Multi-Application Smallsat Tri-band Radar - MASTR

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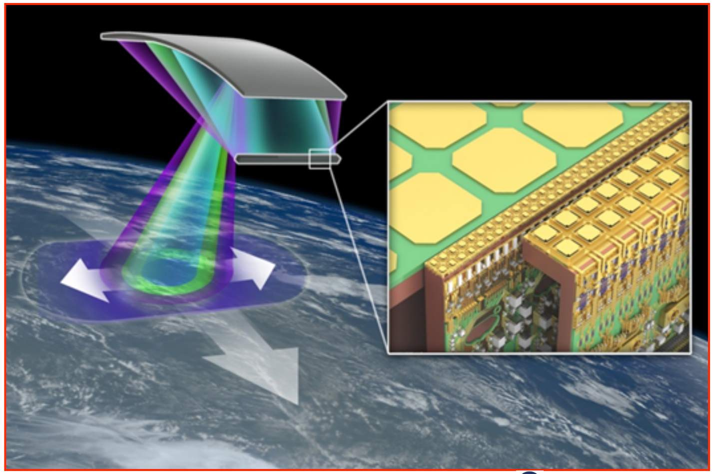
Why MASTR?

Clouds and Precipitation

- Addressed separately by active instruments so far (i.e., TRMM, GPM & RainCube at Ku and Ka band, vs CloudSat and EarthCARE at W-band).
- Three-frequency single aperture radar enables holistic view of the cloud-precipitation process
  - e.g., J. Leinonen, et al. 2014, ACE decadal survey mission concept (Ka- / W-band), Cloud and Precipitation Processes Mission (CaPPM) concept. (Ku-, Ka-, W-band) responses to Decadal Survey 2017.
- Technology maturity over the last decade enables scanning at W-band as well as tri-band integration



Courtesy of Nuvotronics Inc.

Altimetry and Scatterometry

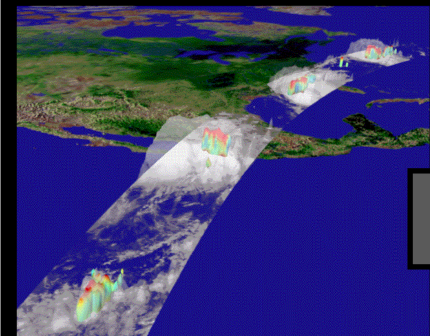
- Once an RF front end for a Ku/Ka-/W- real aperture scanning radar is available, making it suitable for other applications is possible.
  - For altimetry it is "only" a matter of opening up the bandwidth ;
  - For scatterometry more significant changes are necessary, but still possible (i.e., changing viewing geometry and tightening calibration requirements)

MASTR is tri-band (Ku-, Ka-, W-band) **scalable** phased array radar.
Designed to work as a Cloud and Precipitation Radar,
an Altimeter, or a Scatterometer (in a Spinning platform).
A modular, scalable architecture enables technology maturation via an airborne demonstration.
A compact profile allows multiple implementations depending of mission requirements, power, and budget available (ranging from SmallSats to large platforms).

Spaceborne "Tropospheric Radar" landscape (2017)

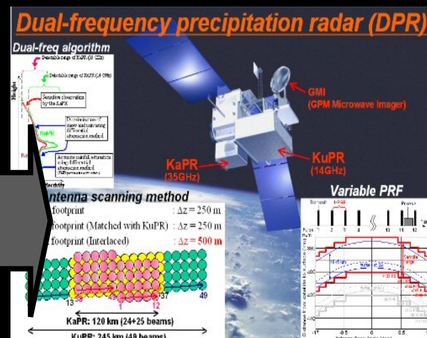
The 5 missions with Spaceborne C&P Radars

TRMM/PR – NICT/JAXA
Ku, Scanning , Tropical Rain



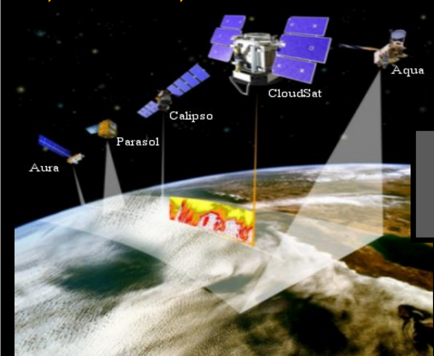
1997-2015

GPM/DPR – NICT/JAXA
Ku/Ka, Scanning, Precipitation



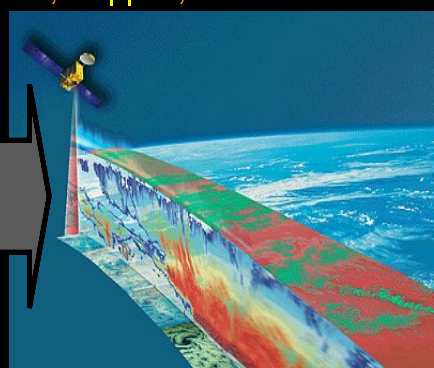
2014-Today

CloudSat/CPR
JPL/NASA/CSA
W, -30dBZ , Clouds



2006 -Today

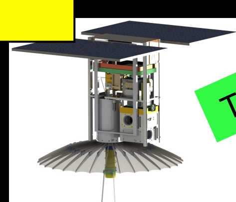
EarthCARE/CPR
NICT/JAXA
W, Doppler, Clouds



NET 2019

Next up: Launch NET Mar 2018

RainCube
JPL/NASA InVEST Tech Demo
Ka, Precipitation, 6U CubeSat



Temporal

NET 2018

Some concepts under development or proposed by the international community

Temporal

NIS (2004)
W/Ka, Scanning, Doppler, GEO

PHDsat (2002)
Ka/Ku, Scanning Doppler

SnowSat / PPM
W/Ka, Doppler

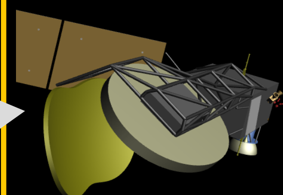
StormSat on ISS (2016)
Ka/, DPCA Doppler

Dynamics

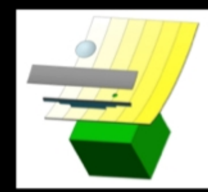
Wide Swath Winds
W Conical Scanning

ES DS 2007:
ACE Mission Concept Radar
Ka/W, Doppler, Scanning

ACERAD (Ka)



ReflectArray ACE radar



Water Vapor in Cloud

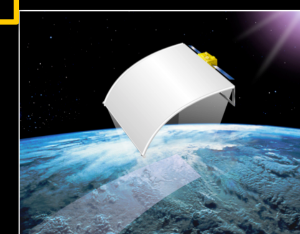
VIPR
183 GHz line
Water Vapor

StereoRadar
Dual Beam

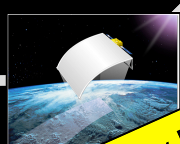
Precip Mapping

Scanning W on ISS
W Scanning
Wide Swath
Ka/Ku Scanning

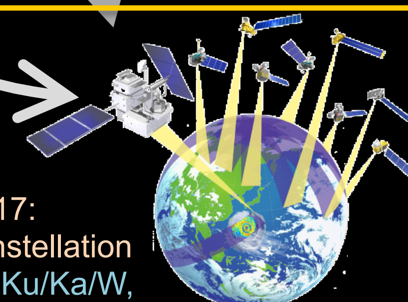
ED DS 2017:
CaPPM 3CPR
Ku/Ka/W, all Doppler,
all Scanning



IIP 2016: MASTR
Ku/Ka/W,
Scanning, SmallSat



New Entry



ES DS 2017:
Radar Constellation
Core S/C: Ku/Ka/W,
Trains: RainCube

Recent GPM/ACE joint Experiments

The GPM ground validation program and the ACE Science Working Group have successfully completed two joint projects where **multi frequency cloud-precipitation radar** data were acquired:

- **IPHEX/RADEX'14**, N. Carolina, May/Jun 2014
- **OLYMPEX/RADEX'15**, Washington, Nov/Dec 2015.

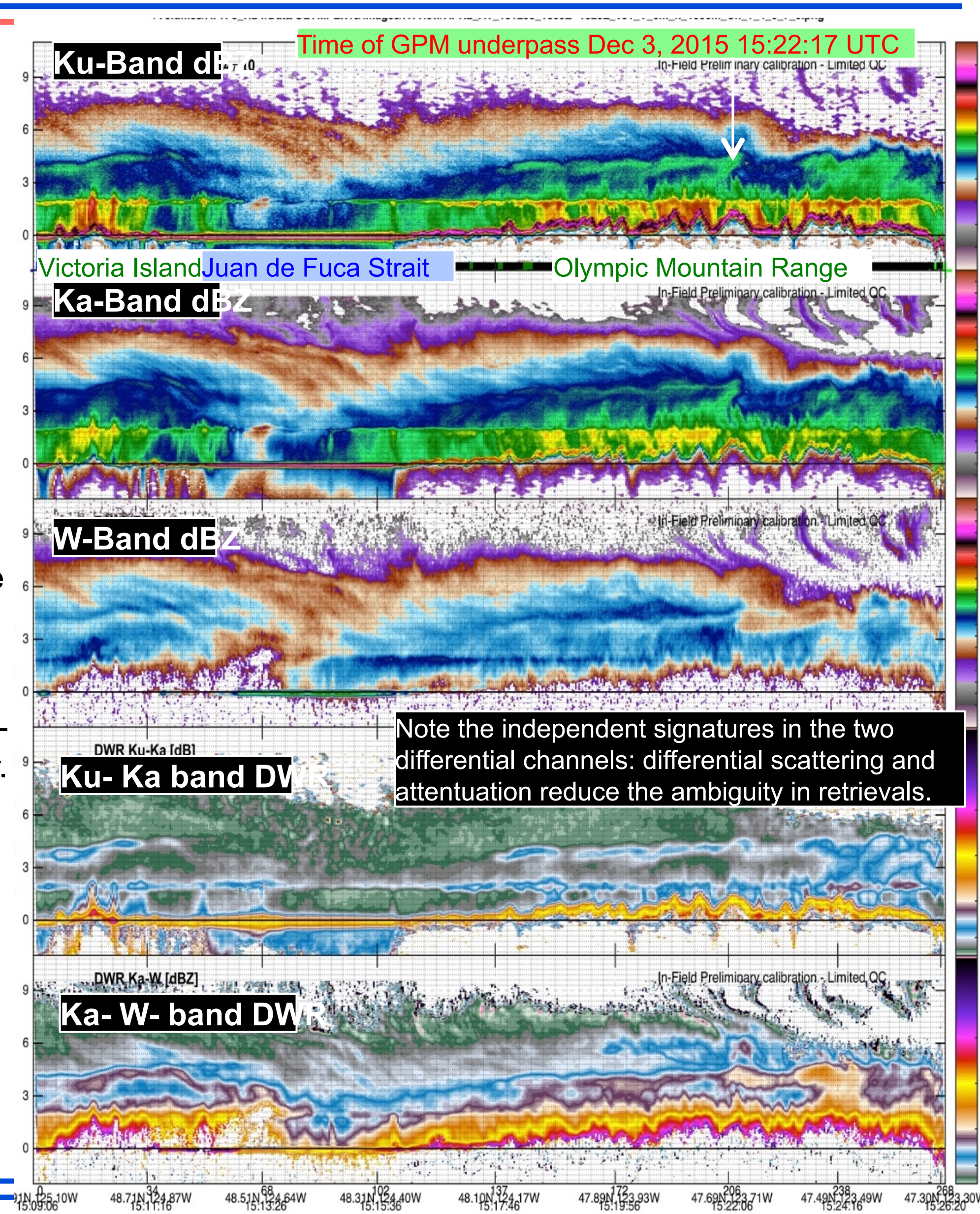
W. Petersen, M. Schwaller, J. Mace, R. Marchand. A. Barros, R. Houze, L. McMurdie and many other.

GPM exploits the multi frequency radar data to better constrain the validation of GPM retrievals.
ACE seeks to demonstrate and refine the definition of the radar for the ACE mission.

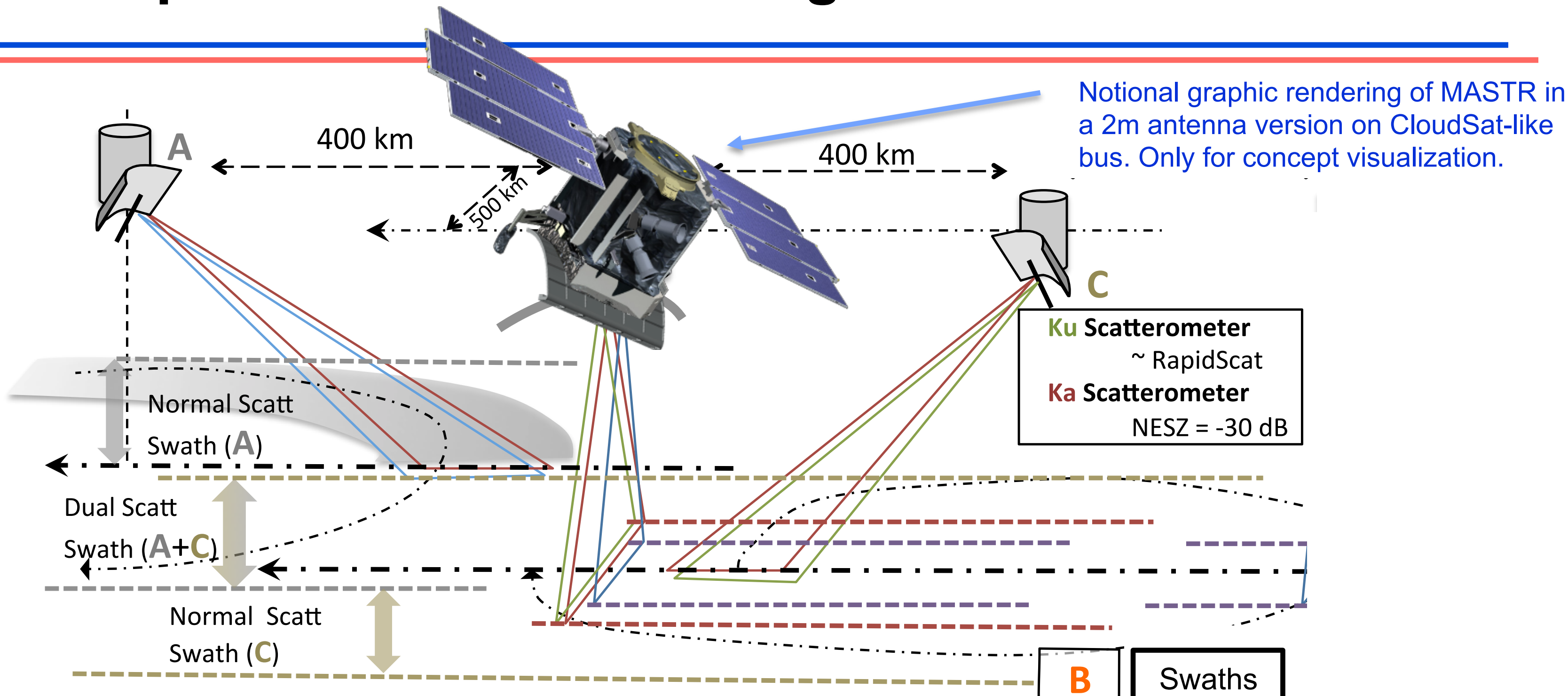
APR-3 (S. Durden, PI, ESTO/AITT Program) is the first 3-frequency (Ku, Ka, W), scanning, Doppler, airborne radar.

One example of the data acquired (preliminary calibration) is shown from a direct GPM/DPR underflight on Dec 3, 2015.

APR-3 is an airborne proxy to **3CPR** and **MASTR**.



One possible mission configuration for MASTR



A

Ka Scatterometer, provides 2nd look angle inside the 500 km "Dual swath" with **C**

W Precip "wide survey"
MDZ: 0 dBZ
1000 km swath
Global mapping of precipitation occurrence, atmospheric correction for scatterometric measurements

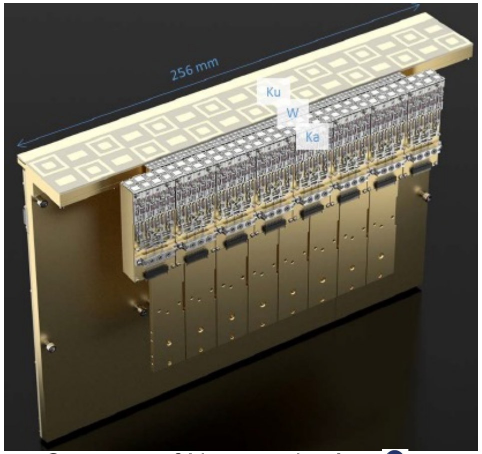
B

Altimeter Mode (over ice sheets, shelves and glaciers)
Ku : 1 beam, NESZ: -15 dB,
W : 7 beam (fill the Ku footprint), NESZ: -15 dB,
Cloud & Precip Mode (elsewhere):
Ku : 33 beams, 85 km swath
MDZ: +10 dBZ, above 400 m asl
W : 33 beams, 25 km swath,
MDZ: -25 dBZ @ nadir above 400 m asl (short pulse)
-10 dBZ off nadir above 600 m asl (chirp pulse)
Precip Mode (always):
Ka : 45 beams, 85 km swath, MDZ: -5 dBZ

Swaths
Ku
Ku
W

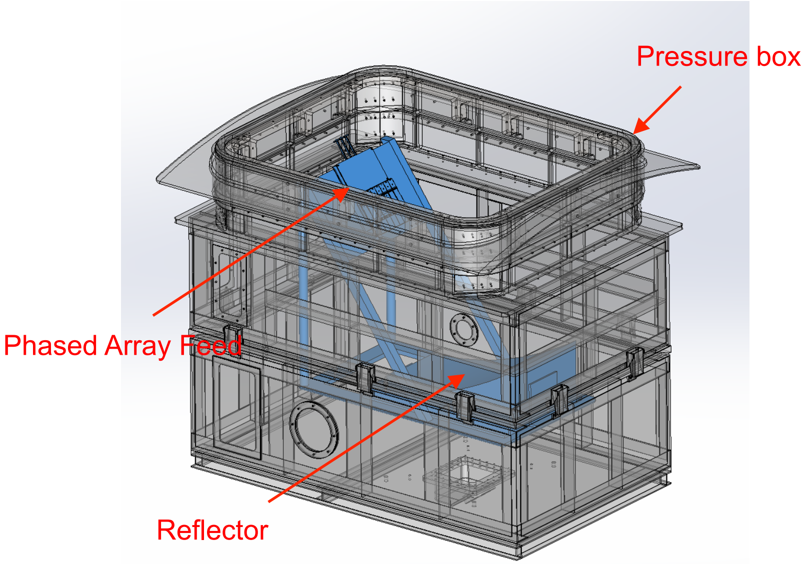
AirMASTR Instrument

- Airborne demonstration of MASTR.
- The modular architecture enables a demonstration with a scaled version of MASTR focused on raising the TRL of the subsystems.
- AirMASTR will be capable of Ku/Ka/W-band scanning, Doppler, and polarimetry.
- Reflector size 30cmx50cm.
- Digital electronics based on Raincube.
- Direct frequency conversion.
- Platform: NASA DC-8.



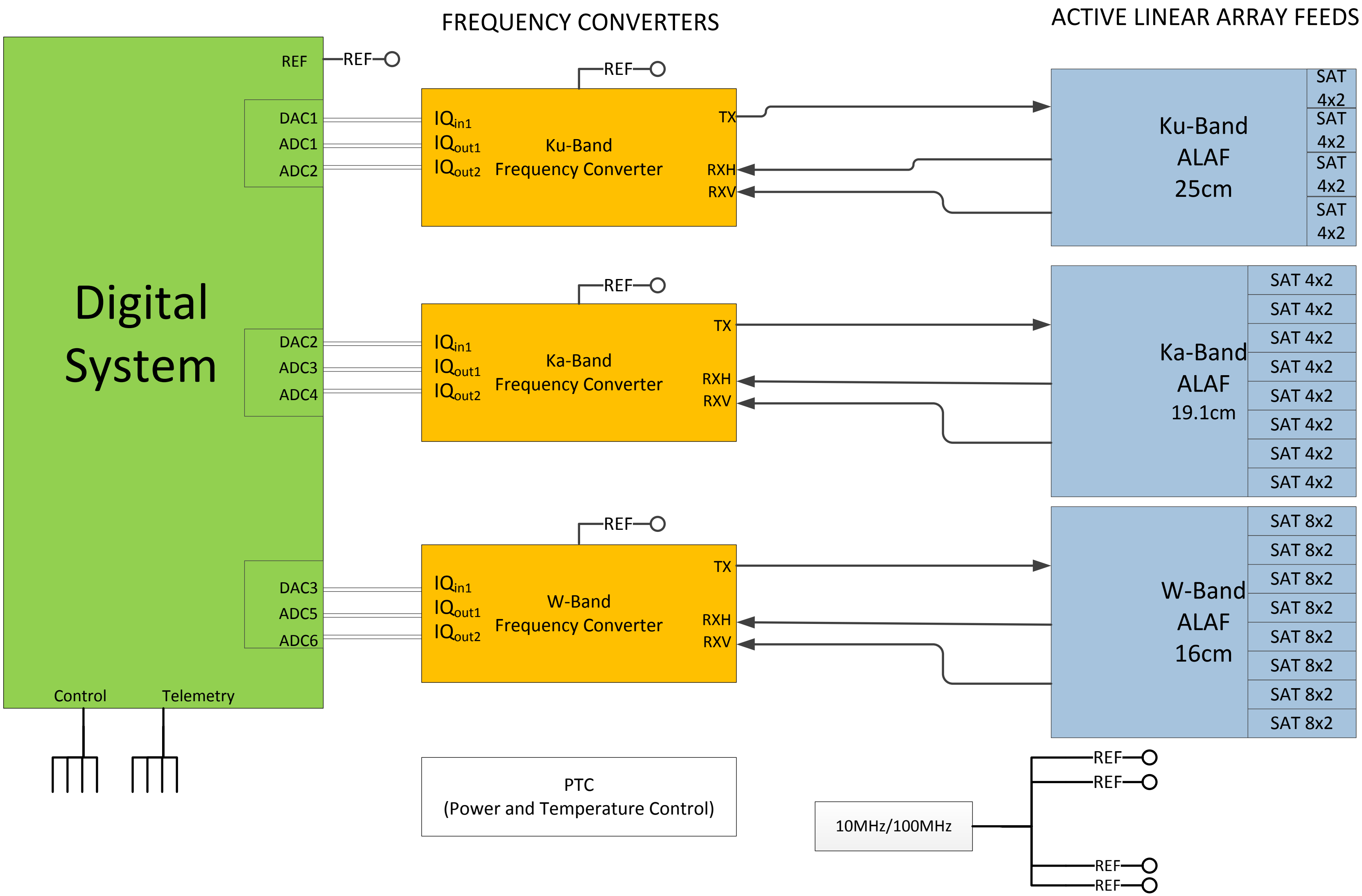
Courtesy of Nuvotronics Inc.
Tri-band Phased Array Feed

	Ku-band	Ka-Band	W-Band
Number of Tiles	4	8	8
Total Number of Transmit elements	16	32	64
Array Peak Transmit Power	320W	160W	96W
Array width [mm]	256mm	176mm	158.4mm



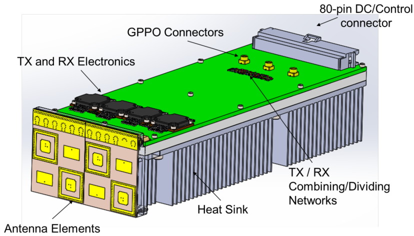
Feed reflector model inside the DC8 pressure box

AirMASTR Block Diagram

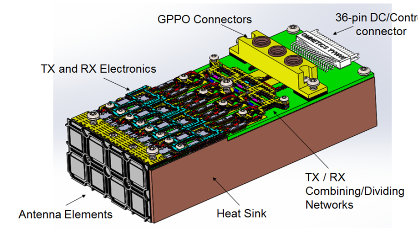


Resources

- Ku/Ka-Band Scanning Array Tiles
  - Based on design made by Nuvotronics under SBIR Phase II contract: NNX15CP18C.
  - Nuvotronics is on contract to develop Ku-band and Ka-band SATs for AirMASTR.
- W-band Active Linear Array Feed
  - Under development by 3CPR - IIP-13, PI Sadowy
- Phased Array Integration
  - Co-I Andrew Brown - Raytheon
- Digital Electronics Subsystem
  - Based on Raincube's architecture.
  - Modifications of Trident's Space qualifiable digital transceiver, developed under SBIR NNX14CP10C
- Frequency converters
  - Currently under development at JPL.
- Parabolic reflector
  - 3CPR - IIP-13, P.I. Sadowy
- NASA DC8
  - Engaged NAFRC Payload Engineer Adam Webster.

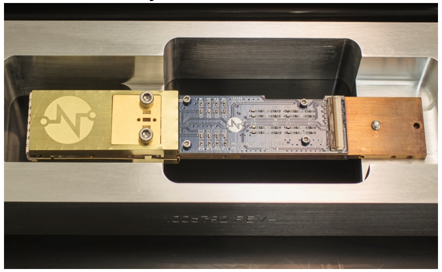


Ku-band 2 by 4 Phased Array Tile model



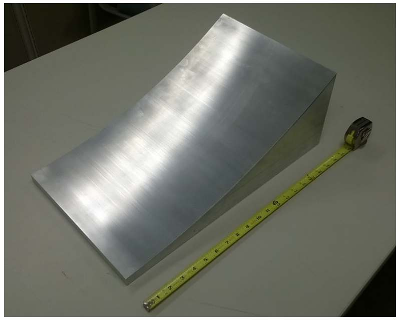
Ka-band 2 by 4 Phased Array Tile model

Courtesy of Nuvotronics Inc.



W-band 2x8 Phased Array Tile prototype

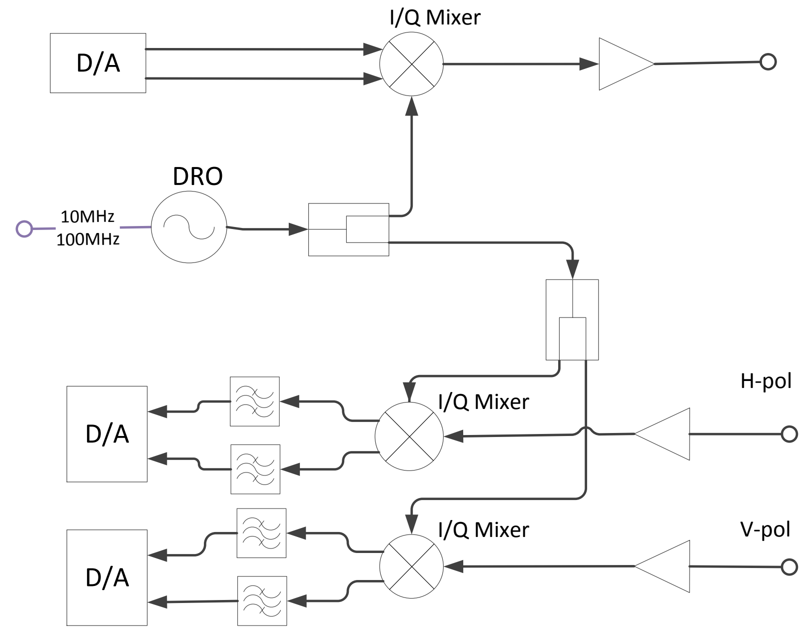
Space Qualifiable Digital Radar Transceiver



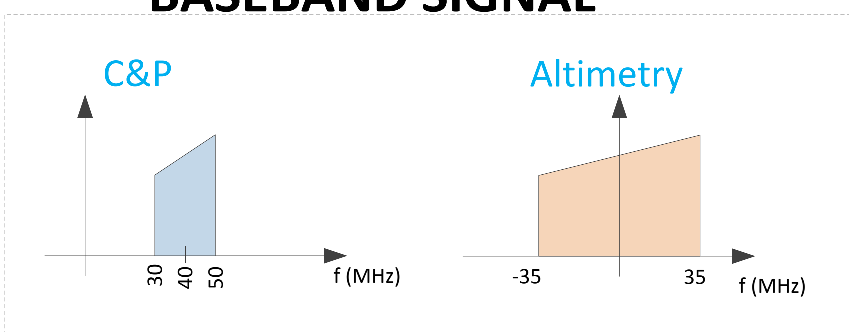
Reflector

Frequency Converters

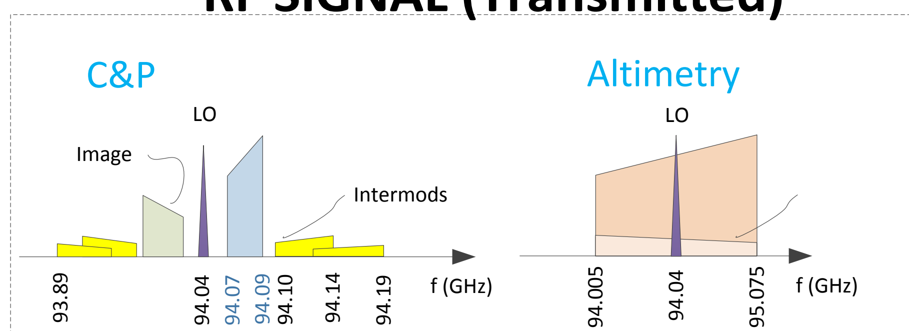
- Direct up and down conversion based on Raincube frequency conversion.
- Single stage conversion reduces number of components, mass, power.
- C&P mode uses offset baseband. The offset displaces intermodulation products in frequency to enable digital filtering on receive.
- Altimetry high bandwidth is achieved by centered base-band. In band intermodulation products do not affect performance requirements for Altimetry.



BASEBAND SIGNAL



RF SIGNAL (Transmitted)

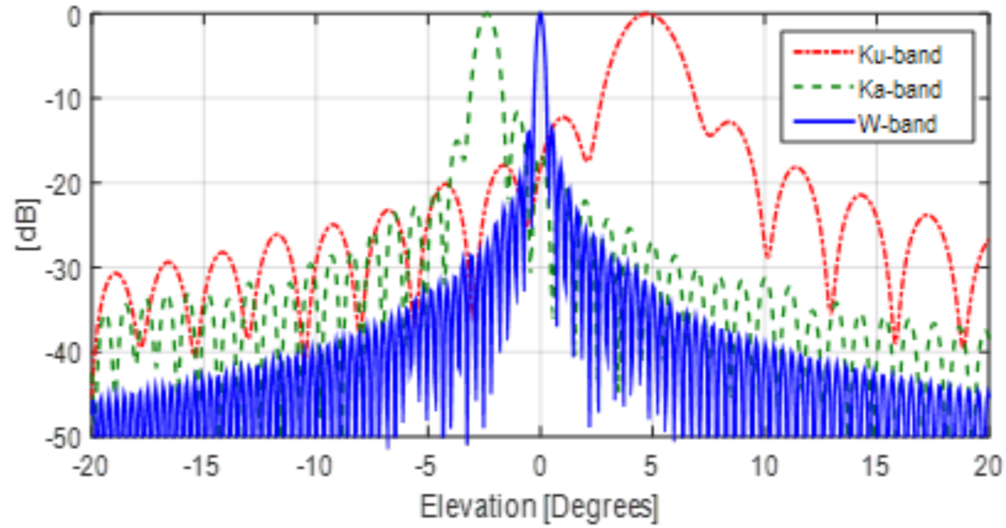


Scanning Array Tile Specifications

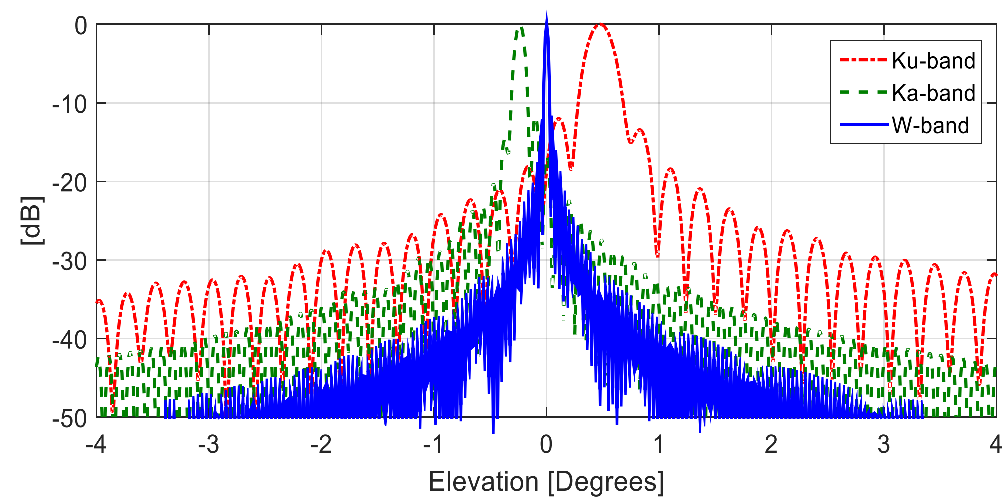
	Ku-band	Ka-band	W-band
Frequency Response	13.4GHz	35.75GHz	94GHz
Power handling	20W per radiating element.	5W per radiating element	1.5W per radiating element
Elements per tile	2x4	2x4	2x8
Polarization	Transmit Horizontal Receive Horizontal Receive Vertical	Transmit Horizontal Receive Horizontal Receive Vertical	Transmit Horizontal Receive Horizontal Receive Vertical
Transmit Duty Cycle	<10%	<10%	<10%
Electronic scanning	±4.5 degrees	±12 degrees	±10 degrees
Size	64mm wide 44mm tall 175mm deep	22mm wide 16mm tall 54mm deep	19.8mm wide 10mm tall 127mm deep

Antenna Reflector Scaling

In both cases the W-band feed is at the focal point of the reflector, the Ka-band displace 2cm in one direction and the Ku-band displaced 4cm in the opposite direction.



Radiation Pattern of Airborne Concept (50cm)



Radiation Pattern of Spaceborne Concept (5m)

END

BACKUP SLIDES TO FOLLOW