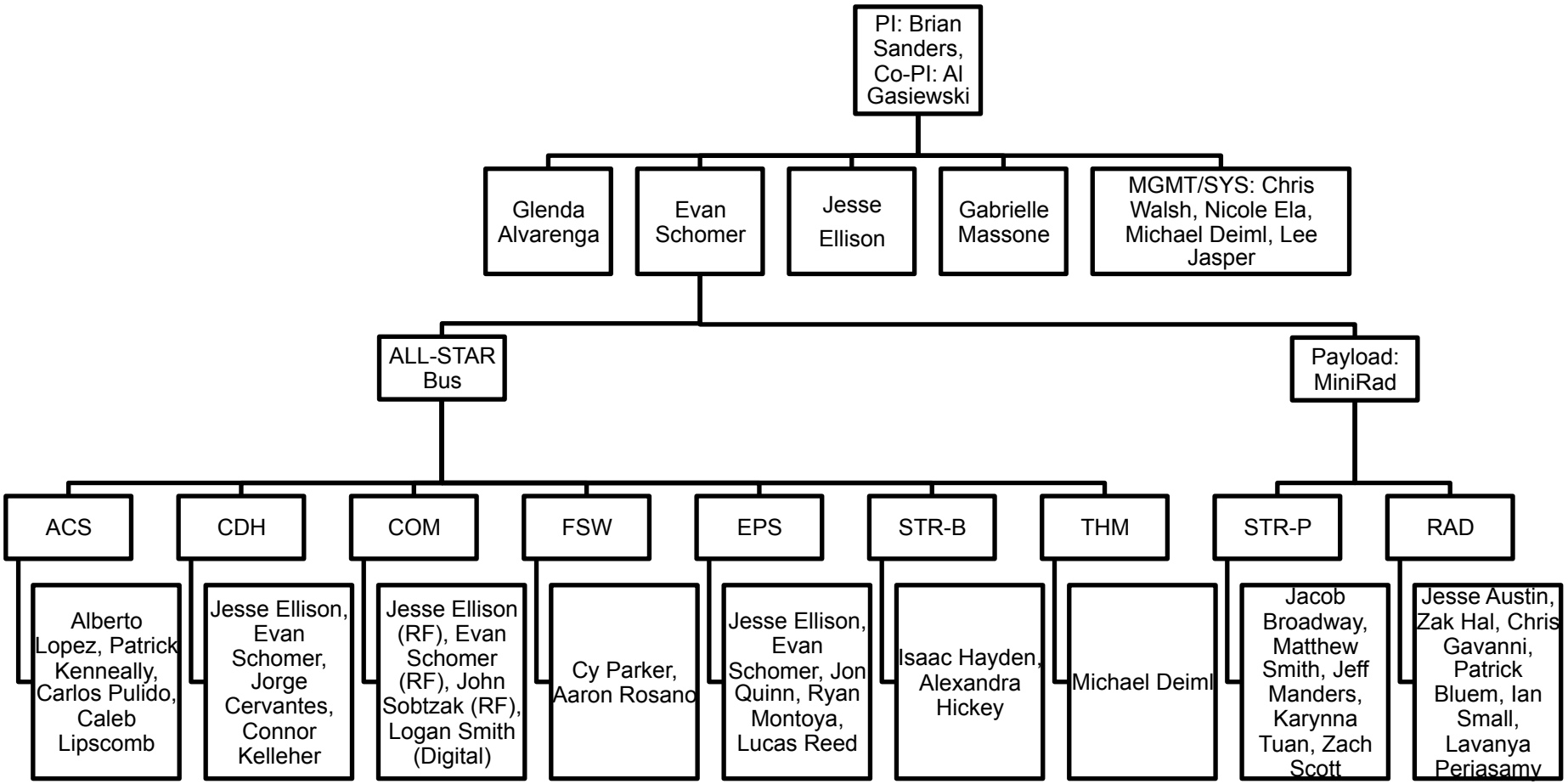


** Note: ALL-STAR Bus Deployment Only, MiniRad Deployment Not Shown

Program Schedule

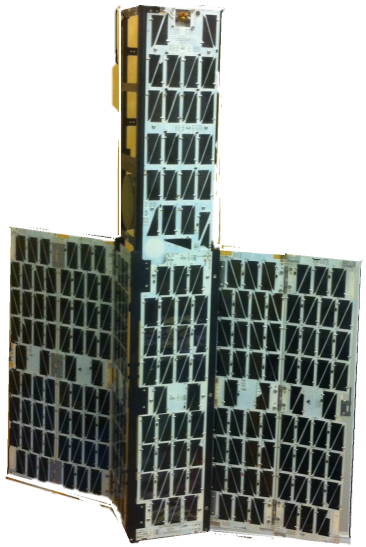


Team Organization



PolarCube Team

- **A student led interdisciplinary team of undergraduates and graduates**
- **Satellite build and delivery history**
  - Hermes 1U CubeSat delivered and launched
  - DANDE Micro-satellite delivered and launched, in operation from 9/2013 to present
  - ALL-STAR-THEIA 3-Axis stabilized 3U CubeSat bus approaching delivery and launch
- **Student Team**
  - Experience in near space suborbital projects
    - High altitude balloon program
    - Sounding rocket program
- **Industry and Academic experts Active Mentoring**
  - Experienced advisors for different disciplines.
    - Current students, alumni, faculty



ALL-STAR-THEIA Integrated Avionics

PolarCube 2014 Team

Thank You

http://spacegrant.colorado.edu/allstar-projects/polarcube