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Pasadena, California

GeoSTAR
Final Test Results

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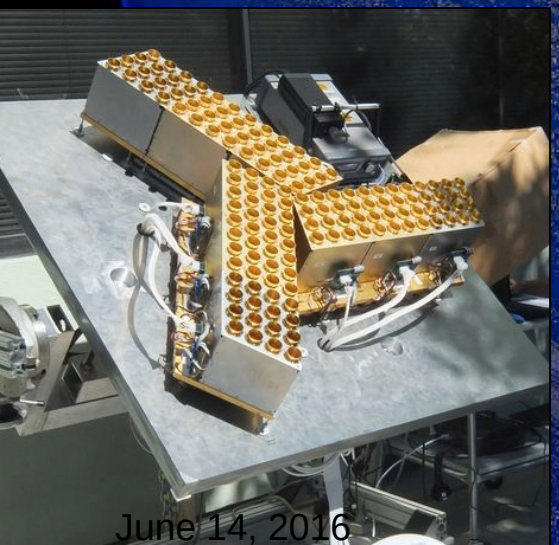
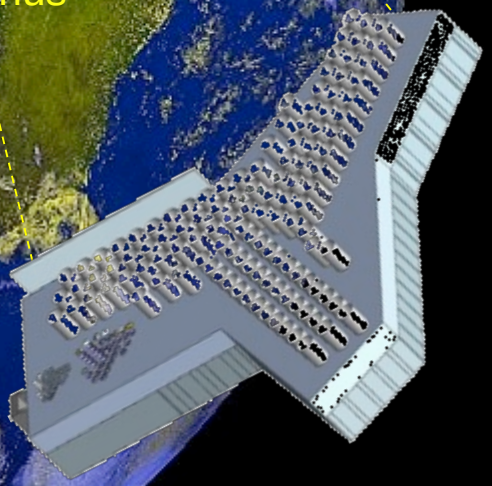
California Institute of Technology
† University of Michigan





Earth Science Technology Forum
Annapolis; June 14-16, 2016

June 14, 2016

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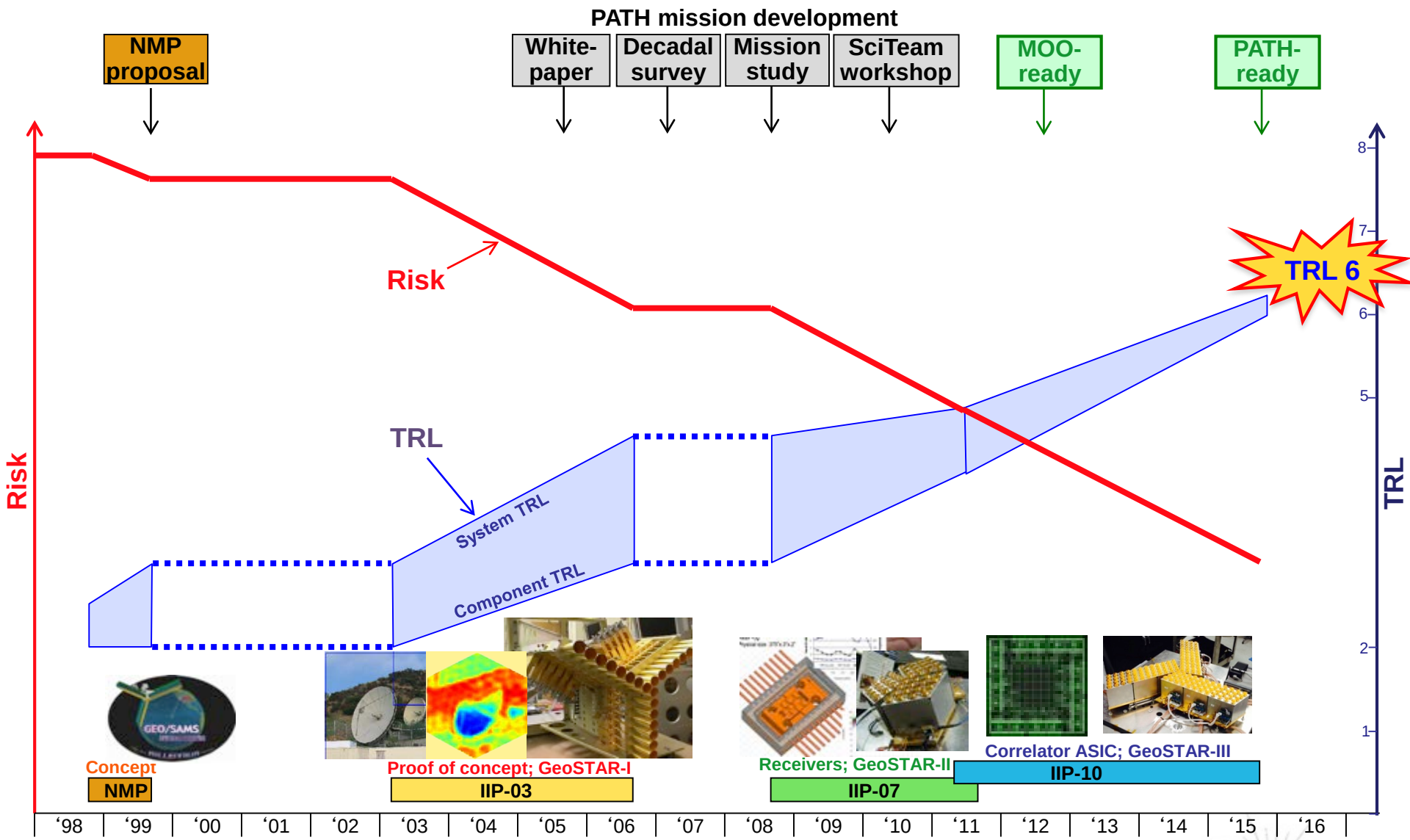
Development timeline



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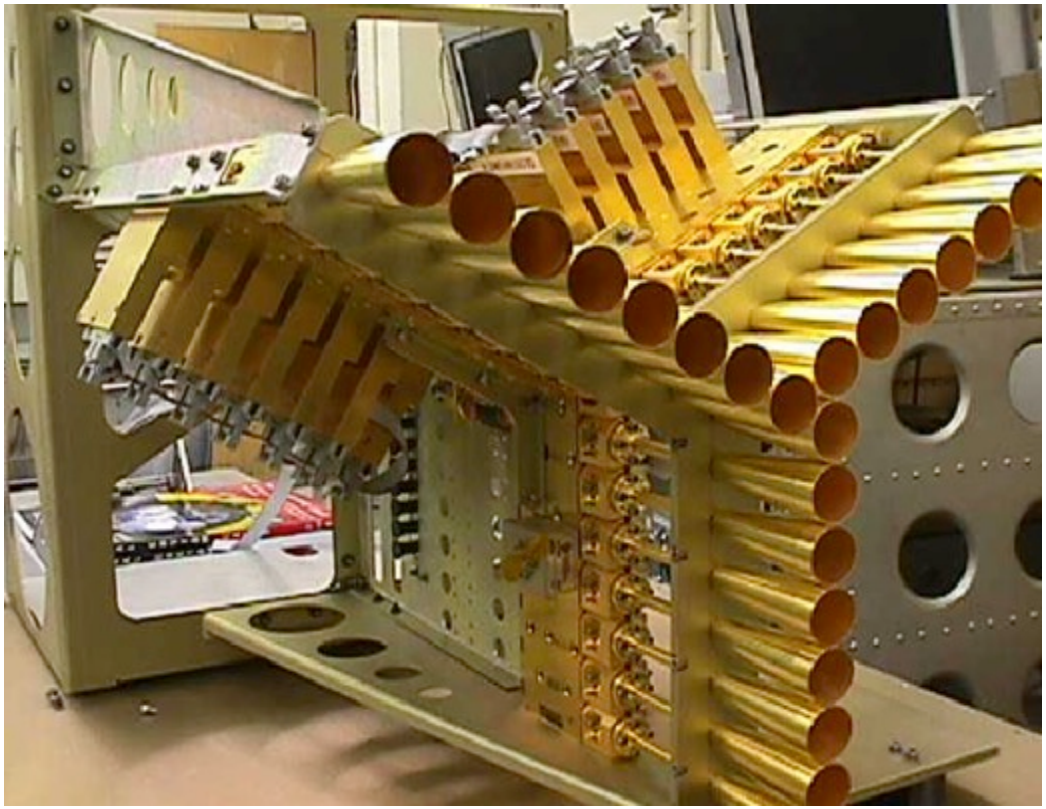
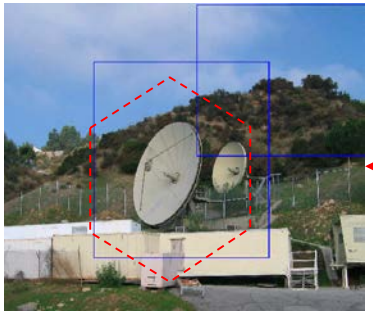
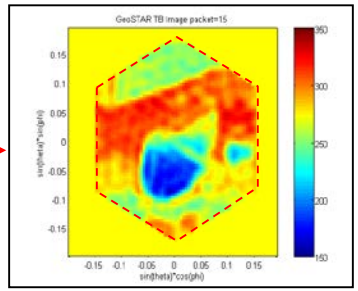
GeoSTAR-I: Proof of concept (IIP-03)

50 GHz synthetic-aperture array







Demonstration of imaging

Calibration

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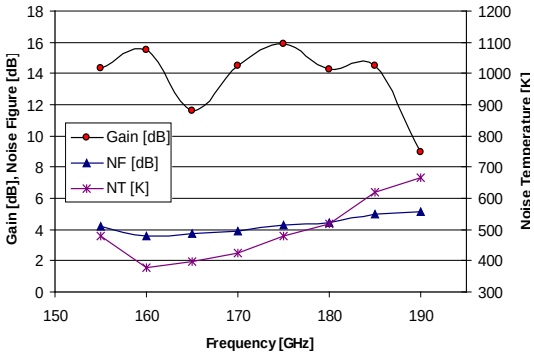
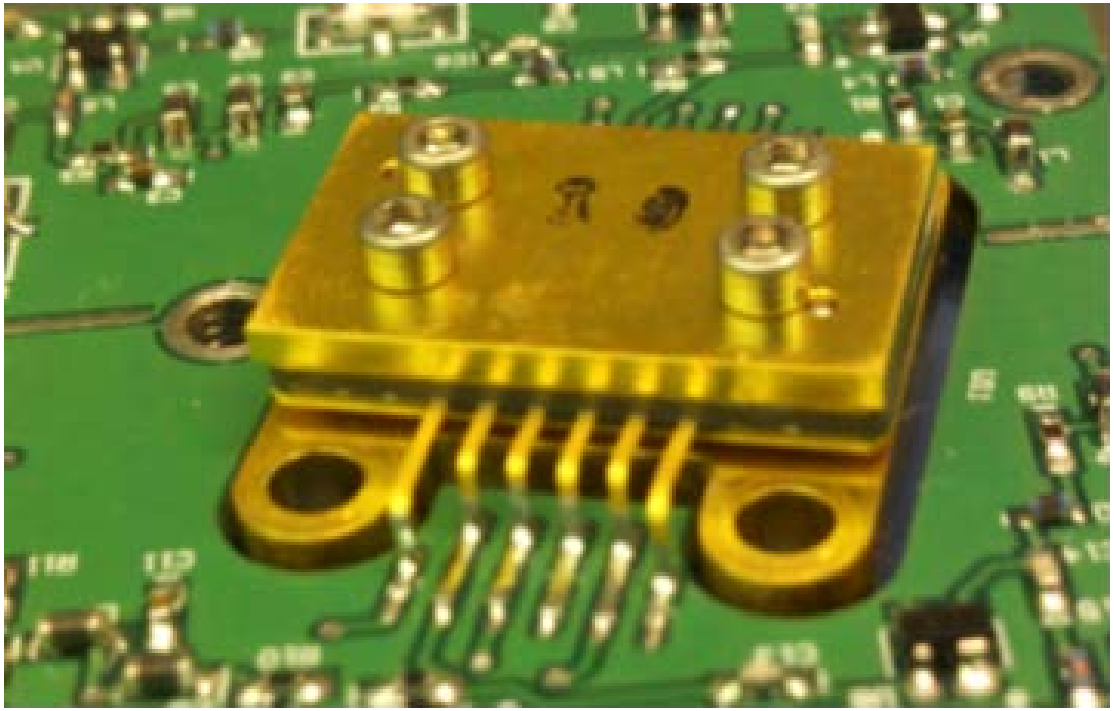
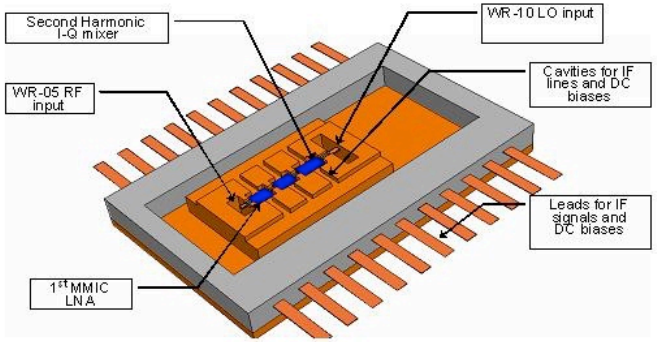
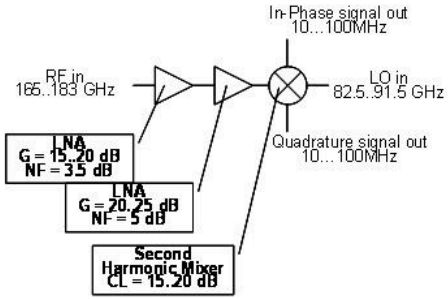
MIMRAM receivers (ACT-05)

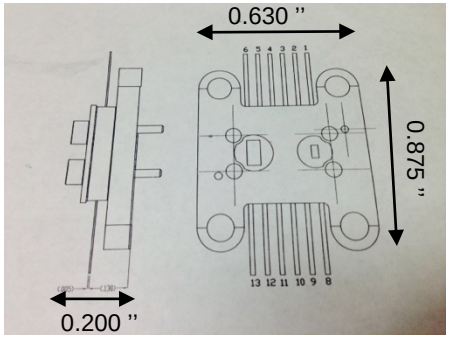
Miniaturization: 25 mW, 3 g per receiver











Complete LNA + mixer receiver; broadband, up to 190 GHz

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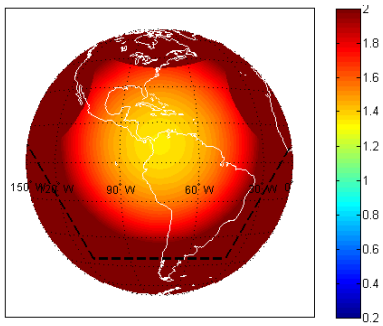
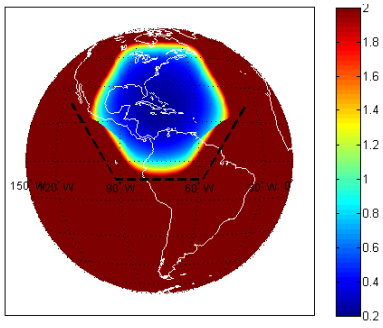
GeoSTAR-II: 183 GHz (IIP-07)

Multi-row antenna design

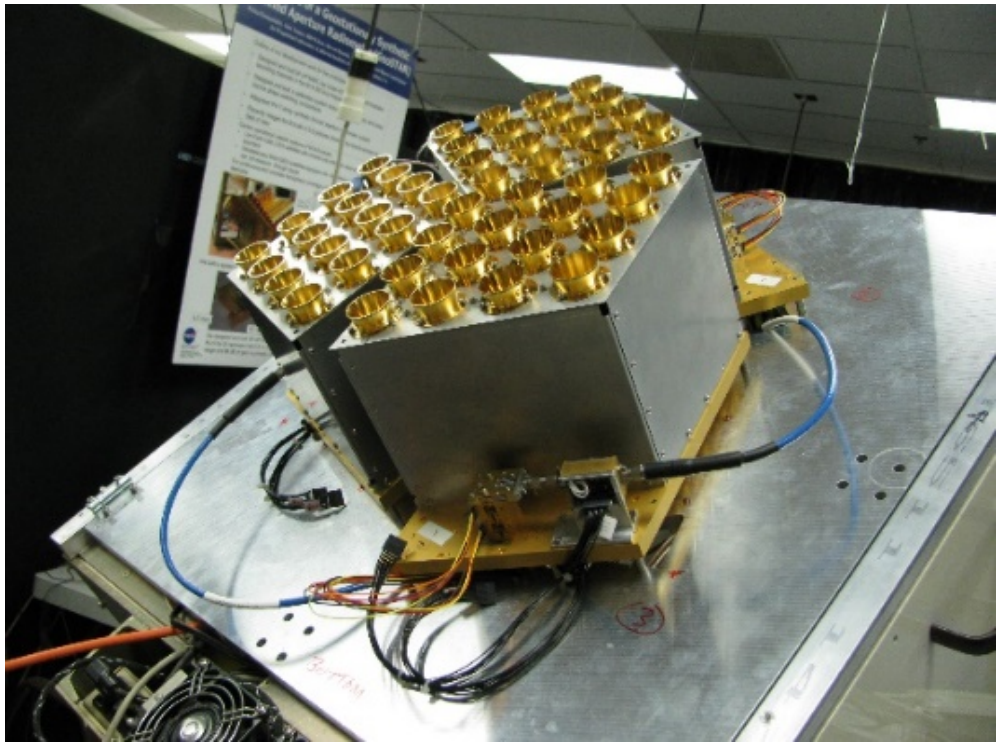
Improved antenna efficiency



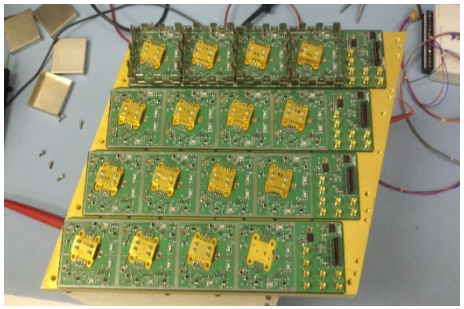
GeoSTAR-I



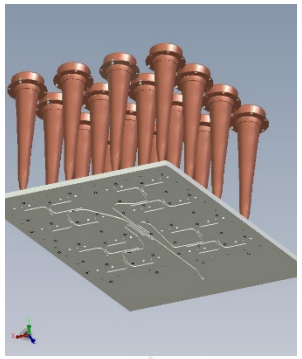
GeoSTAR-II



"Tile" assemblies



MIMRAM receiver arrays



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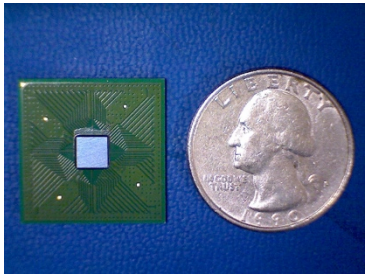
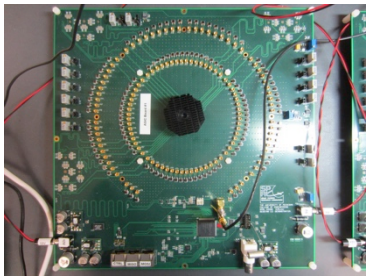
GeoSTAR-III: Correlator (IIP-10)

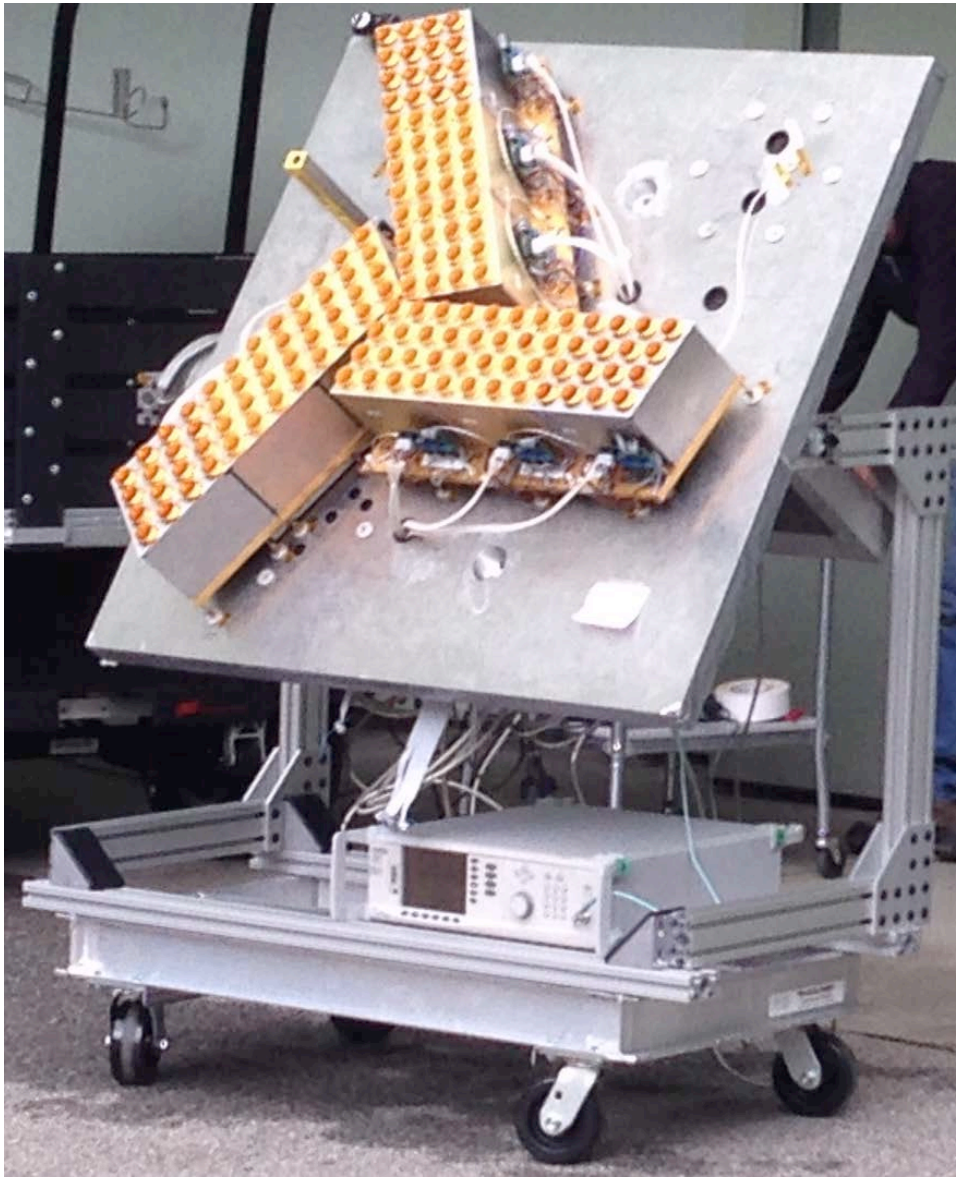
Complete high-gain 183-GHz STAR

ASIC-based correlator





2-bit ADC + digital correlator
128 analog in @ 500 MHz
64x64 = 4096 correlators
98% efficiency @ -15dBM in
Clock speed up to 1.5 GHz
Up to 6.1×10^{12} 2-bit mult/sec
1.44 Watts @ 1 GHz



Key technologies tested to TRL 6

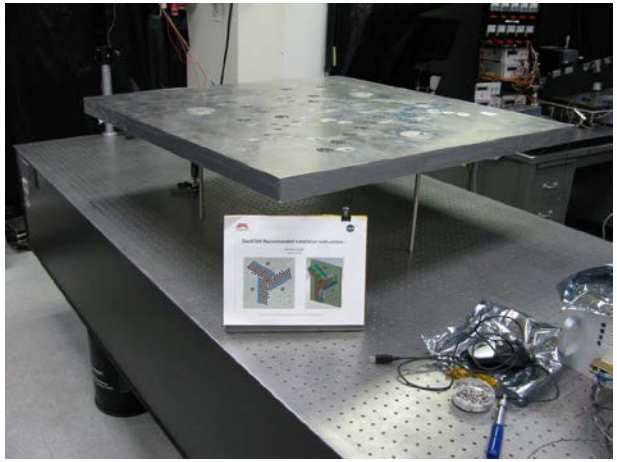
All other elements are engineering developments

Ready for space implementation!

Integration, Assembly, Testing

Mechanical “optical bench”

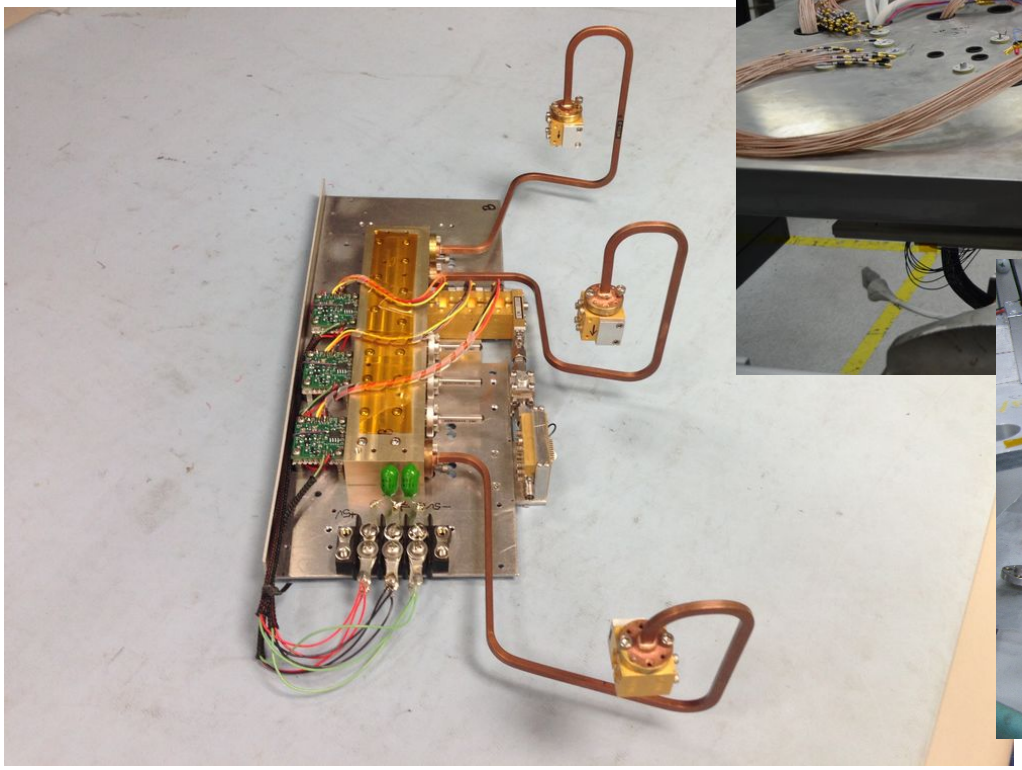
Honeycomb al core ‘optical bench’ bench

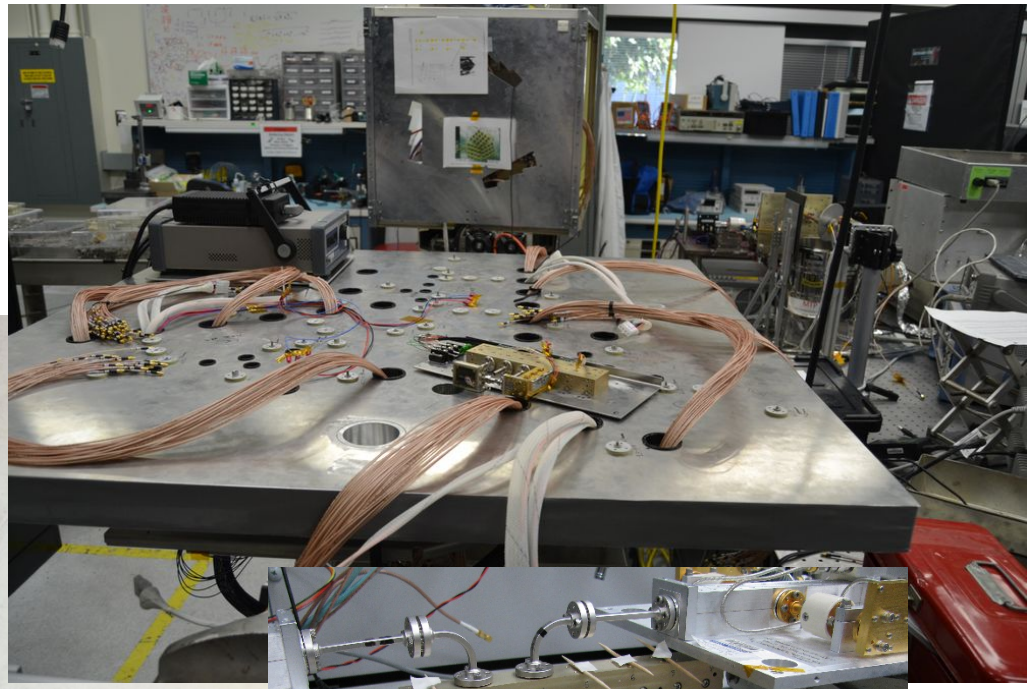


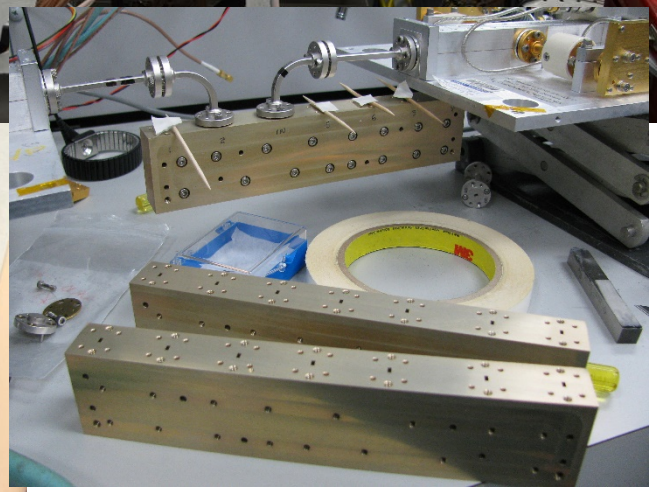
...as mounted on new tilt-table (+ IF cables)

Integration, Assembly, Testing

Local Oscillator buildup

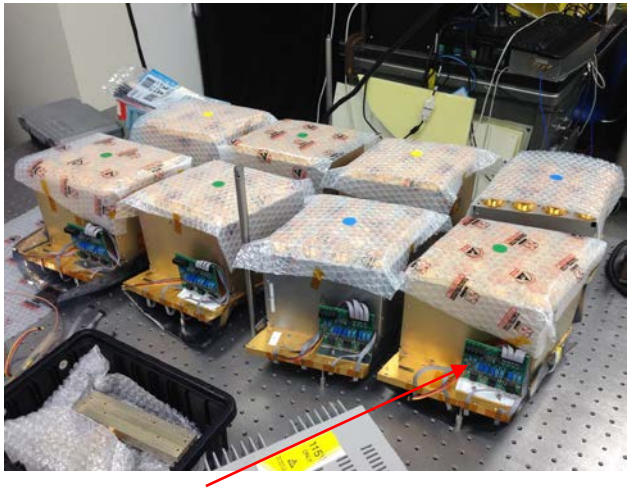




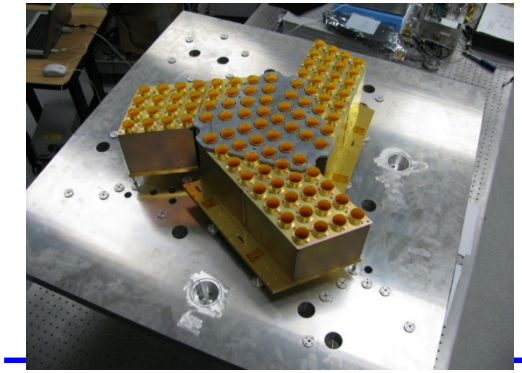


Integration, Assembly, Testing

Manifolds on Optical Bench

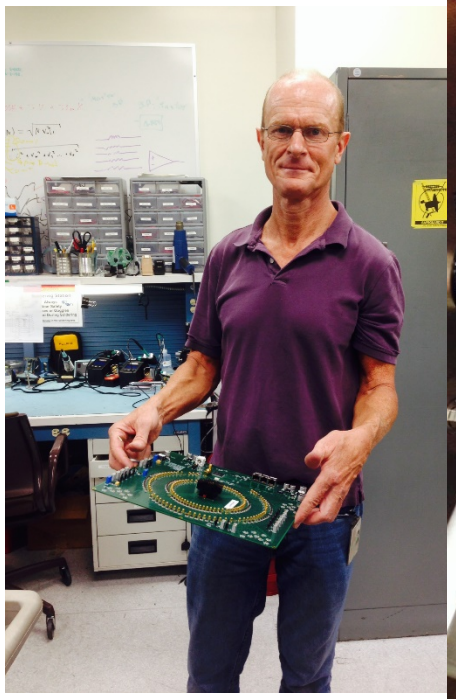


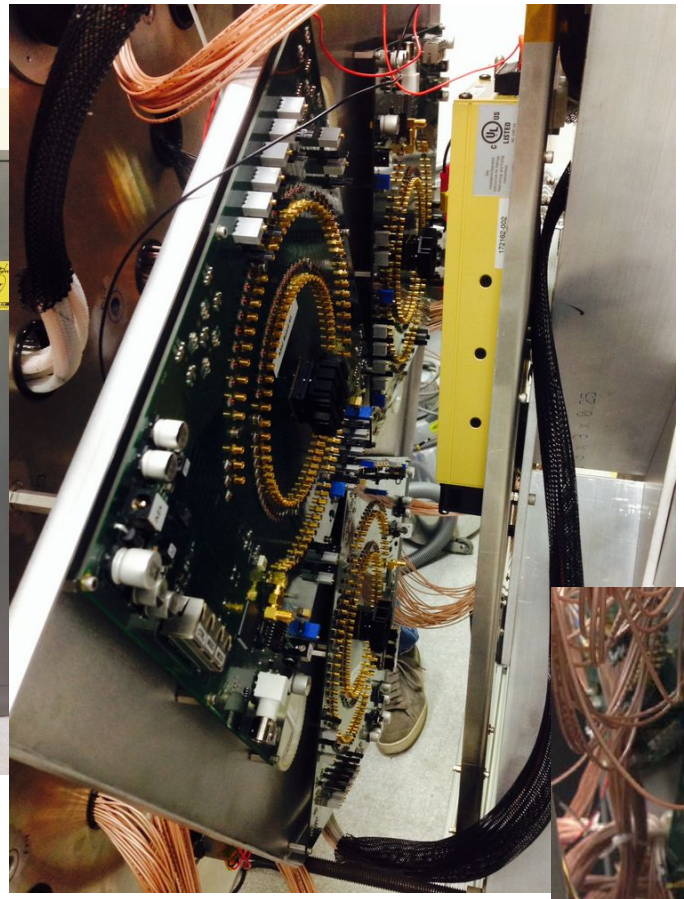
new: Integrated DC-DC power converters

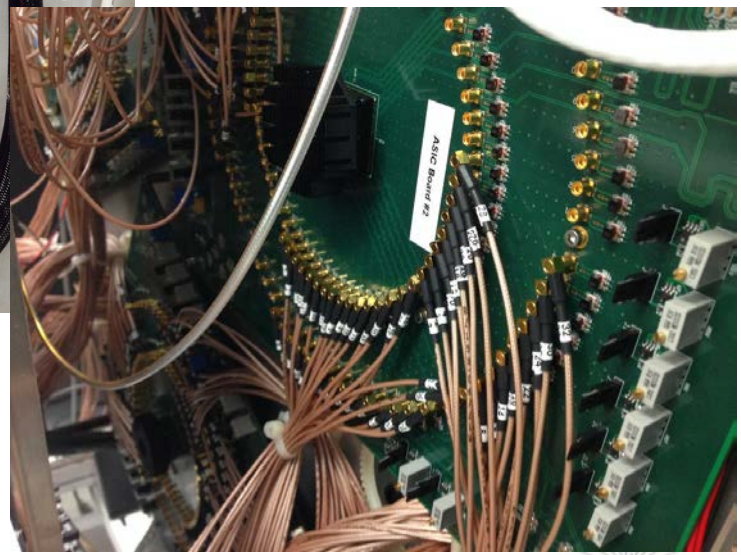


Integration, Assembly, Testing

Correlators

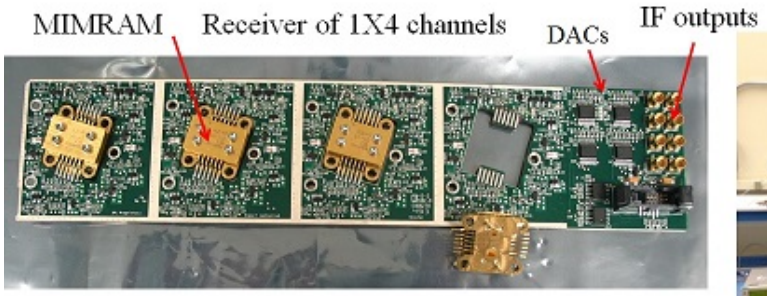


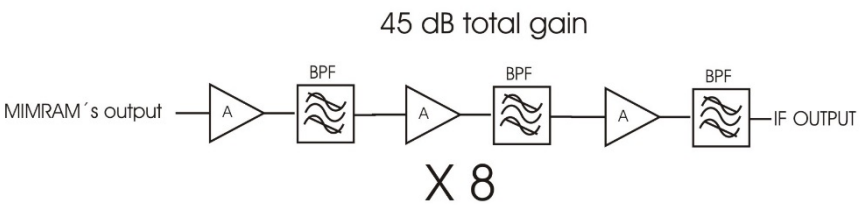


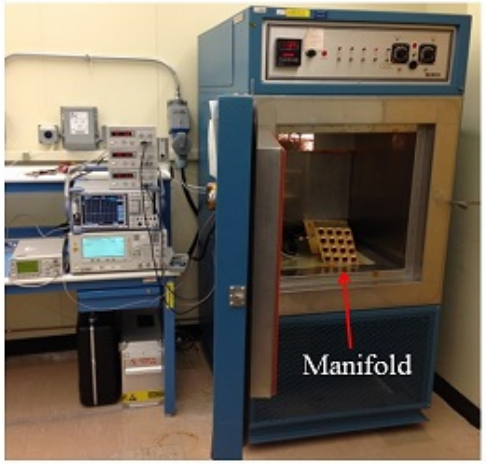


Integration, Assembly, Testing

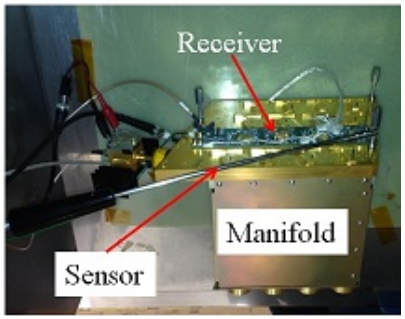
IF boards



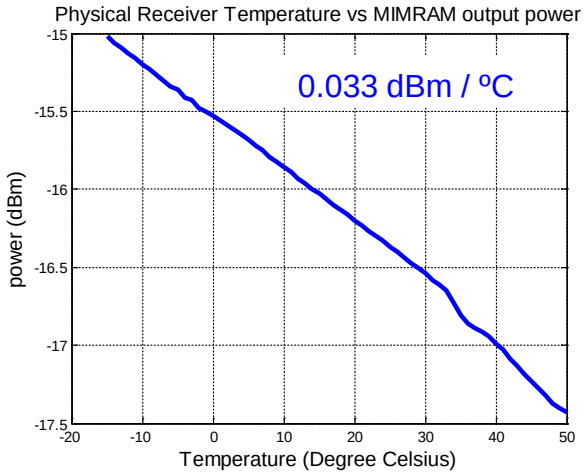


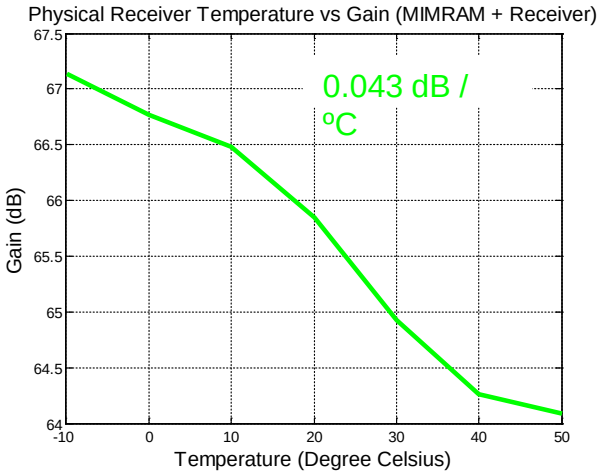


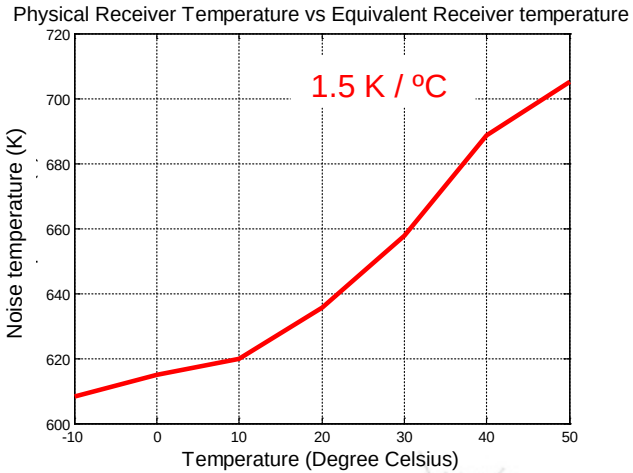
Testing of the Manifolds with the MIMRAMs integrated in the chamber.



Detail of the temperature sensor location.



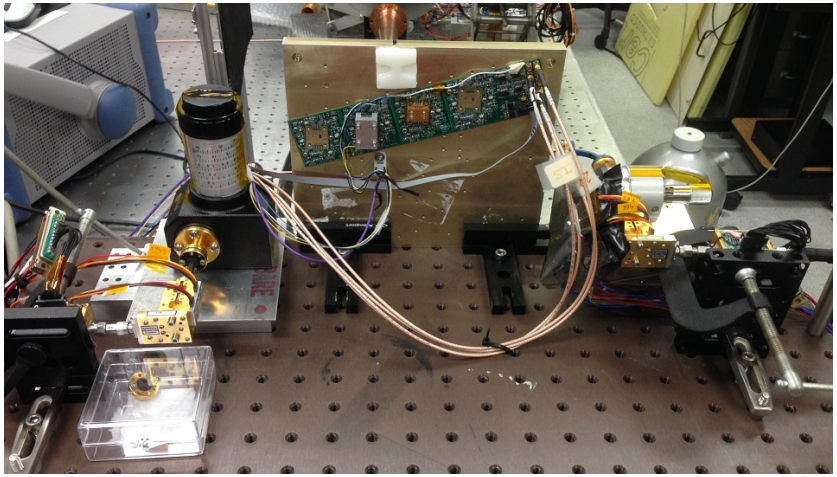


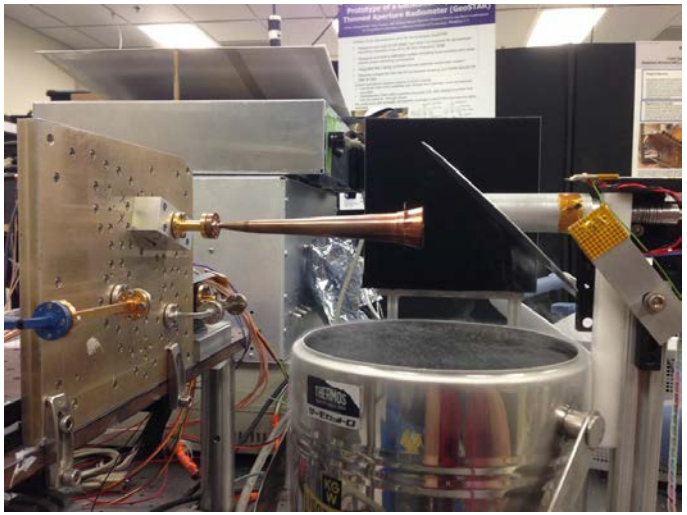


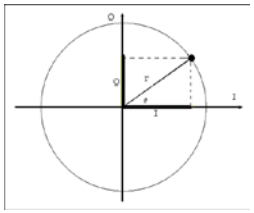
Integration, Assembly, Testing

Receivers

Receivers are mass produced on assembly line
Large number of MIMRAMs to test (144 units)
Automated process in single measurement setup





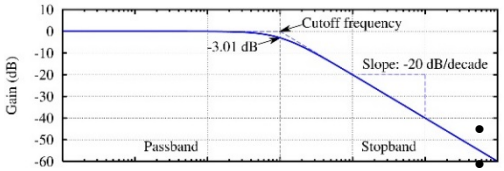


Phase

- Vector voltmeter
- Vector analyzer

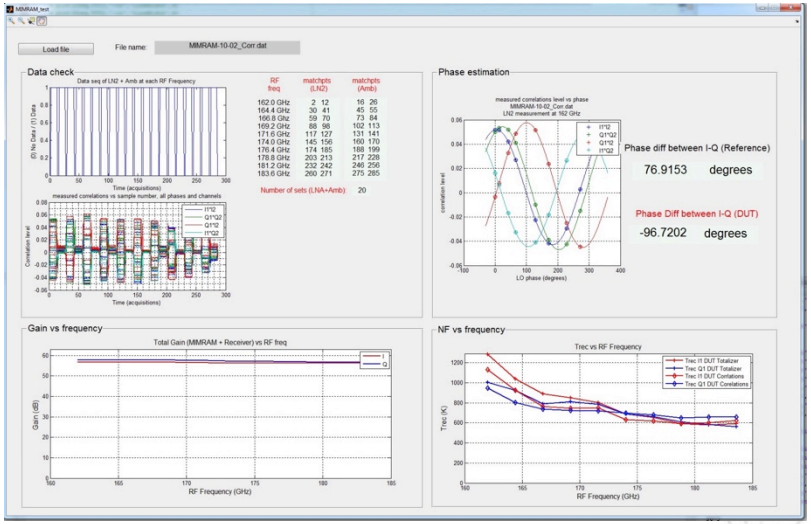
NF

- Noise Figure analyzer
- Power meter (Y factor)



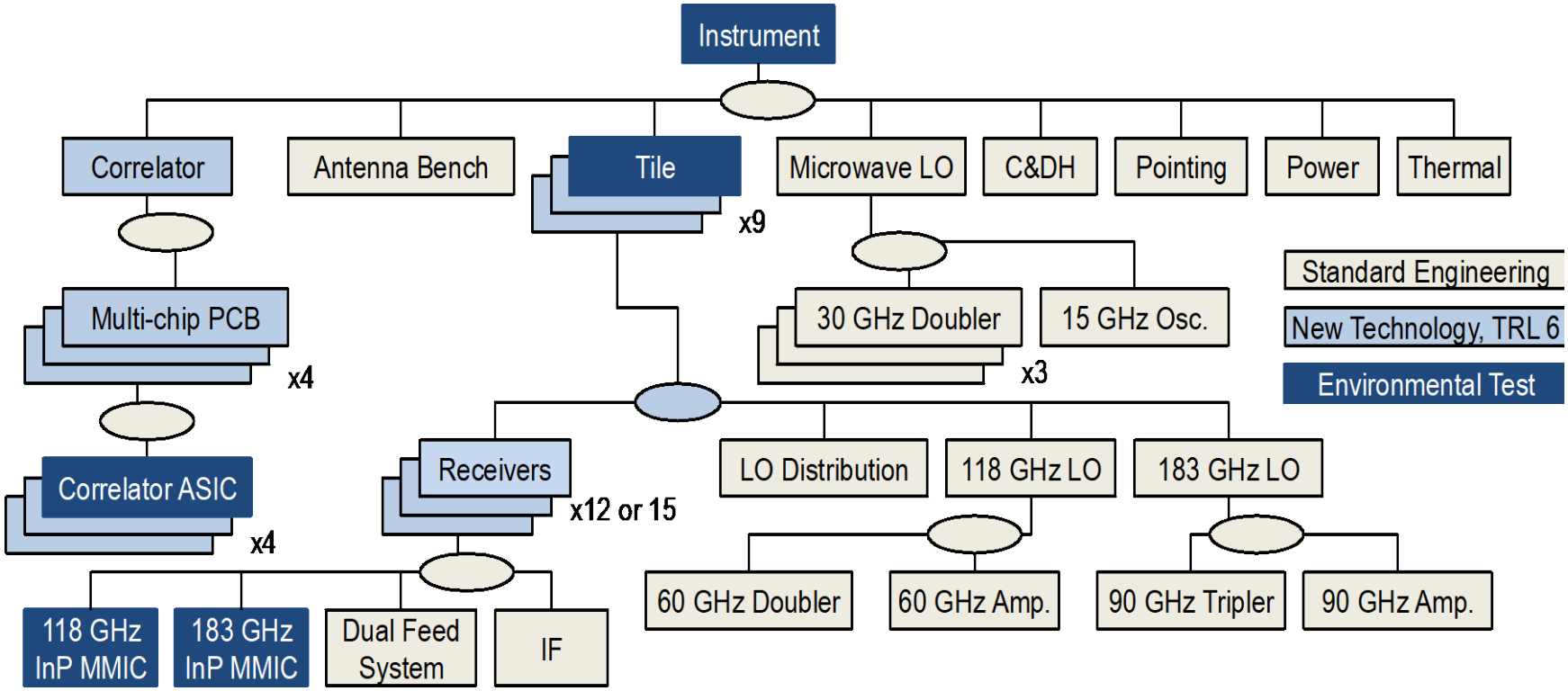
Gain

- Spectral Analyzer
- Power meter



Analysis software

TRL testing philosophy



Example technology map for a dual-band GeoSTAR space instrument

Elements in dark blue contain new technology and are explicitly tested to TRL 6

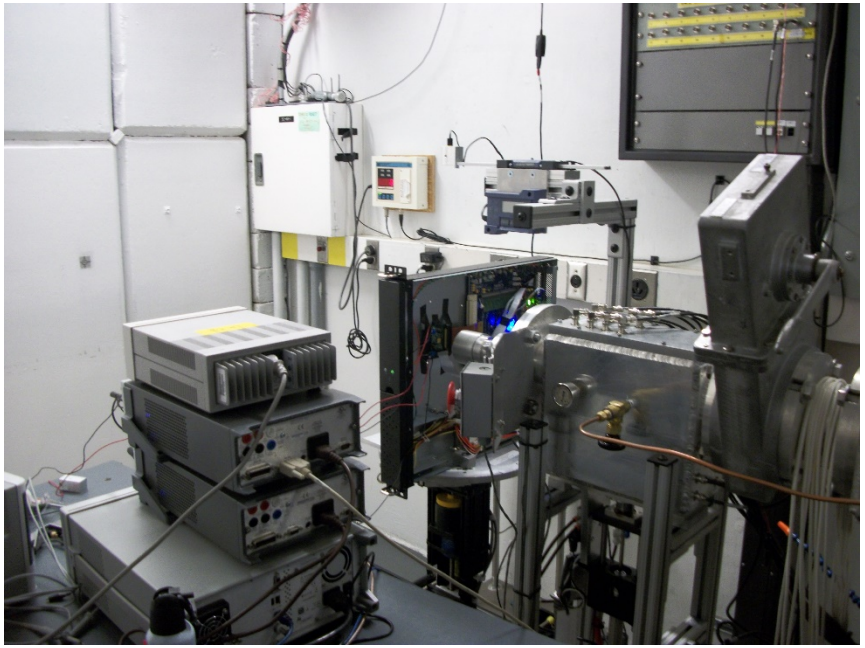
Elements in light blue contain new technology but are tested in context when integrated at a higher level

Elements in white contain standard engineering and do not need to be TRL tested

Radiation test

Correlator ASIC

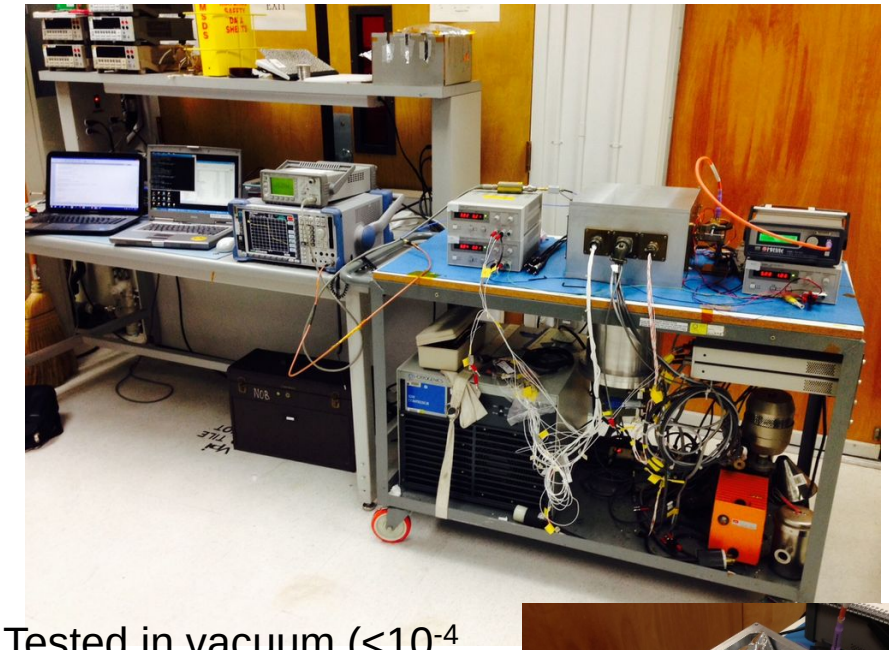
- Texas A&M Cyclotron Facility
  - functioning correlator & ADC ASIC prototypes
  - Data showed no latchups
    - Only single event upsets
  - Analysis for worst case GEO = 0.163 errors per day (from all Weibull fit)
    - Science impact of such error rates is negligible

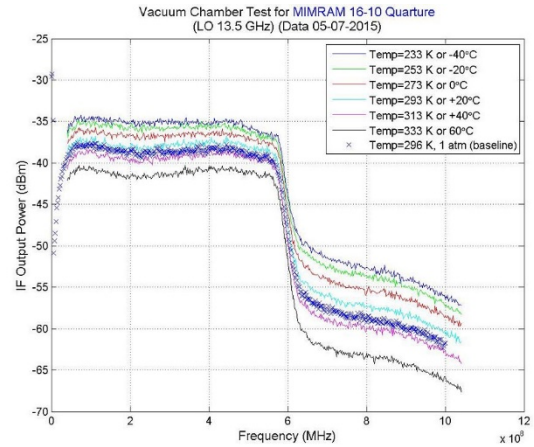


Thermal-Vacuum tests

Receiver boards and tiles

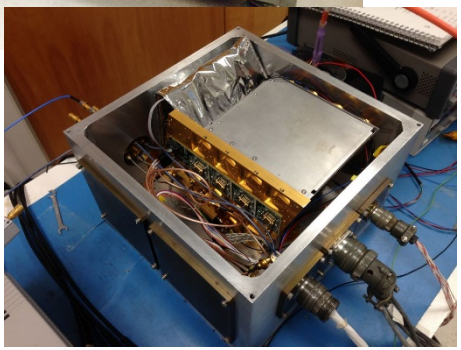
Thermal Vacuum test: IF board + MIMRAMs

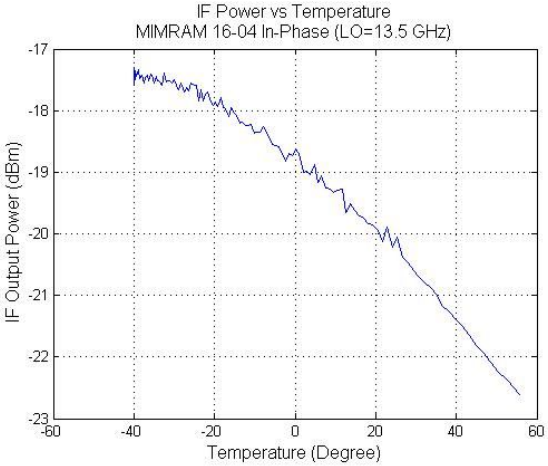




Tested in vacuum (<10^{-4} torr) over AFT ± 10° C

4 IFs monitored, one continuously





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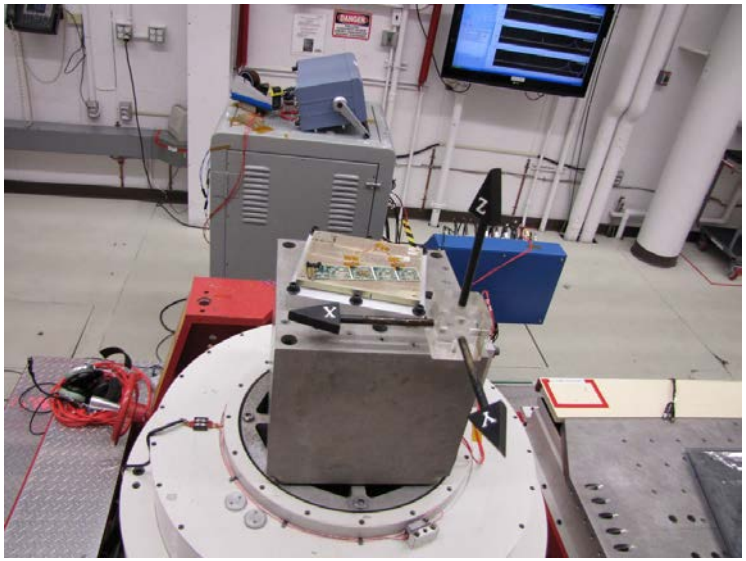
Vibration tests

Receiver boards and tiles

Vibration test: IF board + MIMRAM



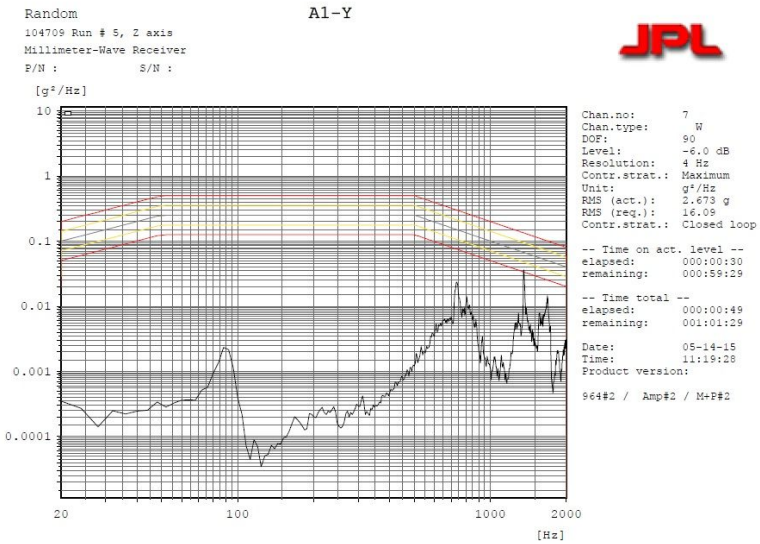
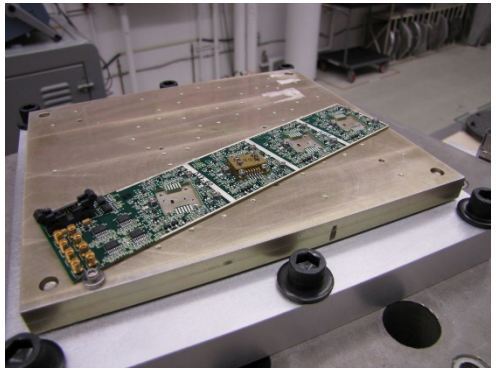
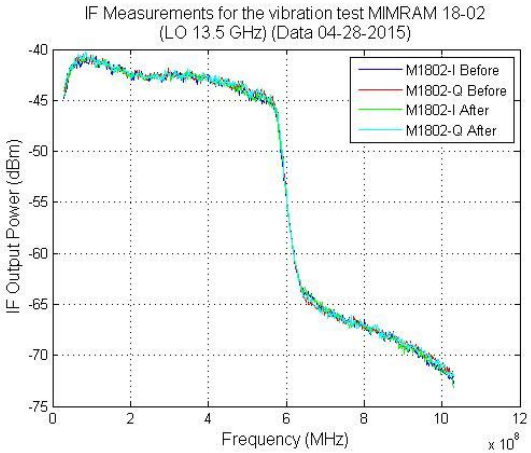


Table 5.2 - GEO Random Vibration Environment

Frequency (Hz)	Level
20	0.4 g^2/Hz
20 – 50	+3 dB /octave
50 – 500	1.0 g^2/Hz
500 – 2000	-4 dB /octave
2000	0.16 g^2/Hz
Overall G_{rms}	32.1

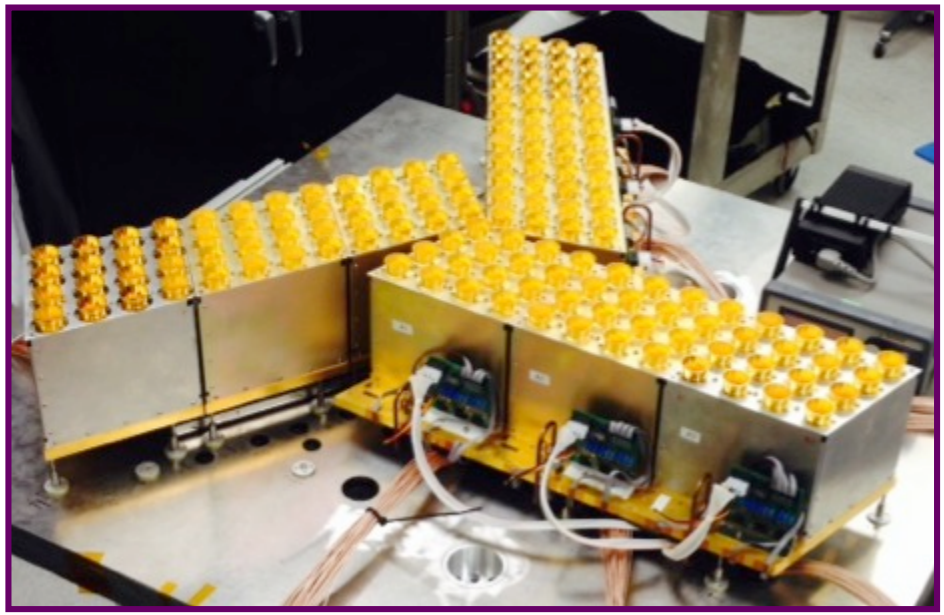
Test duration: 120 seconds

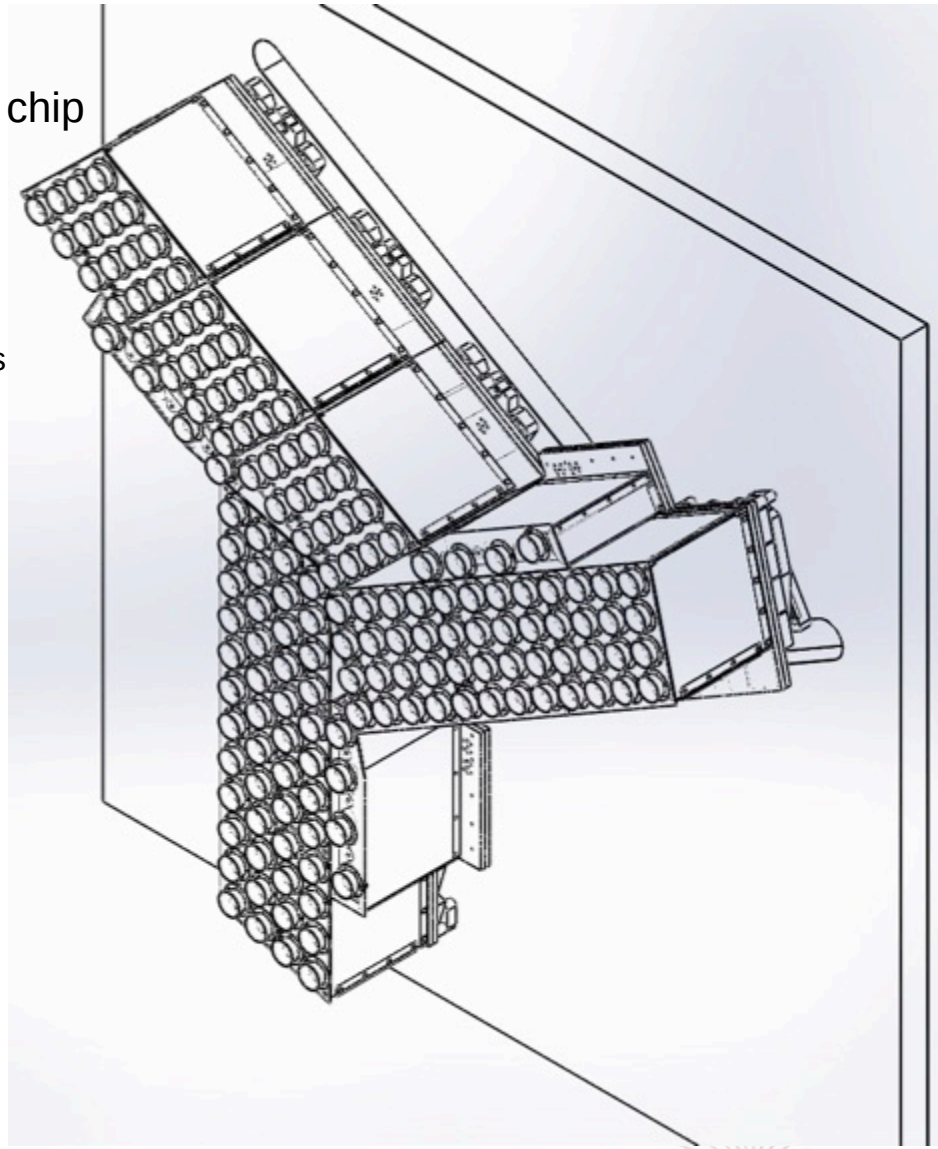




System performance testing: Objectives

- Further testing of correlator ASIC
  - Complete full correlator board hosting new chip
  - Full functional testing of new chip
- System testing
  - Assemble small 183-GHz antenna array
    - Using miniature ultra-low-power MIMRAM receivers
  - Integrate full system with correlator
  - Characterize system performance
  - Imaging demonstration





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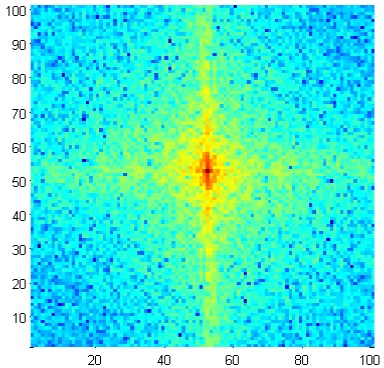
Spatial scales: HGA vs. LGA

Need LGA (GeoSTAR-I) *and* HGA (GeoSTAR-III) for complete image



Full visibility function

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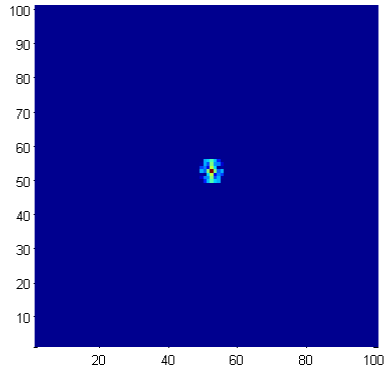

Short baselines

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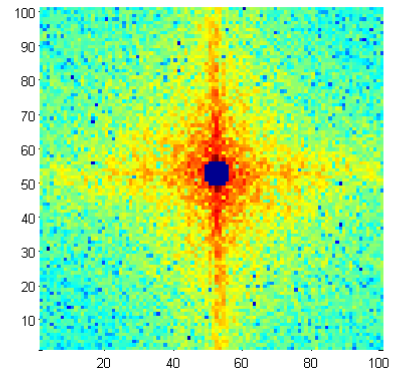
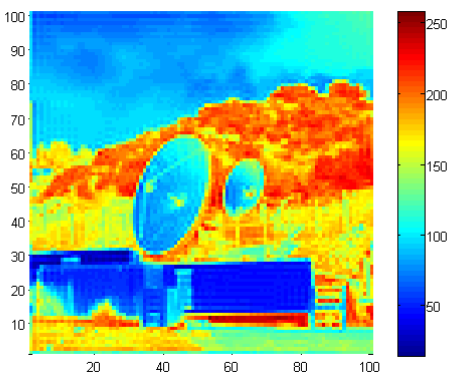


Long baselines



Full image

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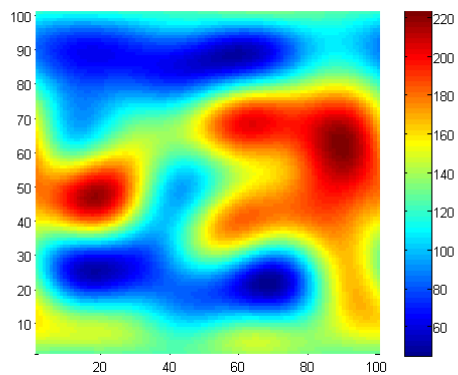
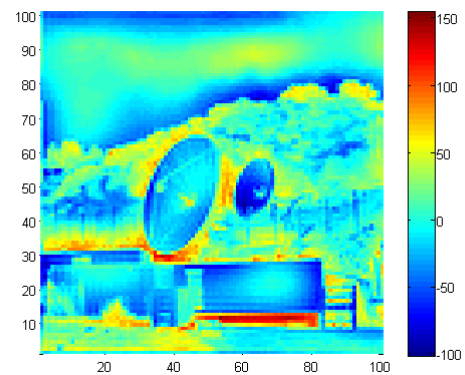


Low gain array (LGA)
Large spatial scales

+



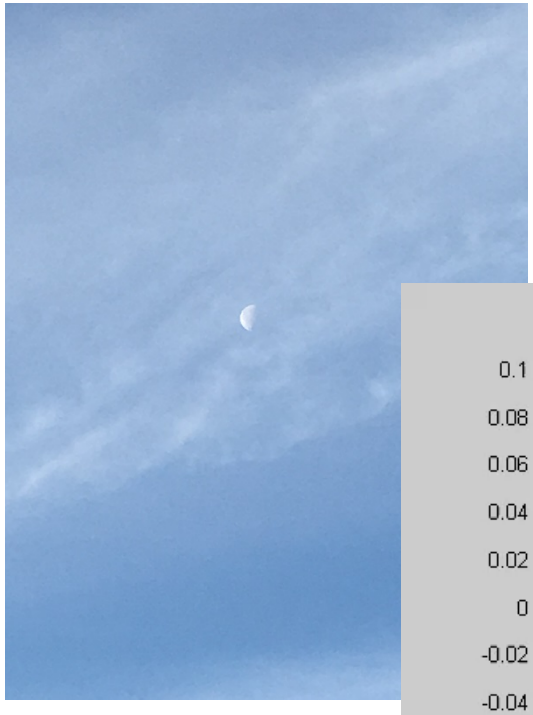
High gain array (HGA)
Short spatial scales

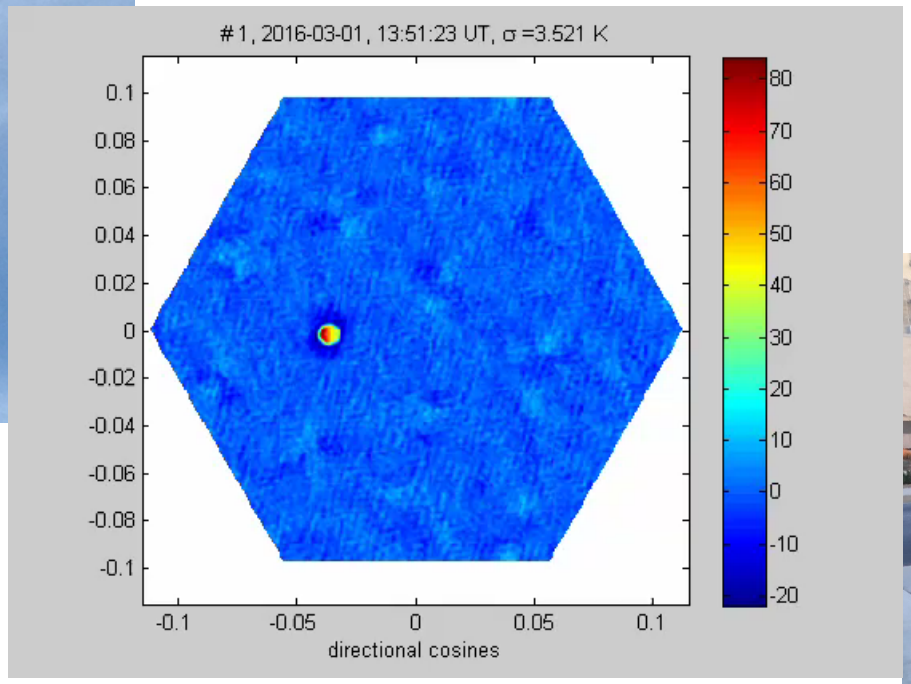
National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Imaging test: Moon

Third quarter moon, March 1 2016



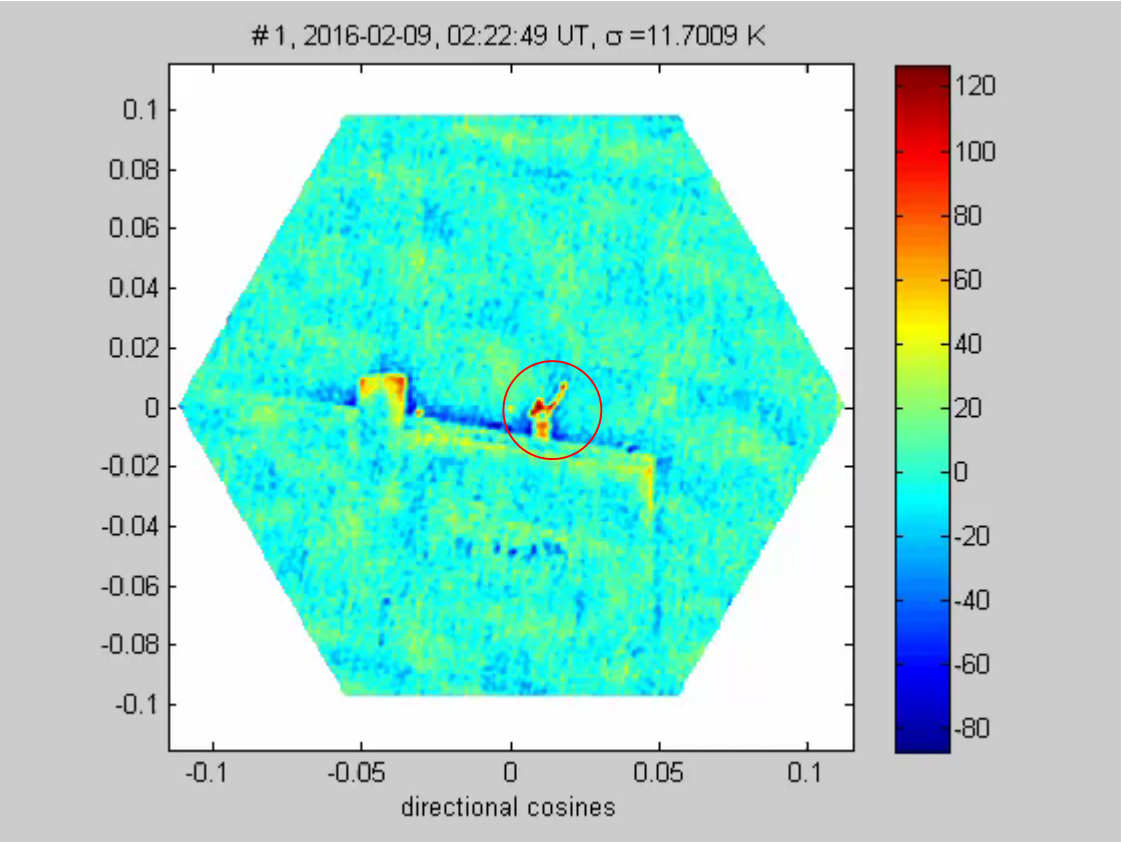


National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Imaging test: Ground scene

Man on top of a building



Summary

- STAR concept demonstrated in IIP-03
  - Developed a functional 50-GHz STAR demonstrator
- Key technologies developed in IIP-07
  - Developed miniature low-power 183-GHz MMIC receivers
  - Developed new alias-rejecting antenna array design
- Ready for PATH mission after IIP-10
  - Full-size 64x64 correlator ASIC is a success!
  - All key technologies are now at TRL 6
  - Can start PATH mission development any time

- We have advanced the technology from Tier-3 level to Tier-1 level – a major achievement