# ADVANCING TECHNOLOGIES FOR CLIMATE OBSERVATION

NASA Goddard Space Flight Center

07/31/2014

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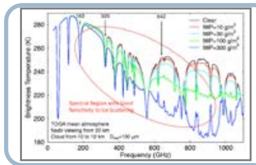
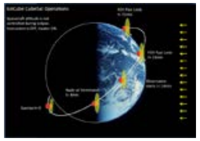
# Outline

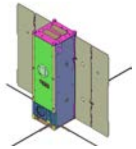




Objectives



Mission requirements



Mechanical configuration

Instrument

Results

Launch plan

# Objectives

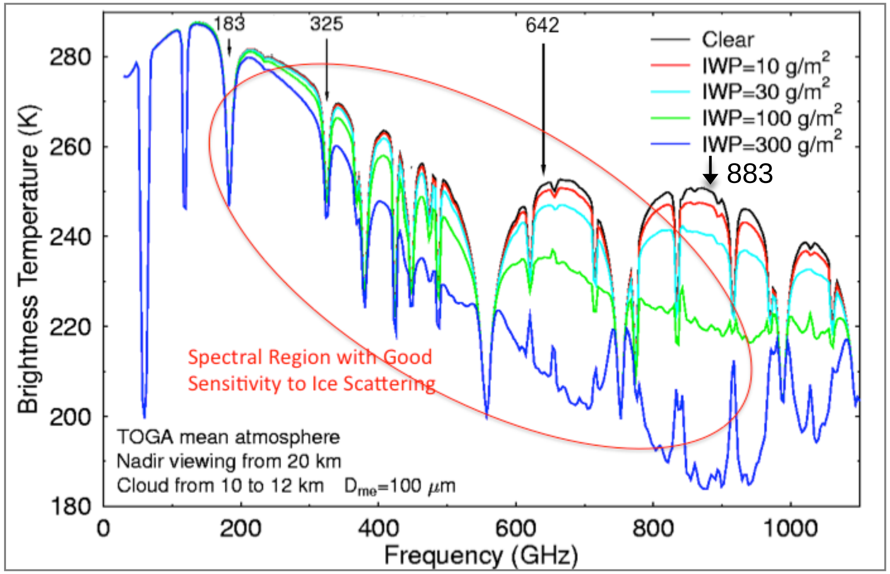


## Climate research needs

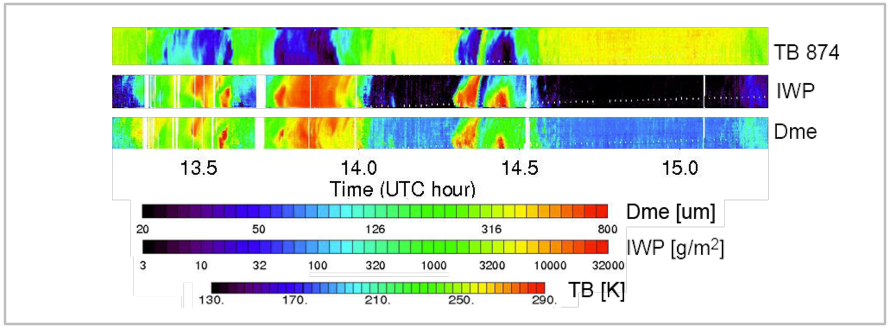
- Accurate global cloud ice measurements
  - Cloud ice properties are fundamental controlling variables of radiative transfer and precipitation
- Cost-effective, sensitive instruments for diurnal and wide-swath coverage
- Mature technology for space remote sensing

## IceCube objectives

- Develop and validate a flight-qualified 883 GHz receiver for future use in ice cloud radiometer missions
- Raise TRL (5→7) of 883 GHz receiver technology
- Reduce instrument cost and risk by developing path to space for COTS sub-mm-wave receiver systems
- Enable remote sensing of global cloud ice with advanced technologies and techniques




The spectral region with good sensitivity to ice cloud scattering (courtesy of Frank Evans).




First-ever 874 GHz cloud measurements acquired by CoSSIR in 2008. CoSSIR measurements of ice clouds were used to successfully demonstrate retrieval of ice water path (IWP) and ice particle median mass-weighted ice particle size ($D_{me}$).

# Mission Requirements



**883 GHz measurement requirements:**

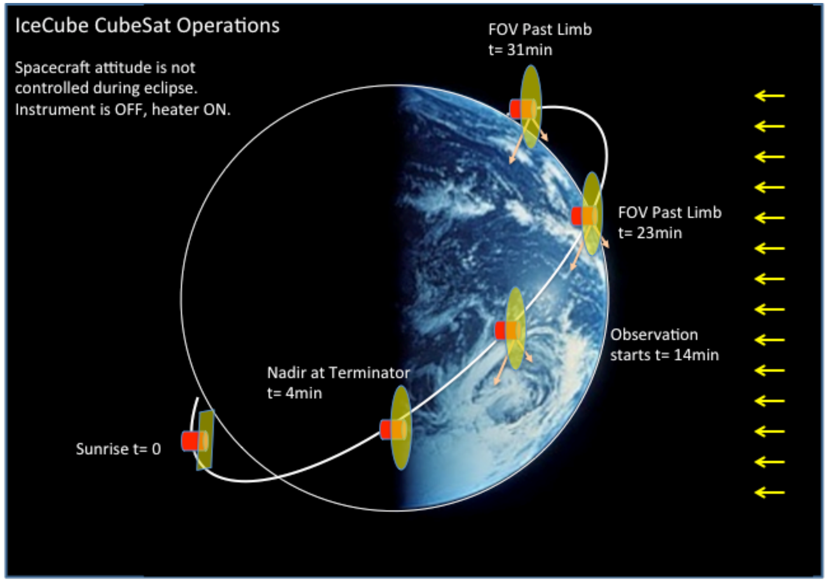
- Accuracy < 2 K
- Precision (NETD) < 0.2 K
- Spatial resolution < 15 km

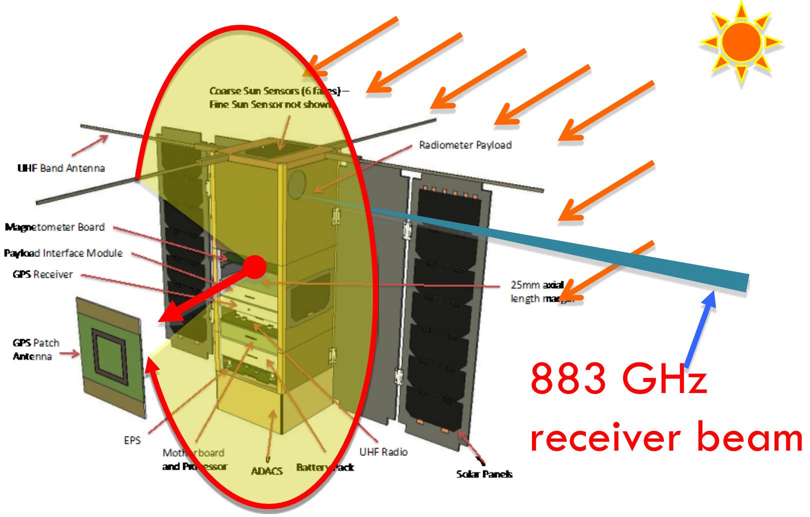
**Mission requirements:**

- In-flight operation 28 days
- Periodic views of Earth (science) and space (calibration) within an orbit
- Science data 30+ % (8+ h /day)
- Pointing knowledge < 25 km

**Validation plan:**

- Lab measurement and verification
- Modeled vs. observed clear-sky radiances for accuracy verification
- Space-view radiances for precision



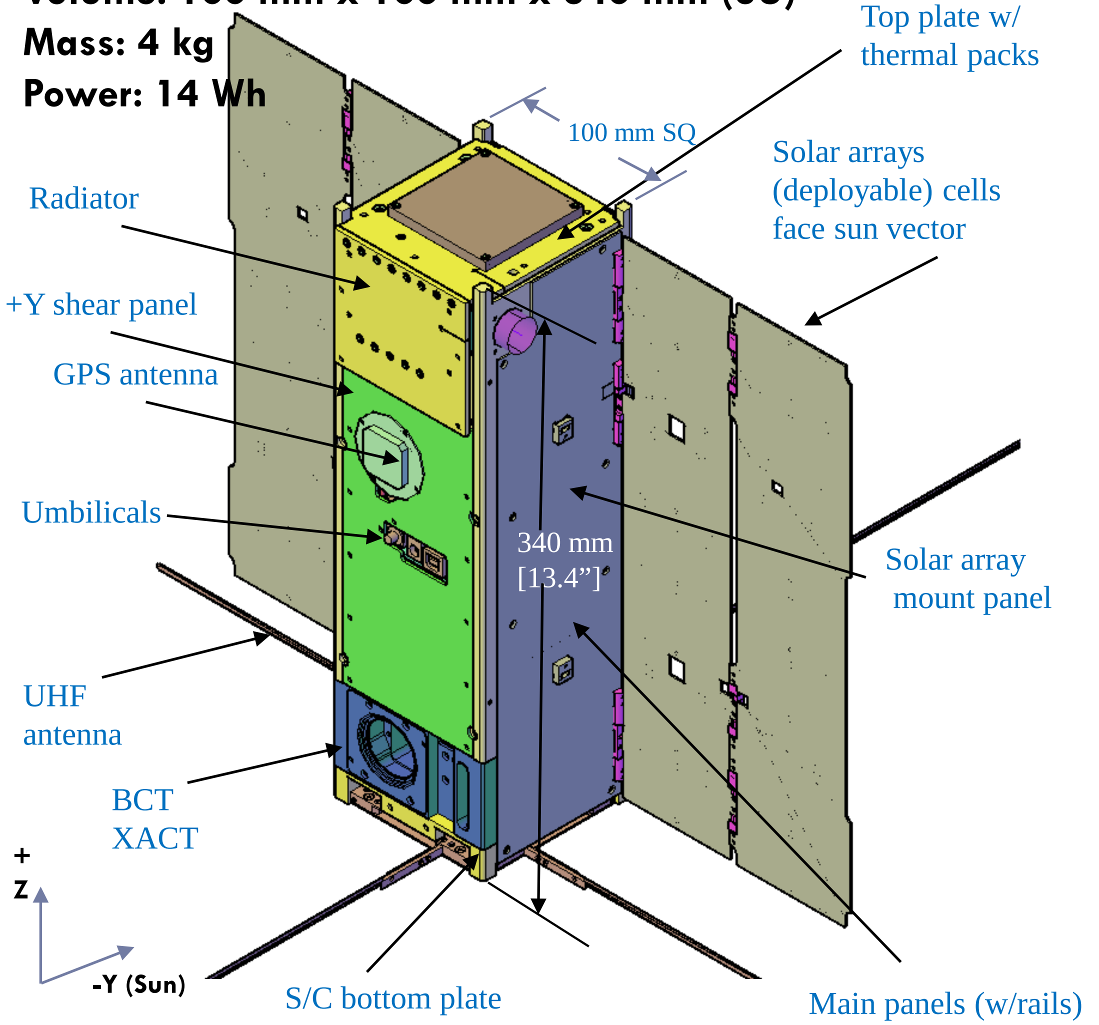
# Flight Configuration

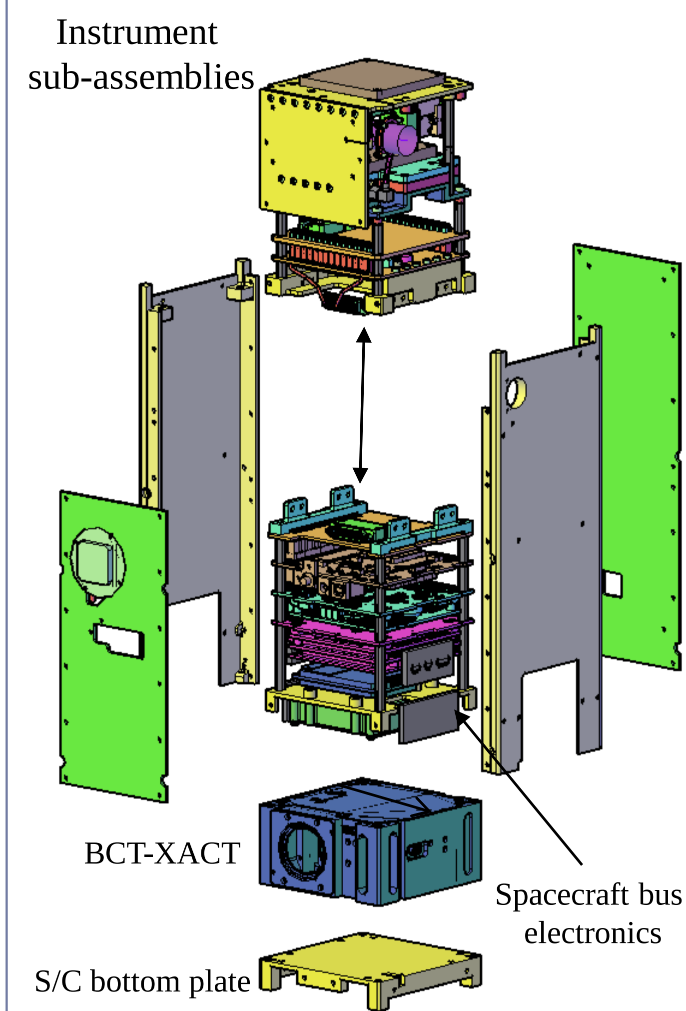


**Volume: 100 mm x 100 mm x 340 mm (3U)**

**Mass: 4 kg**

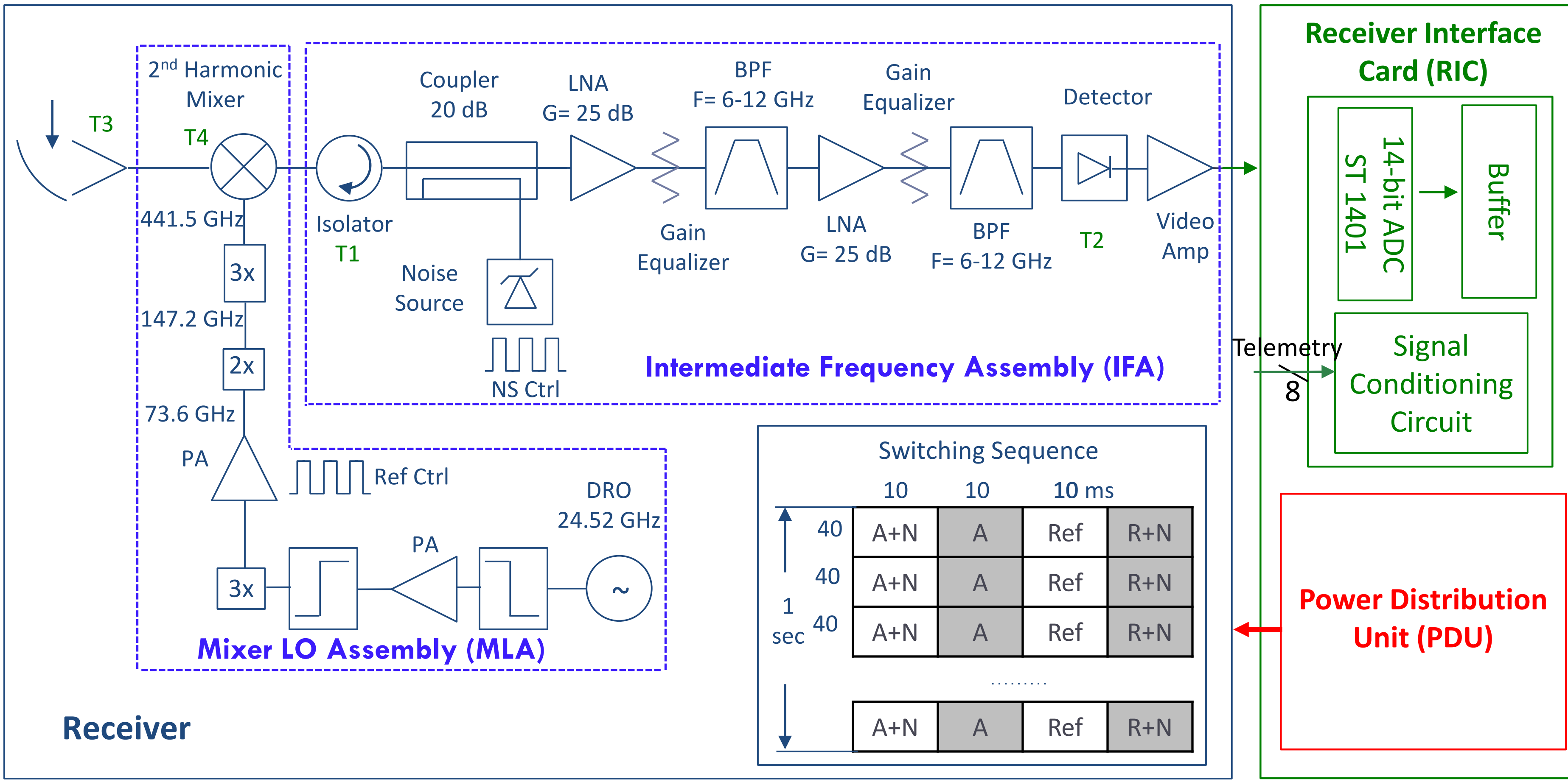
**Power: 14 Wh**



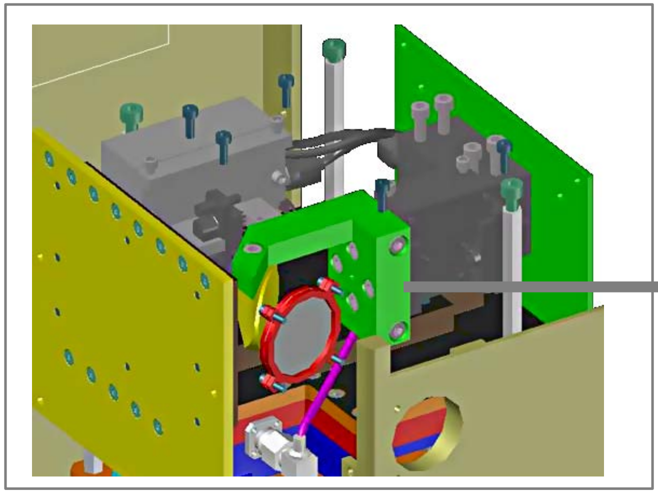



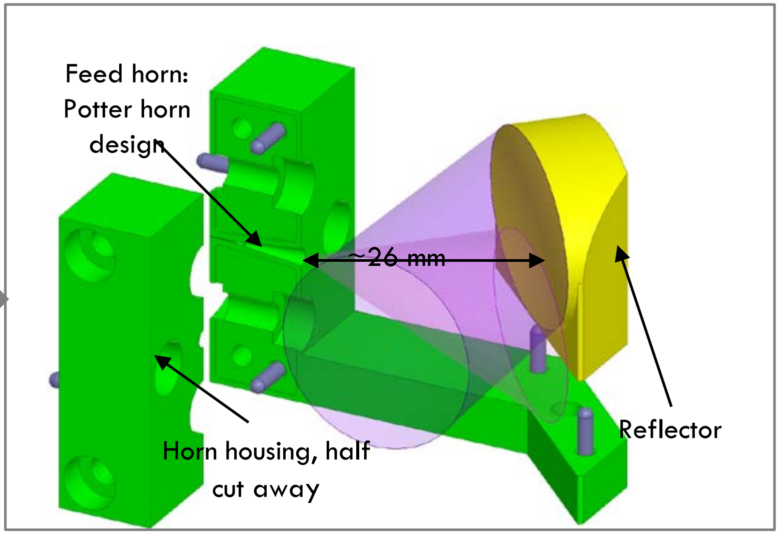
# Instrument: Block Diagram

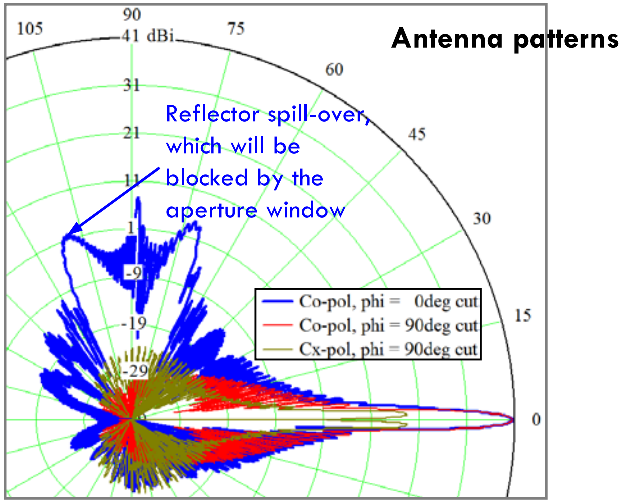


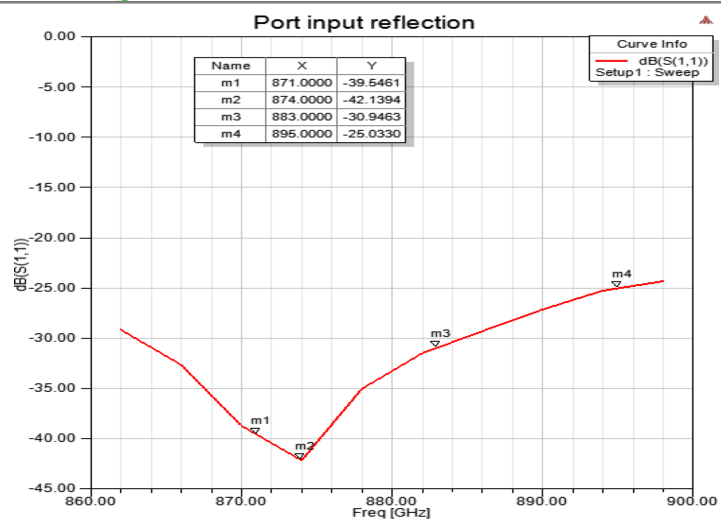


# Antenna





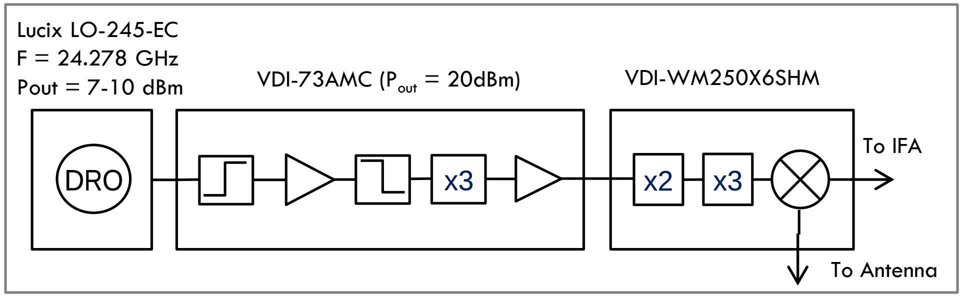



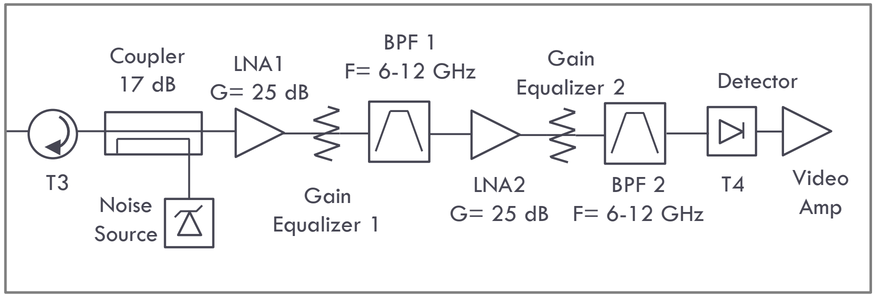



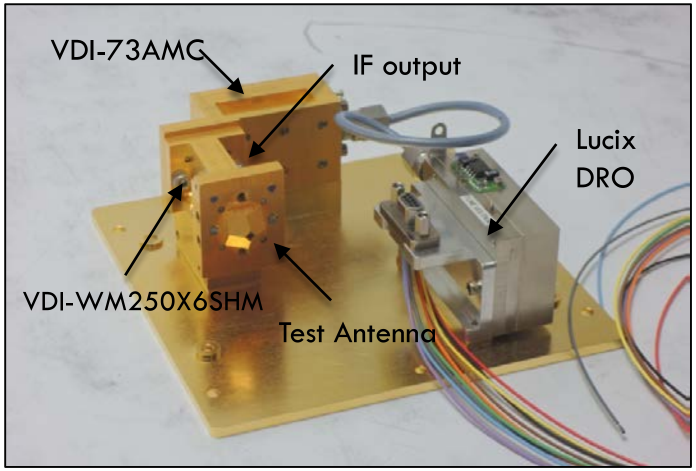

Courtesy of Cornelis F. du Toit

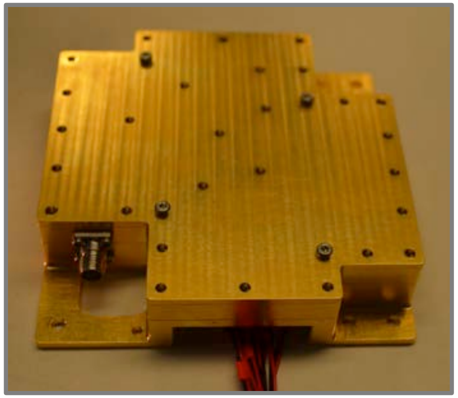
# Instrument: MLA and IFA

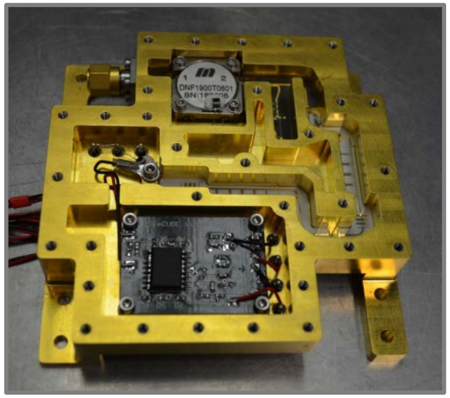




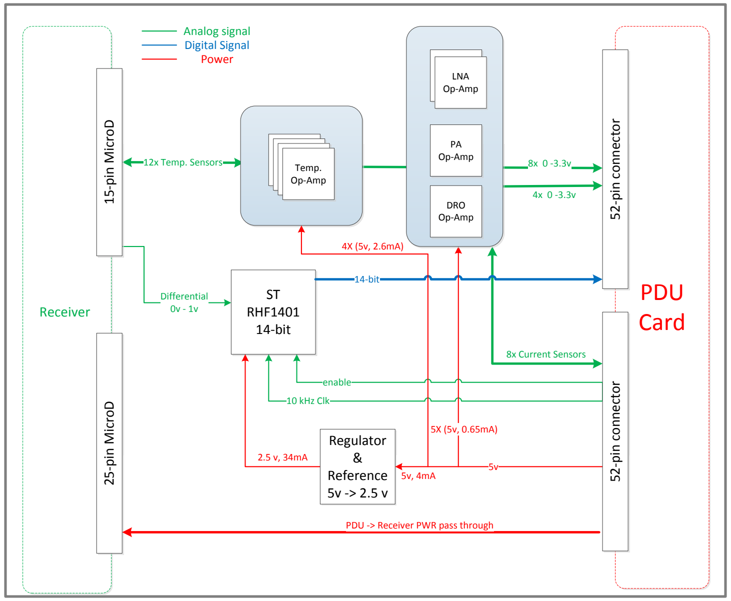


- MLA (Mixer LO Assembly):
  - Measured noise temperature: 4000 K
  - Measured conversion loss: 13 dB
  - Mass and volume: 150 g, 90 x 90 x 35 mm$^3$
  - Power: 1.73 W
- IFA (Intermediate Frequency Assembly):
  - Estimated noise figure: 3-4 dB
  - Gain and bandwidth: 38.1 dB and 4 GHz
  - Mass: 200 g
  - Volume : 90 x 90 x 20 mm$^3$
  - Power: 1.15 W

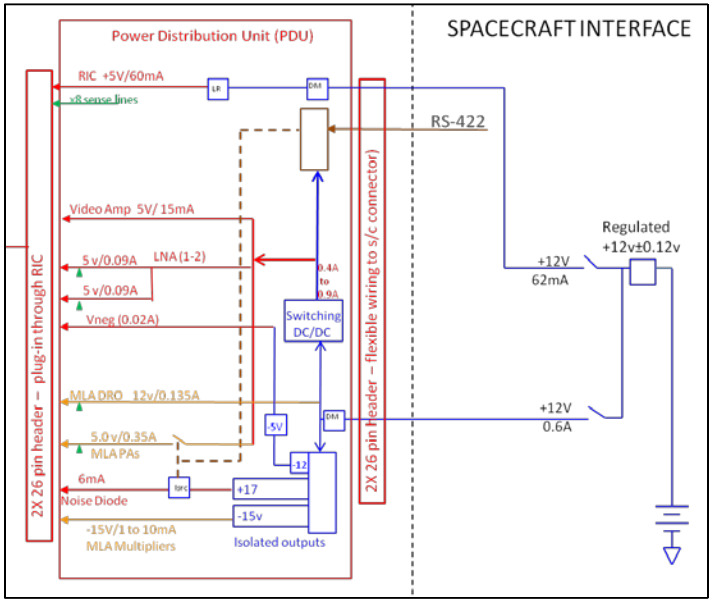
# Instrument: RIC and iPDU

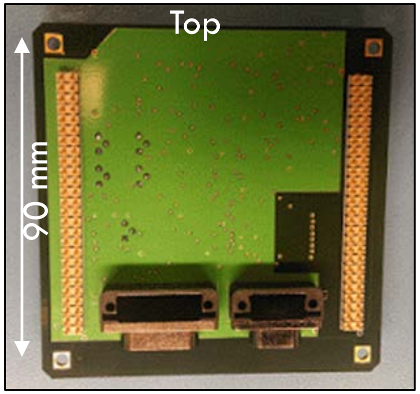


## RIC (Receiver Interface Card)



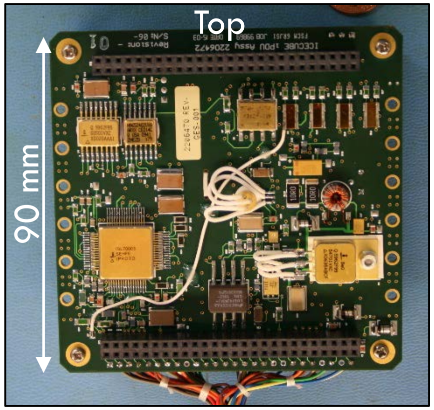

## iPDU (instrument Power Distribution Unit)

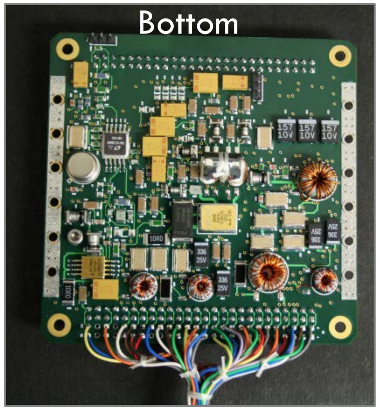




Power: 0.3 W, Mass:100.7 g




Power: 2.23 W, Mass: ~100 g

# Power per Instrument Mode



Based on integrated Engineering Model (EM) instrument measurements:

| | | - ND | | all | | - PA, -ND | | -PA | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Power Per Instrument Mode** | | | | | | | | |
| | | ANT (10ms) | | ANT+Noise (10ms) | | REF (10ms) | | REF+Noise (10ms) | | RIC ON/PDU OFF |
| | Load | Nom | +10% | Nom | +10% | Nom | +10% | Nom | +10% | |
| | Watts | 6.56 | **7.22** | 6.44 | **7.08** | 3.94 | **4.33** | 3.88 | **4.26** | 0.38 |
| non-sw | PDU logic | | | | | | | | | OFF |
| non-sw | Video Amplifier | | | | | | | | | OFF |
| non-sw | MLA_ DRO | | | | | | | | | OFF |
| switched | MLA Power Amplifier | | | | | OFF | | OFF | | OFF |
| non-sw | LNA1 | | | | | | | | | OFF |
| non-sw | LNA2 | | | | | | | | | OFF |
| non-sw | deleted | | | | | | | | | OFF |
| switched | Noise Diode_ Current Source | OFF | | | | OFF | | | | OFF |
| non-sw | MLA Multiplier | | | | | | | | | OFF |
| non-sw | Video amp NEG (linear reg) | | | | | | | | | OFF |
| non-sw | RIC | | | | | | | | | |

Courtesy of Amri Hernandez-Pellerano

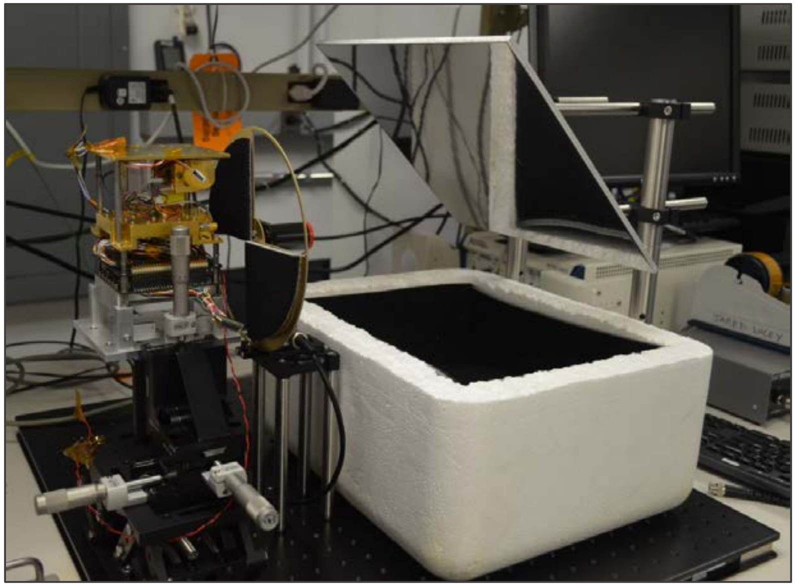
# Instrument Integration & Test



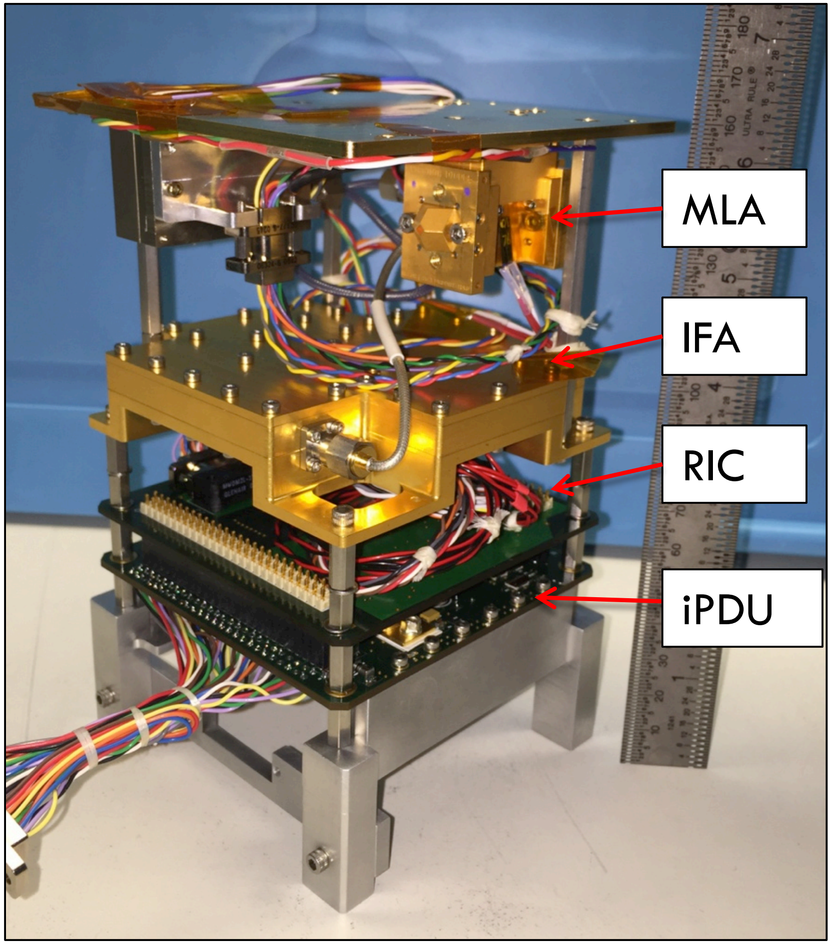
- Verification has been done via alternating between room temperature and $LN_2$ target

- Ambient setup includes:
  - Chopper wheel with room temperature absorber
  - 12” x 12” mirror
  - GSE spacecraft simulator
  - $LN_2$ absorber (Eccosorb AN 72)

- The instrument will be tested over temperature with a Thermal Vacuum Chamber (TVAC)



Engineering Model IceCube Instrument



# Ambient Test Results

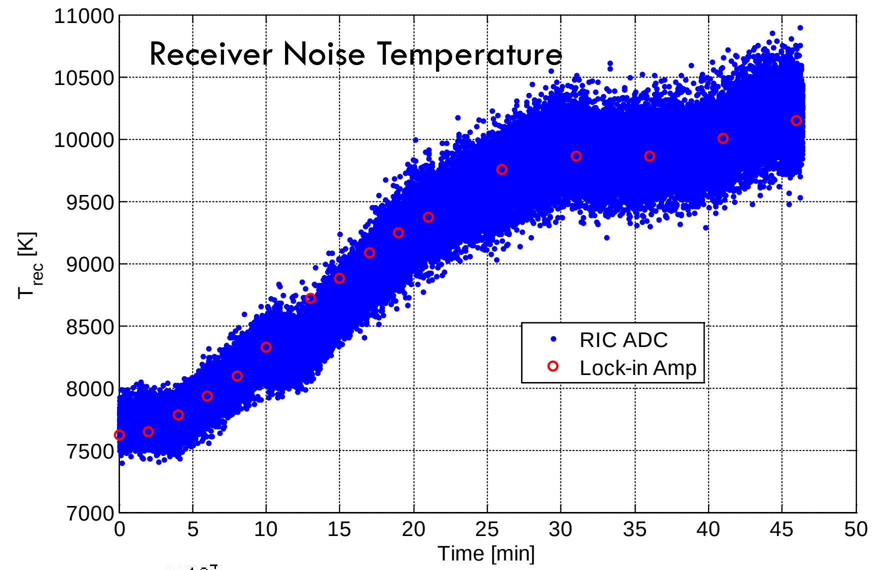


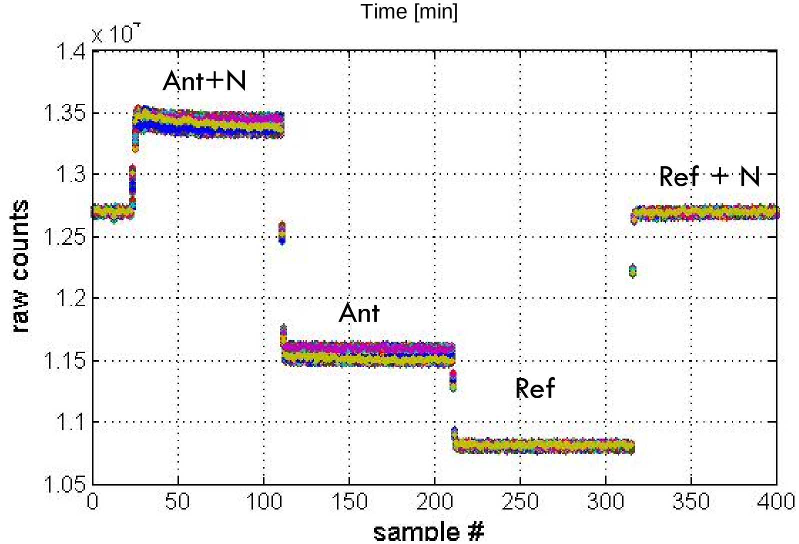
- Receiver noise temperature has been measured via Y-factor measurement both with lock-in amplifier and RIC in the antenna mode.

- The instrument noise temperature varies between 7500 K to 10500 K in 45 mins due to thermal effects.

- The flight instrument has thermal control to stabilize the temperature of the instrument.

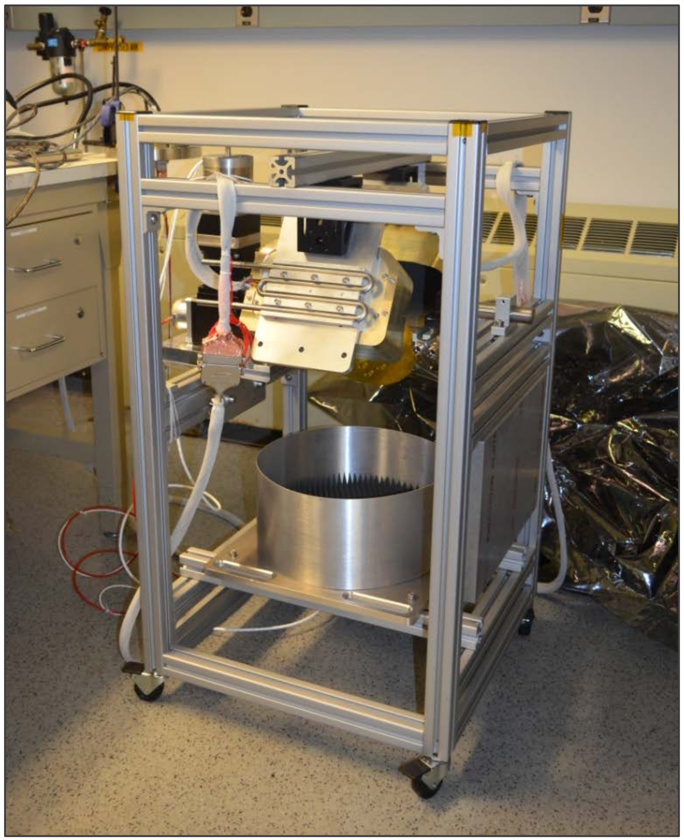
- The instrument is switching states every 10 ms for calibration.



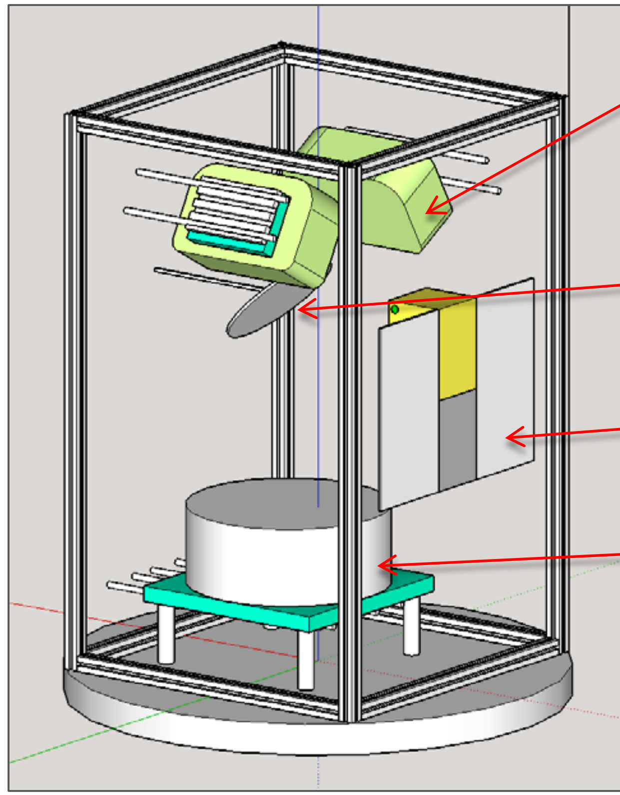



# Instrument TVAC





Courtesy of Kevin Horgan, 555 (inspired by MIT Lincoln Laboratory MicroMAS TVAC structure)



IceCube Calibration Fixture (mounting hardware not shown) (22.6" x 22.6" x 36")

Sub-MMW blackbody cold target (100 K) & hot target (300 K) for external calibration; tolerance ± 1 K

45deg-offset rotating mirror to alternate observed scene/target

Instrument/IceCube

Sub-MMW blackbody target (variable 100-300 K); tolerance ±1 K

# Launch Opportunity and Orbit

- NASA CubeSat Launch Initiative (CSLI)
  - Coordination of upcoming launches
  - 1U, 2U, 3U, or 6U
- International Space Station (ISS)
  - Secondary cargo payload on ISS resupply missions
  - Mid 2016
  - 350-450 km, 51.6° inclination near-circular orbit
  - β angle variation: 0-75°
- 3U CubeSat Launchers
  - NanoRacks CubeSat Deployer from ISS

# Questions?



- NASA ESTO, SMD and CSLI supports
- IceCube Team

| | |
|---|---|
| PI | Wu, Dong (GSFC, 613) |
| Deputy PI | Piepmeier, Jeffrey (GSFC,555) |
| Tech Lead | Esper, Jaime (GSFC, 592) |

**Instrument (GSFC)**

| | |
|---|---|
| Inst. And Sys. Lead | Ehsan, Negar (555) |
| Inst. Scientist | Racette, Paul (555) |
| Antenna | Du Toit, Neils (555) |
| Integration & Test | Horgan, Kevin (555) |
| Calibration Alg. | Hudson, Derek (555) |
| IF subassembly | Lucey, Jared (555) |
| Assembly Tech. | Macmurphy, Shawn (562) |
| Pathways Intern | Cooke, Caitlyn (555) |
| Power Lead | Hernandez, Amri (563) |
| Power | Ortiz-Acosta, Melyane (563) |
| Mechanical | Solly, Michael (562) |
| Parts Support | Fetter, Lula (560) |
| RIC Lead | Wong, Mark (564) |
| Video Amp/RIC | Lu, Daniel (555) |
| GSE Software | Topper, Alyson (561) |

**CubeSat, Ground System, Op (WFF, GSFC)**

| | |
|---|---|
| Mission Sys Engr. | Mast, William (WFF, 598) |
| Mgt. Support | Johnson, Tom (WFF, 8000) |
| Power Systems | Purdy, Christopher (WFF, 569) |
| Power Systems | Corbin, Brian (WFF, 569) |
| Software/Avionics | Daisey, Ted (WFF, 589) |
| Software/Avionics | Lewis, Christopher (WFF, 569) |
| Mechanical/Thermal | Hudeck, John (WFF, 548) |
| GN&C | Heatwole, Scott (WFF, 598) |
| SIC | Duran-Aviles, Carlos (GSFC, 564) |
| SIC | Rush, Kurt (GSFC, 564) |
| Thermal Analysis | Choi, Michael (GSFC, 545) |

**874 GHz Receiver (Virginia Diode, Inc)**

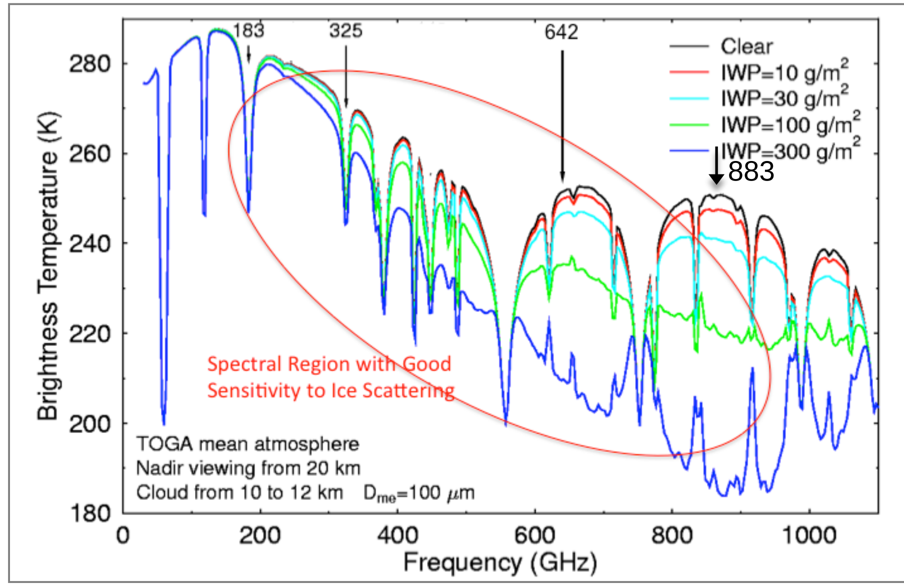
| | |
|---|---|
| Tech POC | Hesler, Jeff |
| LO Drive Module Design | Bryerton, Eric |
| Integration and Testing | Retzloff, Steven |
| CAD and Mechanical | Neff, Chuck |

# Back-Up

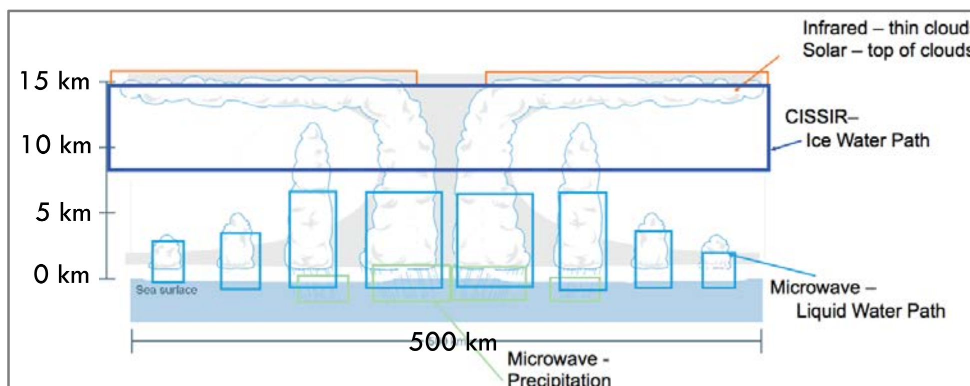
# Motivation and Science Drive



- Cloud ice properties are fundamental controlling variables of radiative transfer and precipitation
- Large discrepancies in ice water path (IWP) exist in global circulation models
- Limited availability of data and poor assumptions about the cloud micro- and macro-physical properties of clouds are principle contributors to the discrepancy
- No ice cloud measurements currently exist for the intermediate altitudes
- mm- and submm-wave radiometry offers great potential to fill the measurement gap in the middle and upper troposphere



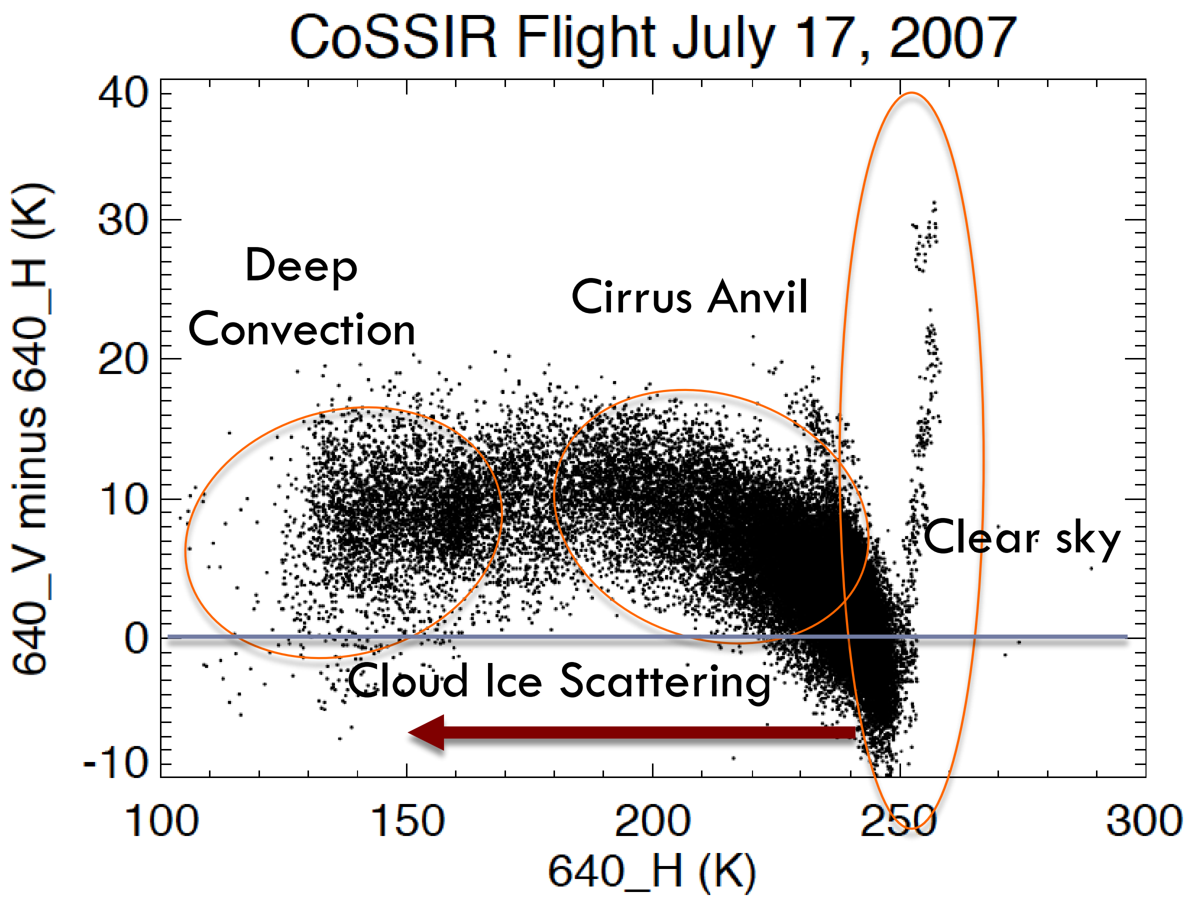

The spectral region with good sensitivity to ice cloud scattering (courtesy of Frank Evans).



# Importance of polarization in cloud ice measurements

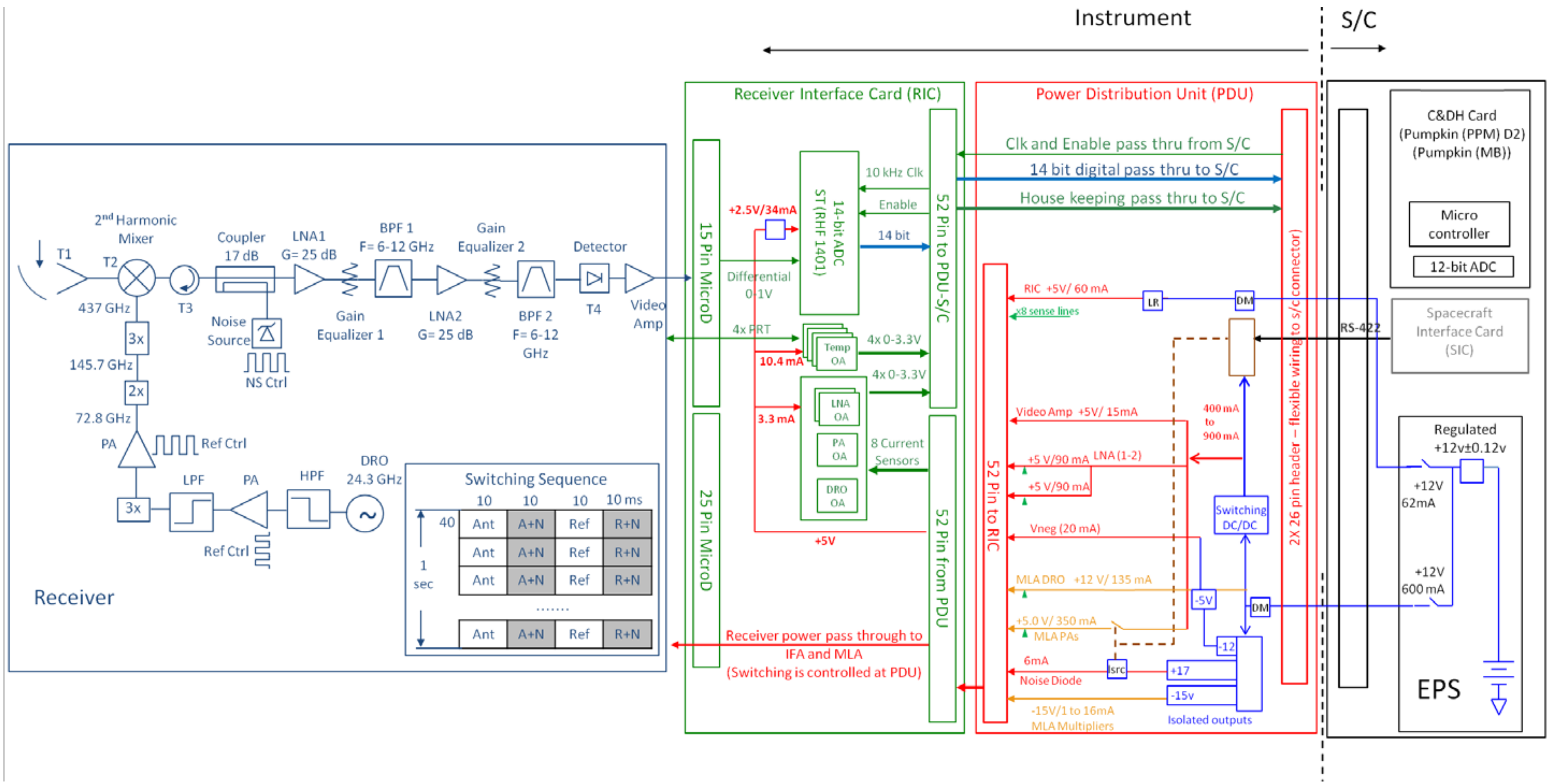


- Determining ice crystal orientation is important for accurate cloud ice retrieval.
- Depending on V or H to use, cloud ice scattering signals can differ by 20-50% for cirrus anvil.
- Global properties of Ice crystal orientation and their variations with cloud type remain unclear.



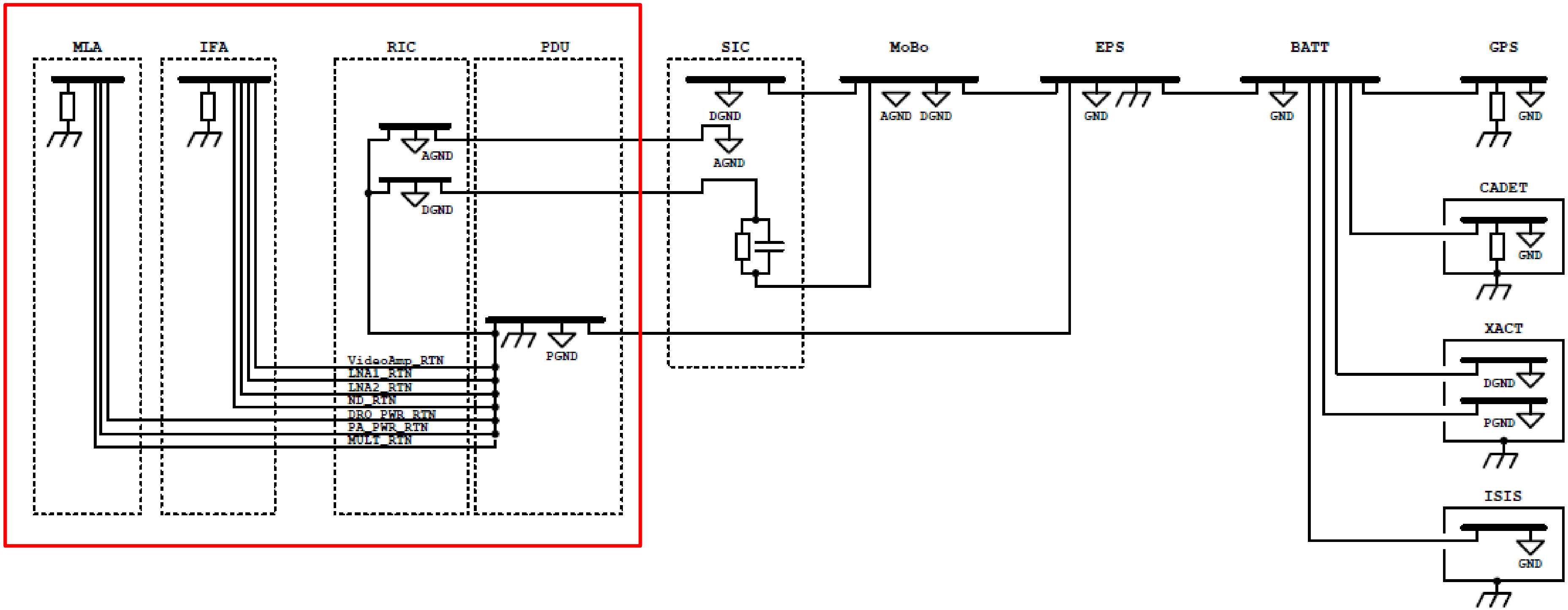
# Instrument: Block Diagram





# Instrument Ground Diagram



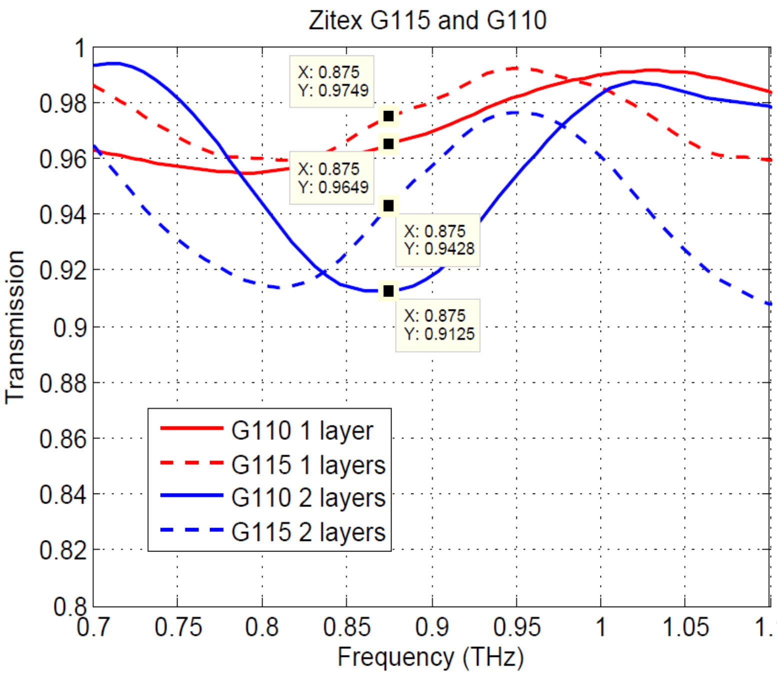


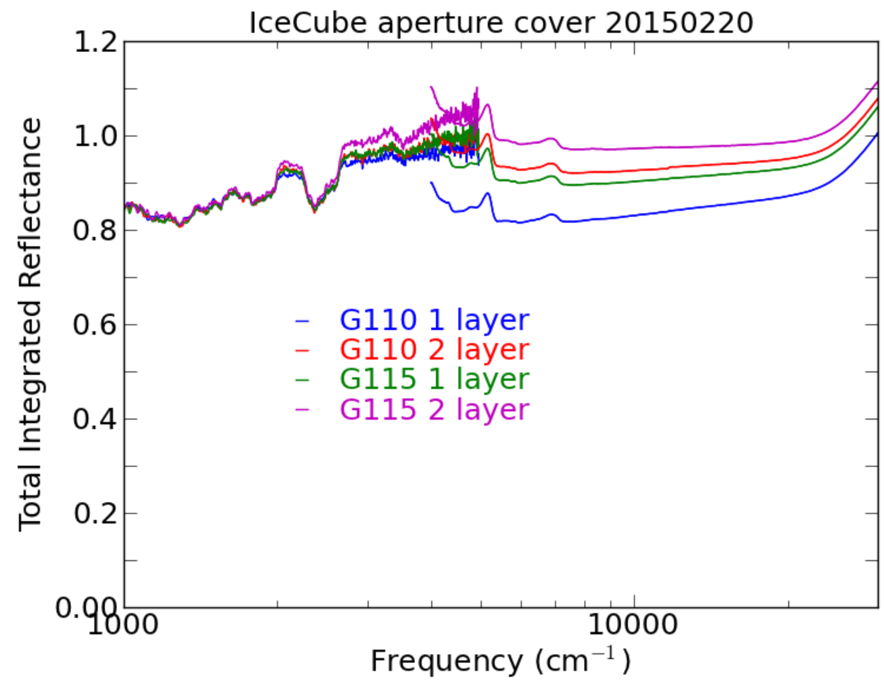

• MLA and IFA are isolated from chassis (there is a high resistive connection to chassis to prevent charge build up). The return path of the loads will be only through iPDU.

• RIC is grounded through iPDU to chassis.

# Antenna Aperture Window Cover

Two samples based on porous PTFE have been measured by Kevin Miller using FTS: Zitex G110 and Zitex G115 (recommended by Ed Wollack).

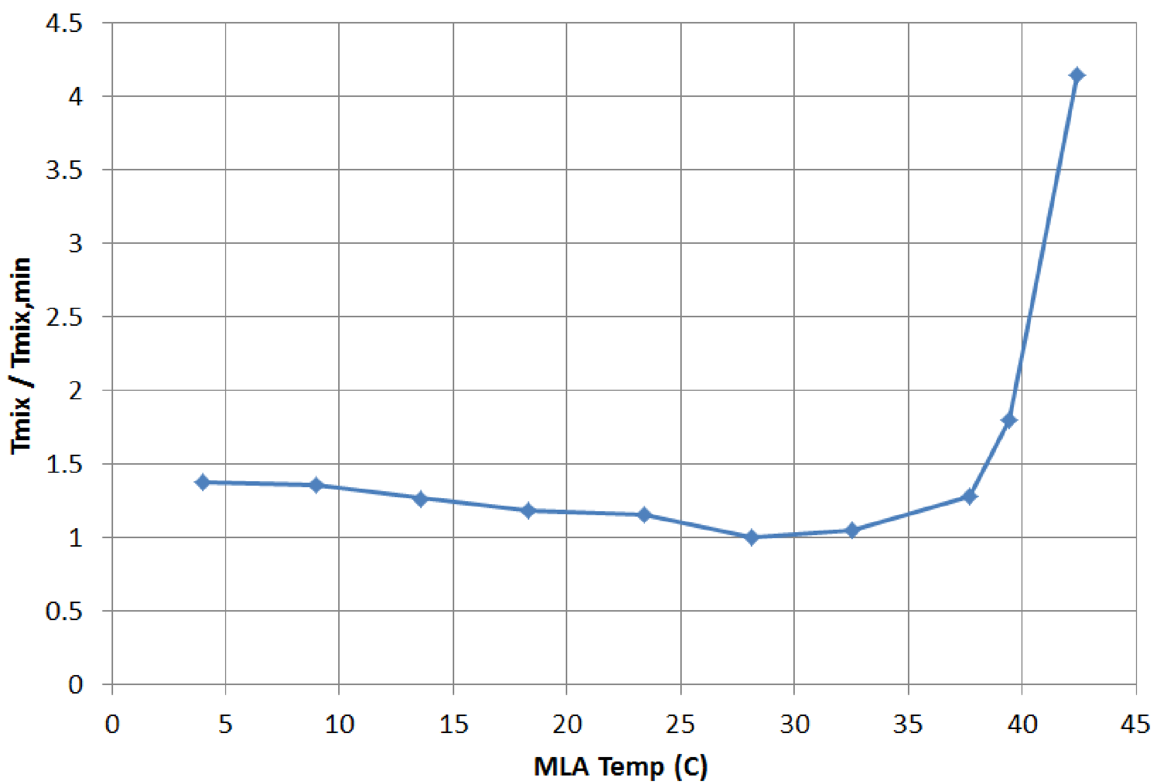



- Fitted material constants $\varepsilon_r=1.4+\iota 0.0001$ (Courtesy of Ed Wollack )
- Both G110 and G115 would perform optimally if the thickness could be increased by 1.4mils.
- G115 was selected based on its superior mechanical strength.

# Back-UP: Mixer Noise vs Plate Temperature

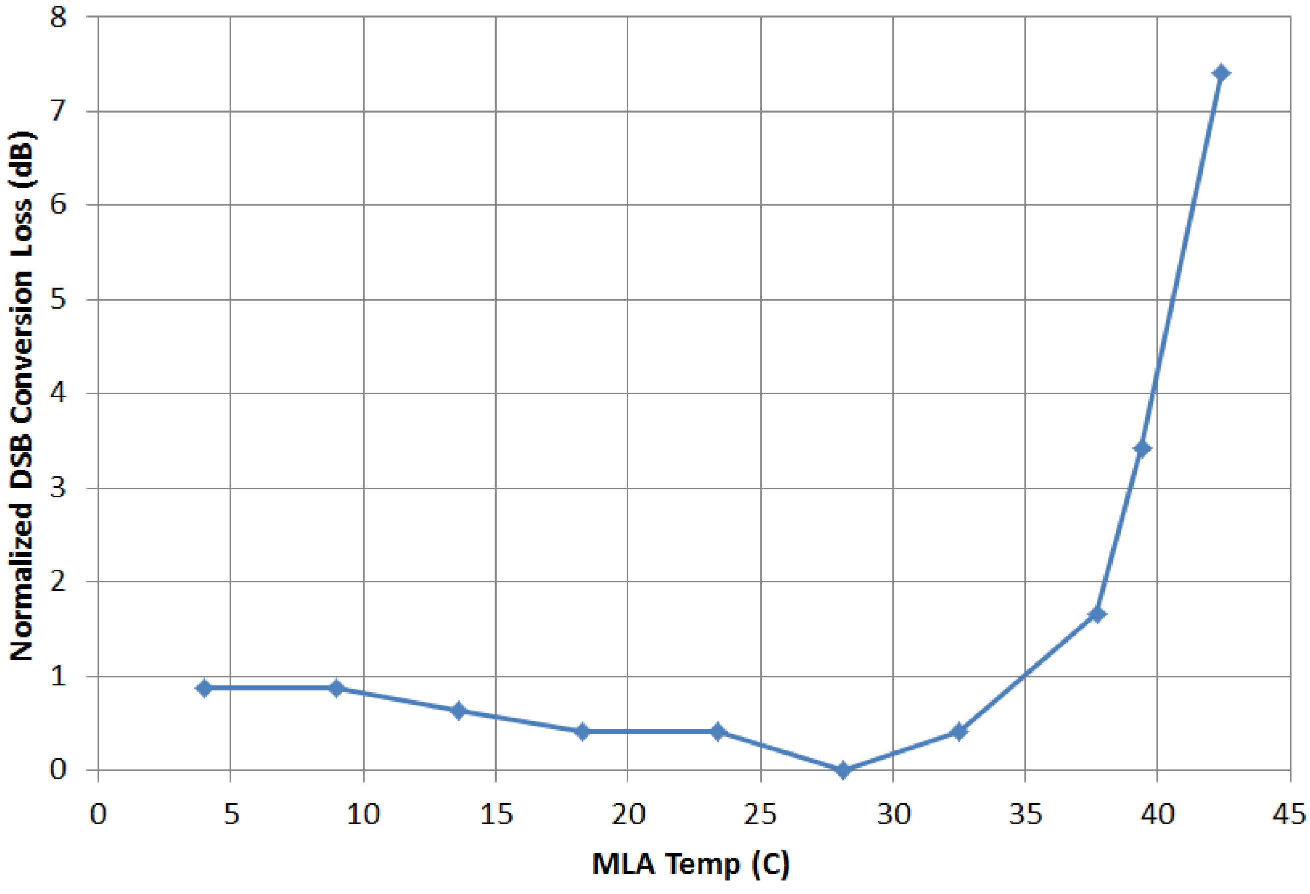





- LO=883 GHz, 8-11 GHz IF
- Relative measurement, $T_{min}$ higher due to loss of taper and WR-10 waveguide
- Optimized for 28 +/- 10 C
- LO power inversely proportional to temperature, so above ~40C, mixer underpumped
- Better to be too cold than too hot!
- This curve can be shifted to right or left with change of resistor in 73AMC bias circuit

# Mixer Loss vs Plate Temperature





# I&T