NASA Ka-Band RF Propagation Studies

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Management Committee Meeting (MCM7)

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Outline of Presentation

- ✓ <u>Introduction</u>
- ✓ <u>Hardware Description</u>
- ✓ <u>Site Characteristics</u>
- ✓ <u>Results Highlights</u>

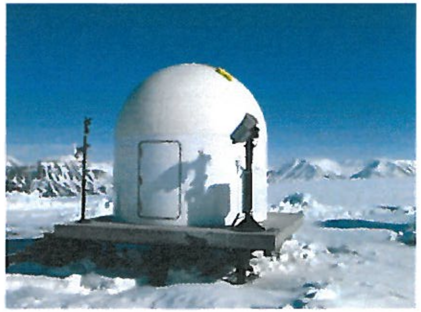
NASA Ka-Band RF Propagation Studies

Task Description:

- Collect phase decorrelation, attenuation, and surface weather data, as necessary, at candidate sites.
- Perform a statistical characterization of the diurnal, annual and secular path length fluctuations and attenuation to provide a good understanding of Ka-band propagation effects.
- Provide data for RF Propagation model validation at Ka-Band.
- Develop tools to mitigate these effects
- Open communications with the Science community to explore potential relevance of our weather data gathered through our propagation studies for Earth Science applications.

Measurement Instruments:

Site Test Interferometer



Microwave Receivers (Ka-band Radiometers)

Benefits:

- Provides accurate determination of expected Ka-band attenuation due to atmospheric gaseous components and rain over long time scales (years)
- Provides accurate determination of expected path length/Time delay variation due to atmospheric effects over long time scales (years)
- Provides mission planning data to manage expectations and maximize mission success and data throughput
- Provide validation to existing ITU-R and global propagation models at NASA operational sites

GRC POC and Partners:

GRC PI:
Dr. Roberto Acosta – GRC
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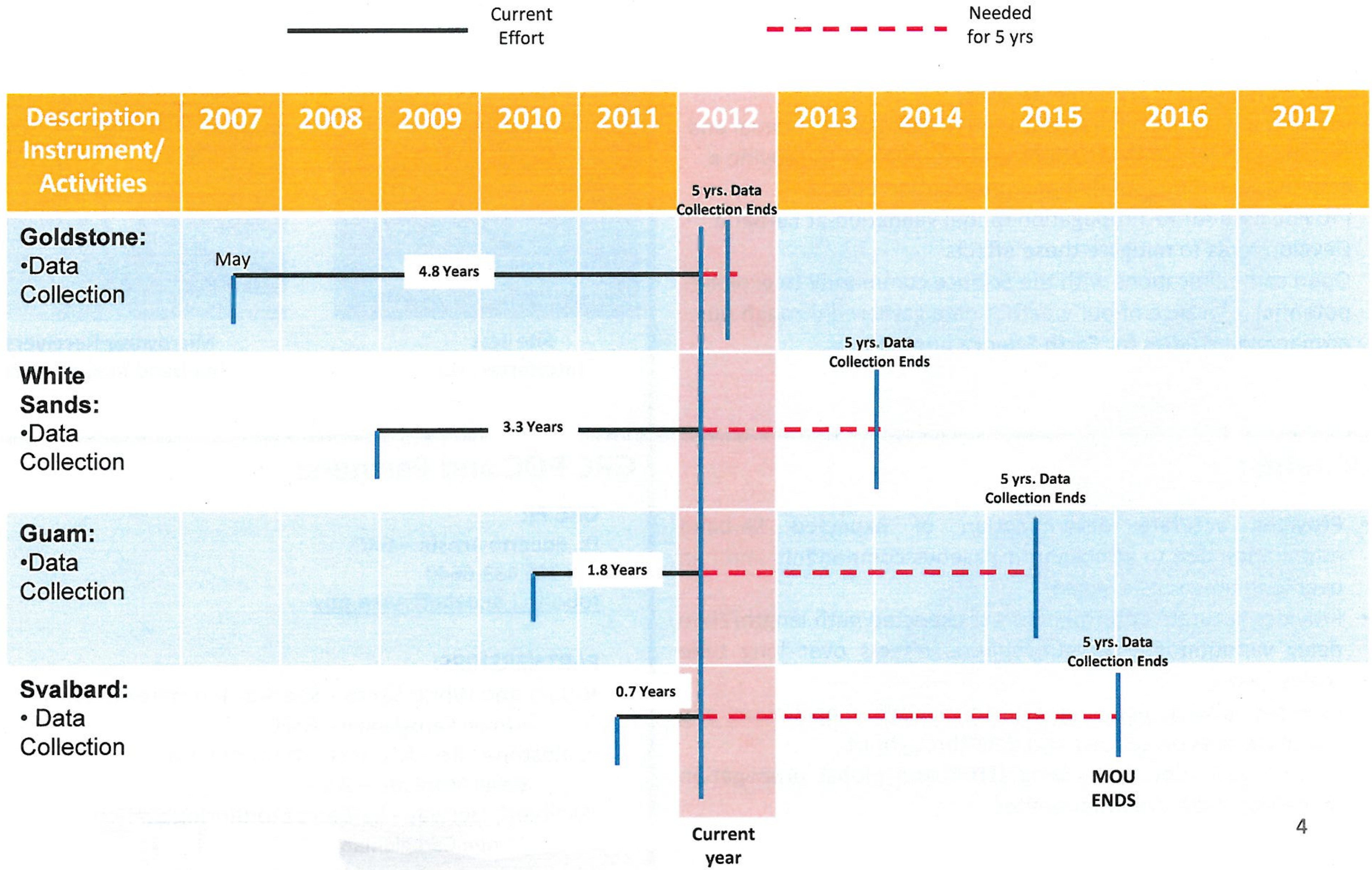
PARTNERSHIPS:

•Guam and White Sands - Site Test Interferometer
 Armen Caroglanian – GSFC

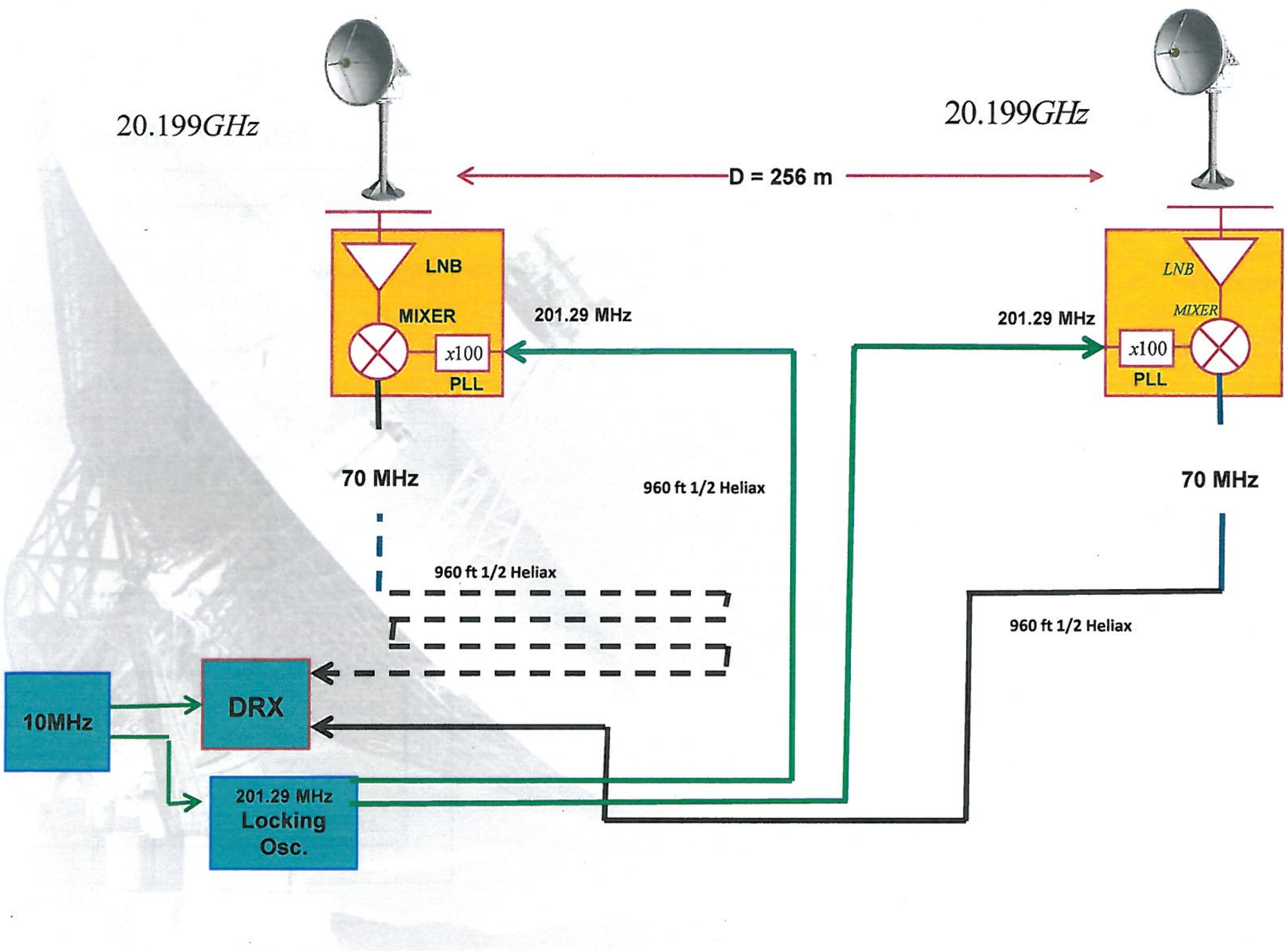
•Goldstone Site - Site Test Interferometer
 David Morabito – JPL

•Svalbard, Norway - Ka-Band Monitoring Station
 Armen Caroglanian - GSFC

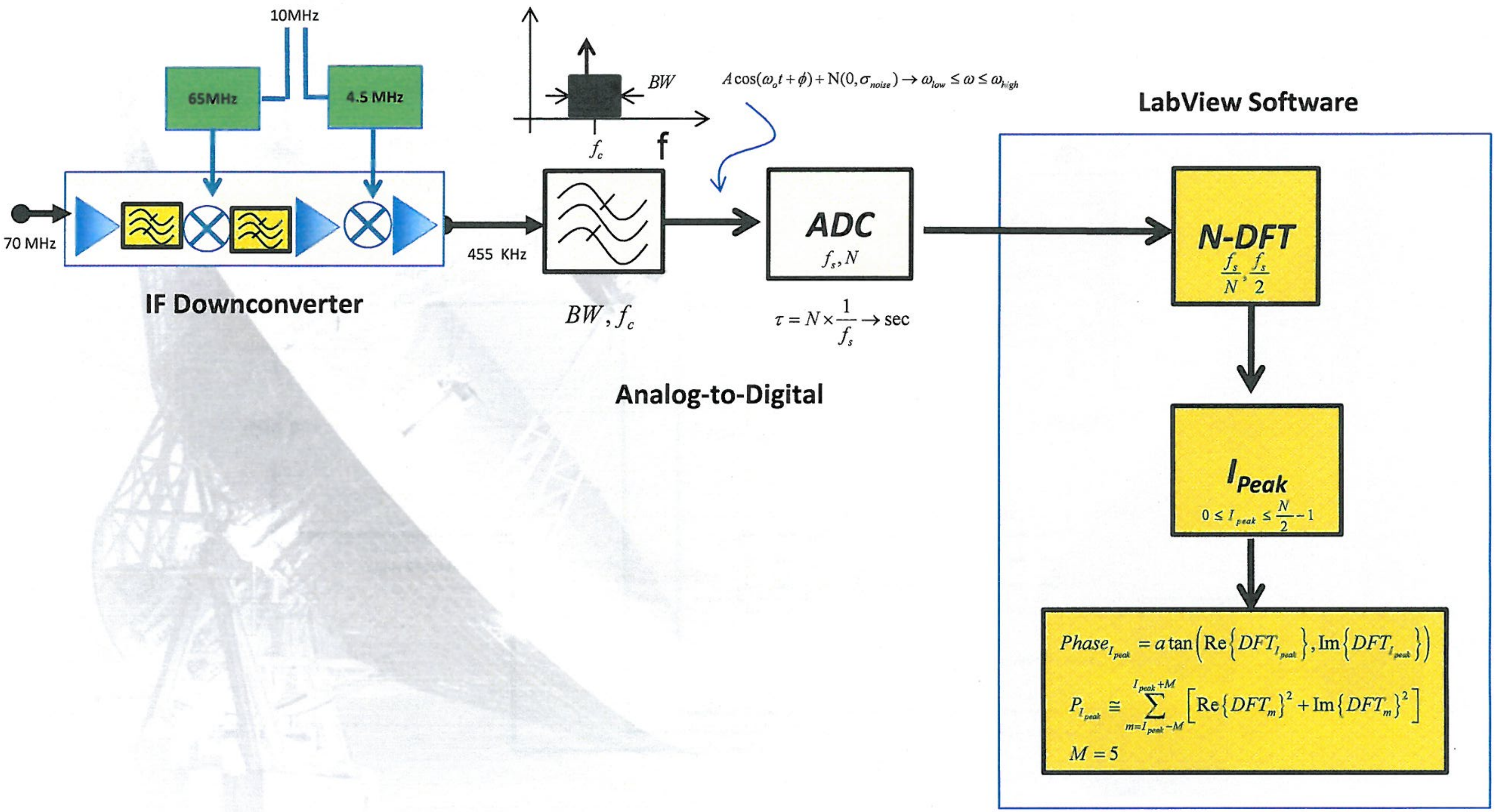
NASA Ka-Band RF Propagation Studies



Basic GRC Interferometer Architecture



Basic GRC DRX Architecture

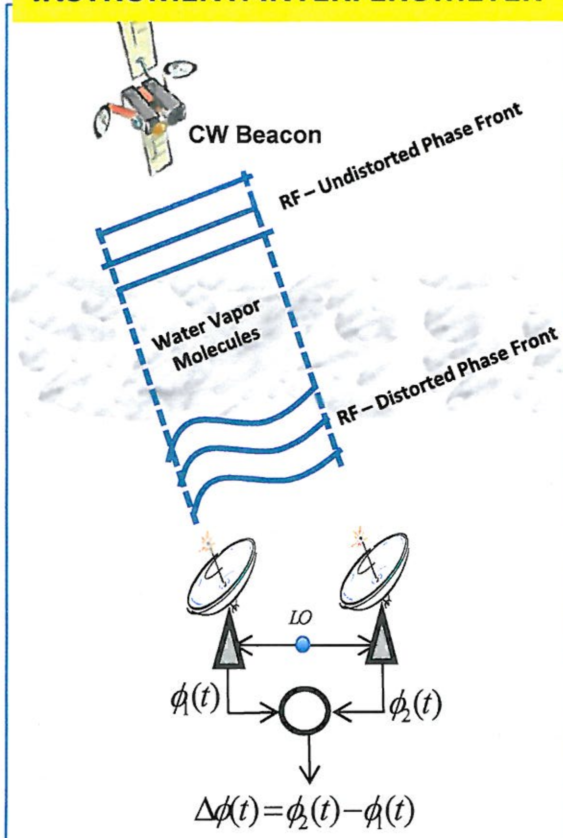


DRX = Digital Receiver

Measurements 101

Goldstone, White Sands and GUAM

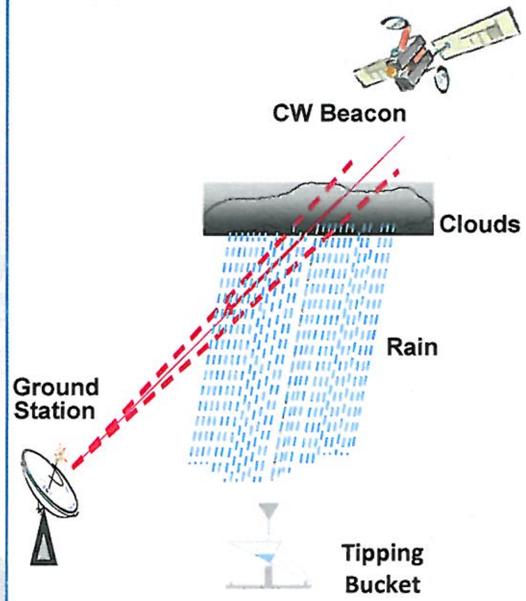
INSTRUMENT: INTERFEROMETER



Phase Decorrelation Due to Water vapor

Goldstone, White Sands and GUAM

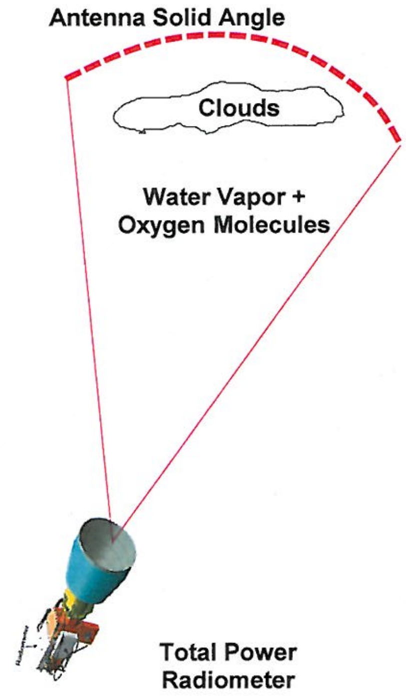
INSTRUMENT: BEACON RECEIVER



Attenuation due to Gases, Clouds and Rain

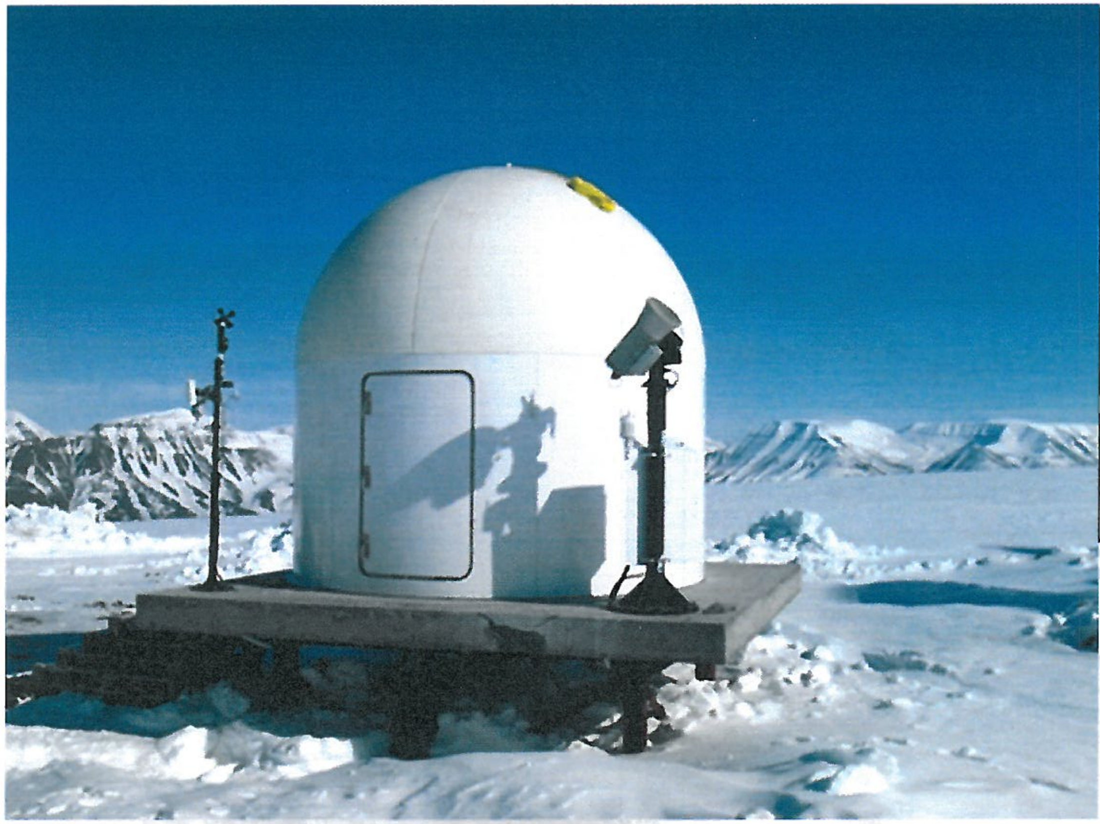
Goldstone and Svalbard

INSTRUMENT: RADIOMETER



Attenuation due to Gases and Non-Precipitating Clouds

Svalbard Operations and Data Collection

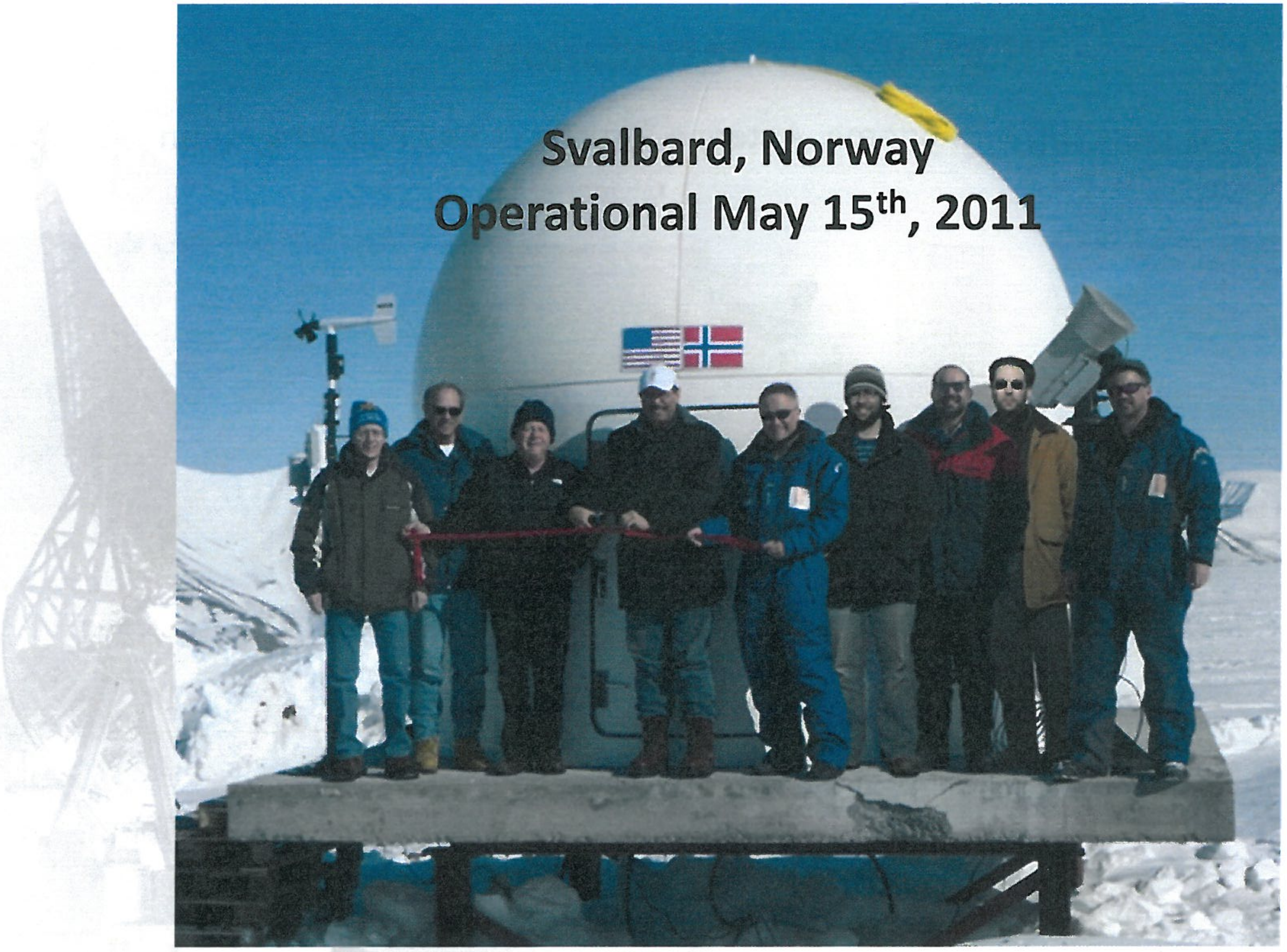


Longyearbyen, Svalbard		
Site	Latitude	78.22733333°
	Longitude	E15.42060000°
	Altitude	1512 ft
Sensor	Multi Channel Radiometer (Total Power)	
	Elevation Angle	**10.0 - 45.00°**
	Azimuth	180.0°
	Frequency	20 – 30 GHz
	Polarization	Linear V

Instrument : Ka-Band Radiometer

Data Collection Started : *May 2011* ✓

Svalbard Operations and Data Collection



Svalbard Operations and Data Collection

Highlights of Installation

Milestone 1 (as per CDR) --- Radome, Antenna Structures and Pad Integration

D. Raible

J. Nessel

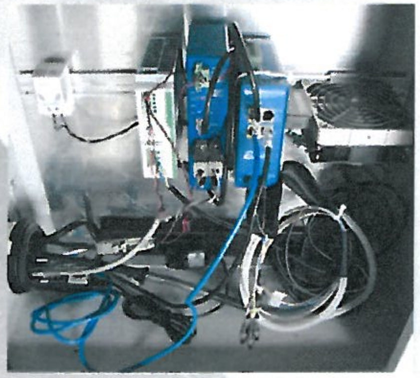
KSAT Team

Svalbard Operations and Data Collection

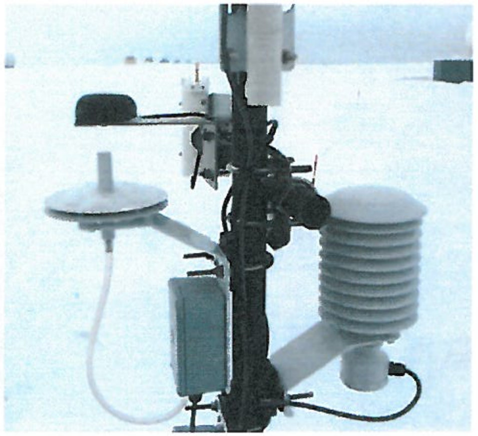
Highlights of Installation

<u>Milestone 2 (as per CDR)</u>--- Pad Power, Electronics, Weather Station and Radiometer Installation

Power



Comm. Electronics



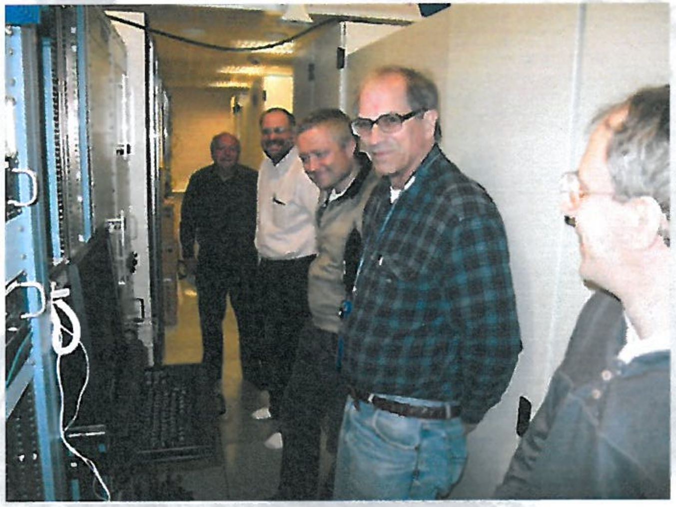
Weather Station

Radiometer Antenna

Svalbard Operations and Data Collection

Highlights of Installation

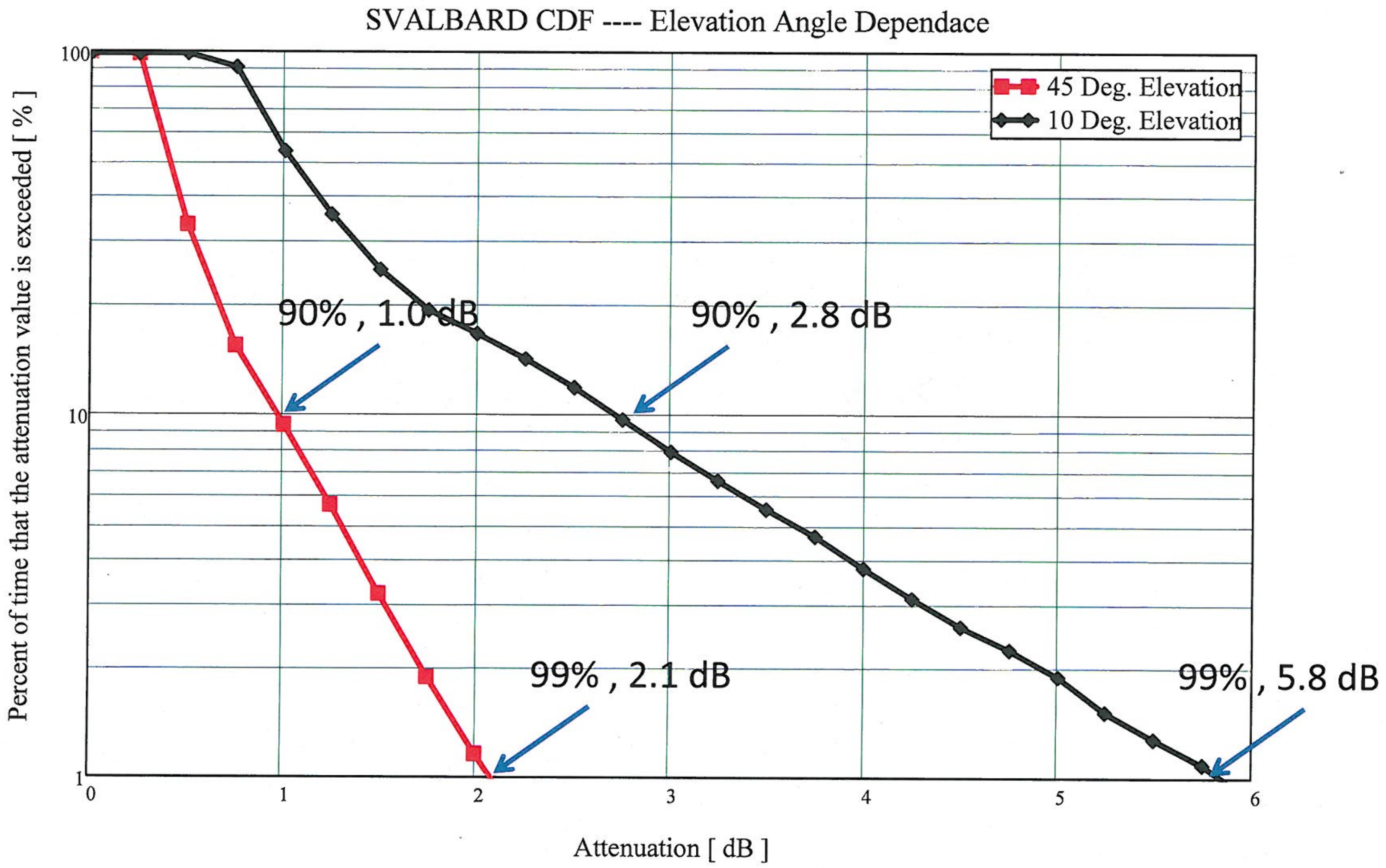
Milestone 3 (as per CDR) --- System Check-out and Operator Training



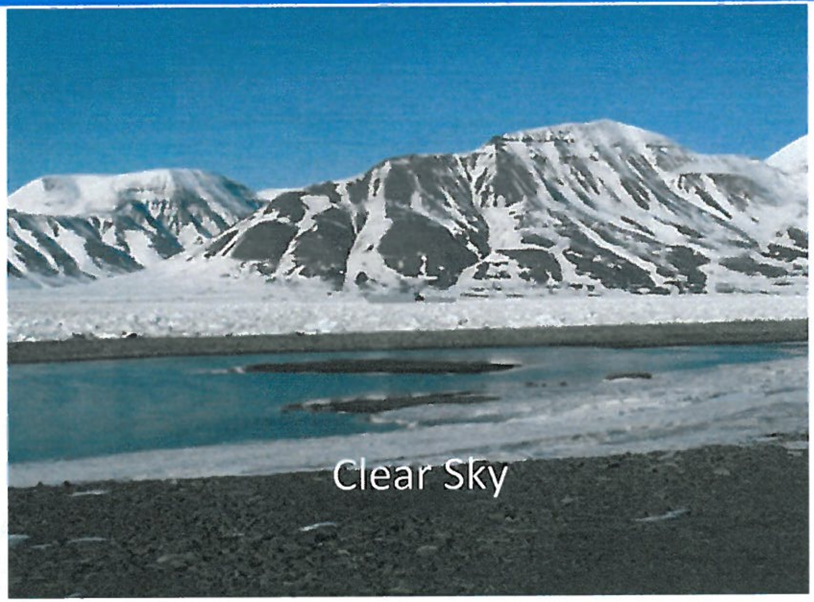
Left to Right --- J. Jackson (GSFC), A. Caroglanian (GSFC), Sten Christian (KSAT), P. Harbath (GRC), and B. Frantz (GRC)

KSAT Operators

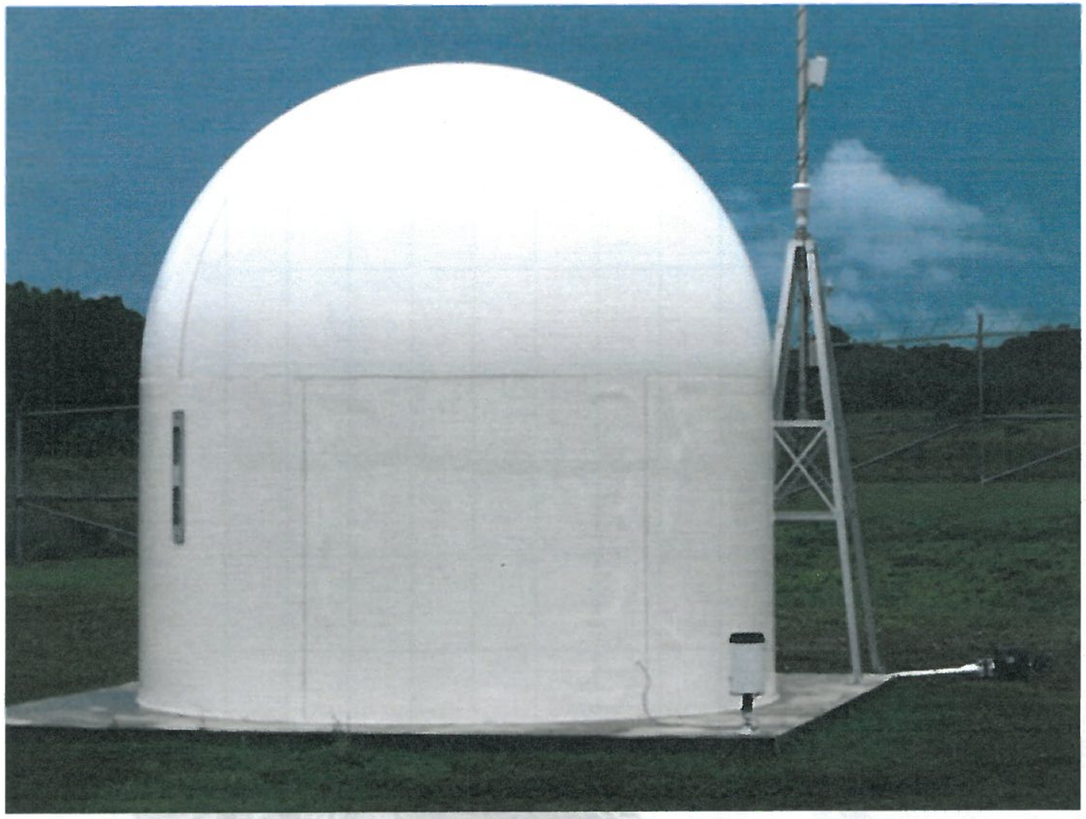
Svalbard Operations and Data Collection



Svalbard Operations and Data Collection



Guam Operations and Data Collection

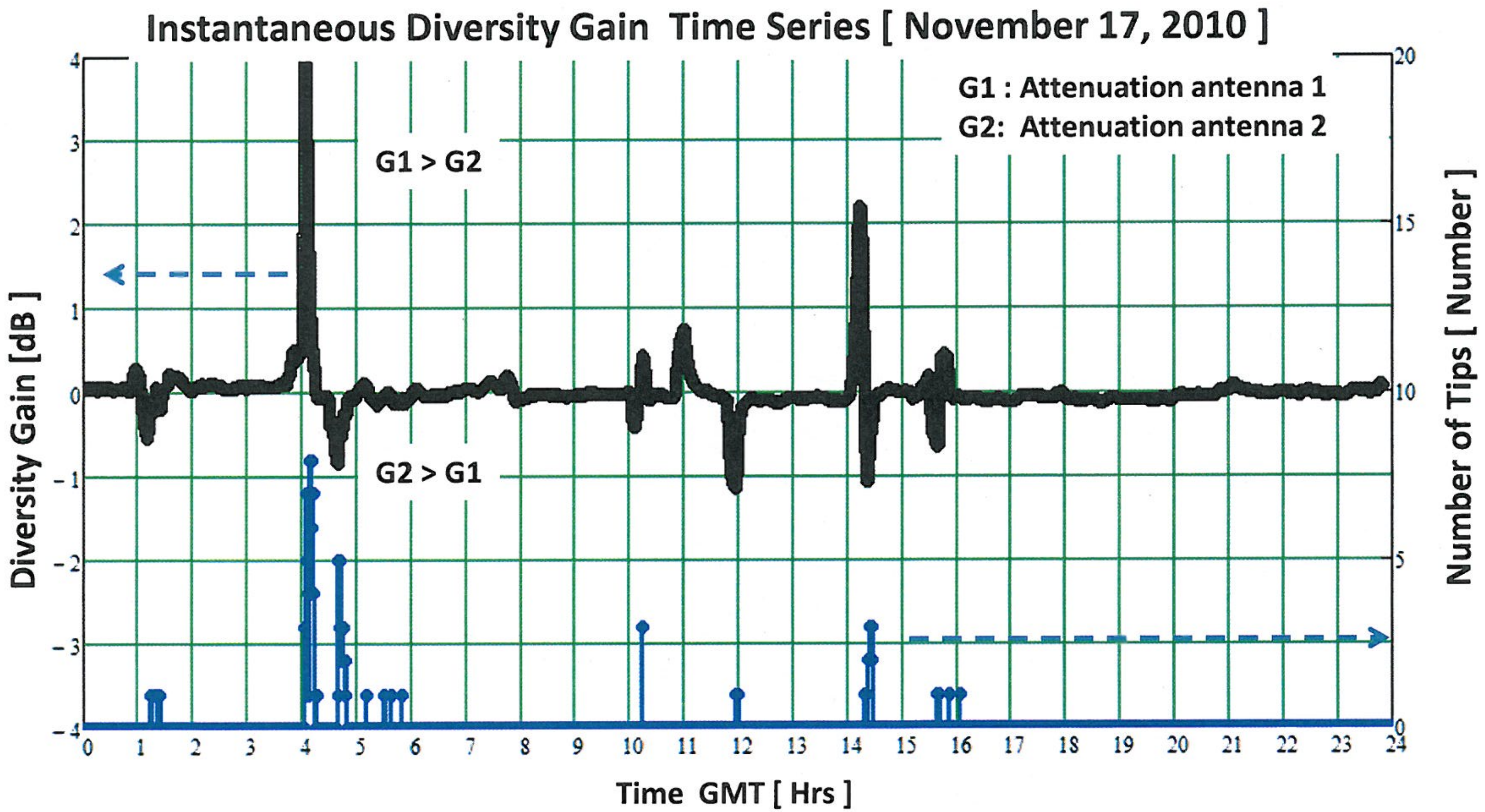


GUAM , USA		
Baseline	Azimuth	180º (N-S)
	Length	**600 m**
Satellite		UFO 8
	Orbital Longitude	171 º
	Elevation Angle	**38 º**
	Azimuth	253º
	Beacon	20.7 GHz
	Polarization	Circular RH
	South Radome	
	Elevation	= 464 ft
	North Latitude	= 13 Deg. 35.200'
	East Longitude	= 144 Deg. 50.455'
	South Radome	
	Elevation	= 464 ft
	North Latitude	= 13 Deg. 35.200'
	East Longitude	= 144 Deg. 50.455'

Instrument : Two-Element Ka-Band Interferometer

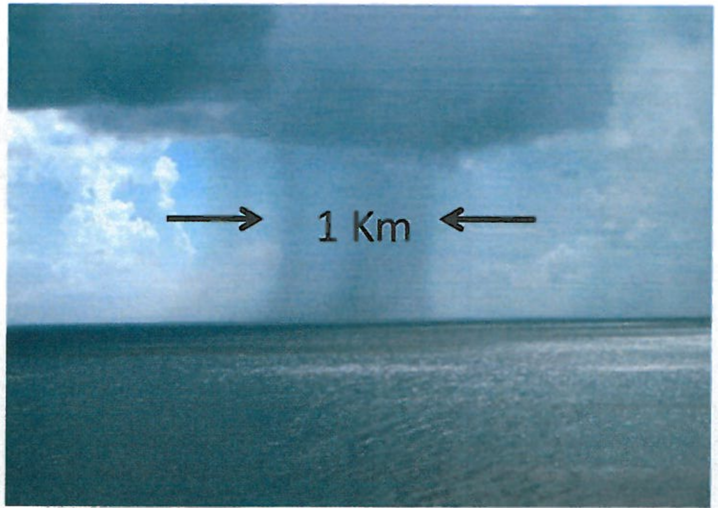
Data Collection Started : *<u>May 2010</u>* ✓

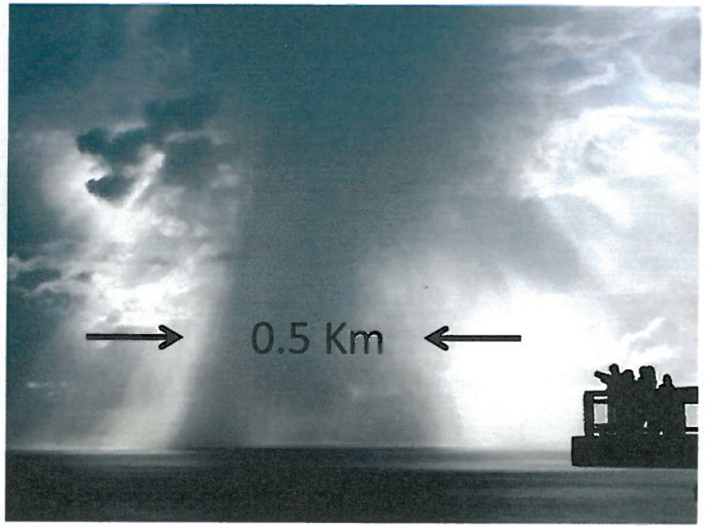
Guam Operations and Data Collection



- LARGEST DIVERSITY GAIN IS OBSERVED DURING MEDIUM TO HEAVY RAIN PERIODS
- DIVERSITY GAIN IS MORE PRONOUNCE WITH LOCAL RAIN FALL (AT THE ANTENNA)

Guam Operations and Data Collection





Goldstone Operations and Data Collection

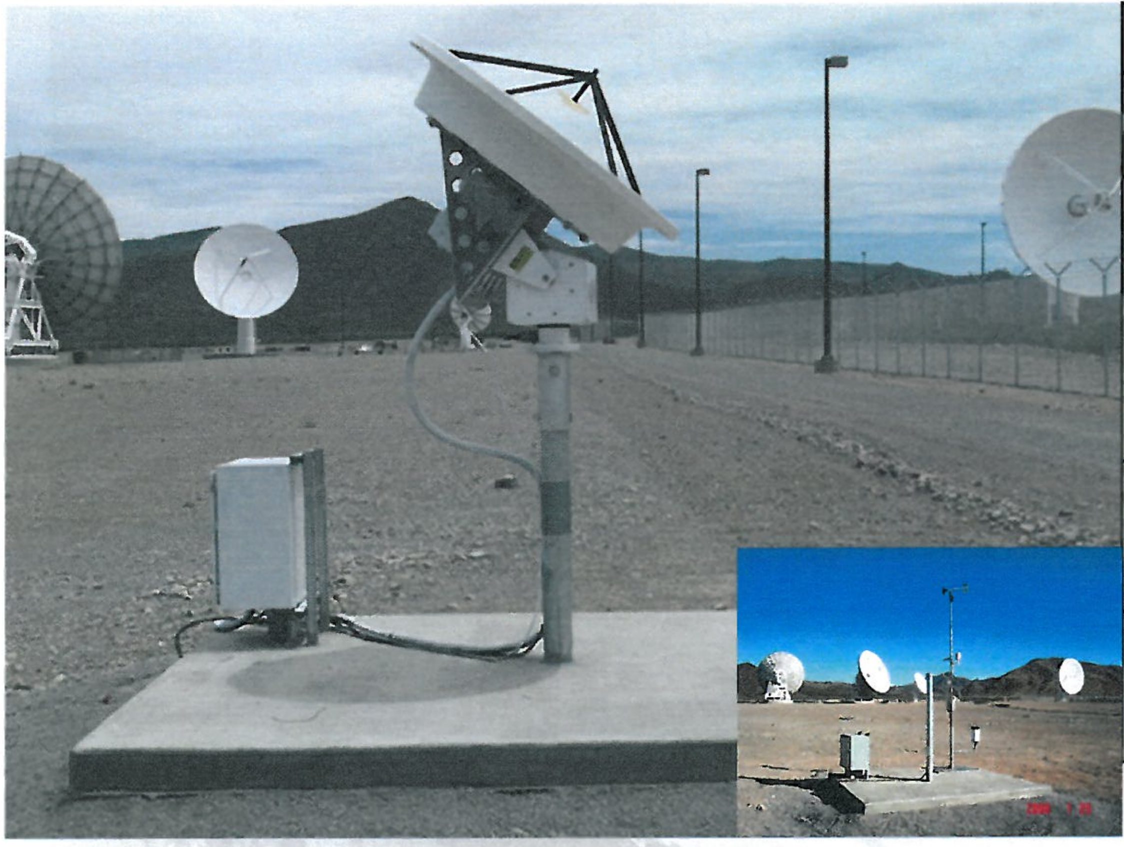
Goldstone , California		
Baseline	Azimuth	90° (E-W)
	Length	**252 m**
Satellite		ANIK F2
	Orbital Longitude	111.1°
	Elevation Angle	**48.63°**
	Azimuth	170.20°
	Beacon	20.2 GHz
	Polarization	Linear V (7.95°)
	East Antenna (51)	
	Elevation	= 1039.122 m
	North Latitude	= 35.24773789°
	East Longitude	= 116.791462936°
	West Antenna (59)	
	Elevation	= 1051.452 m
	North Latitude	= 35.247164164°
	East Longitude	= 116.794120592°

Instrument : Two-Element Ka-Band Interferometer

Data Collection Started : May 2007

Goldstone Operations and Data Collection

White Sands Operations and Data Collection



White Sands, New Mexico		
Baseline	Azimuth	180° (N-S)
	Length	**208 m**
Satellite		ANIK F2
	Orbital Longitude	111.1°
	Elevation Angle	**51.8°**
	Azimuth	188.3°
	Beacon	20.2 GHz
	Polarization	Linear V (6.95°)
	West Antenna (North)	
	Elevation	= 4812 ft
	North Latitude	= 32.5441333°
	East Longitude	= 1066139.°
	West Antenna (South)	
	Elevation	= 4821 ft
	North Latitude	= 32. 5422667°
	East Longitude	= 106.61391667°

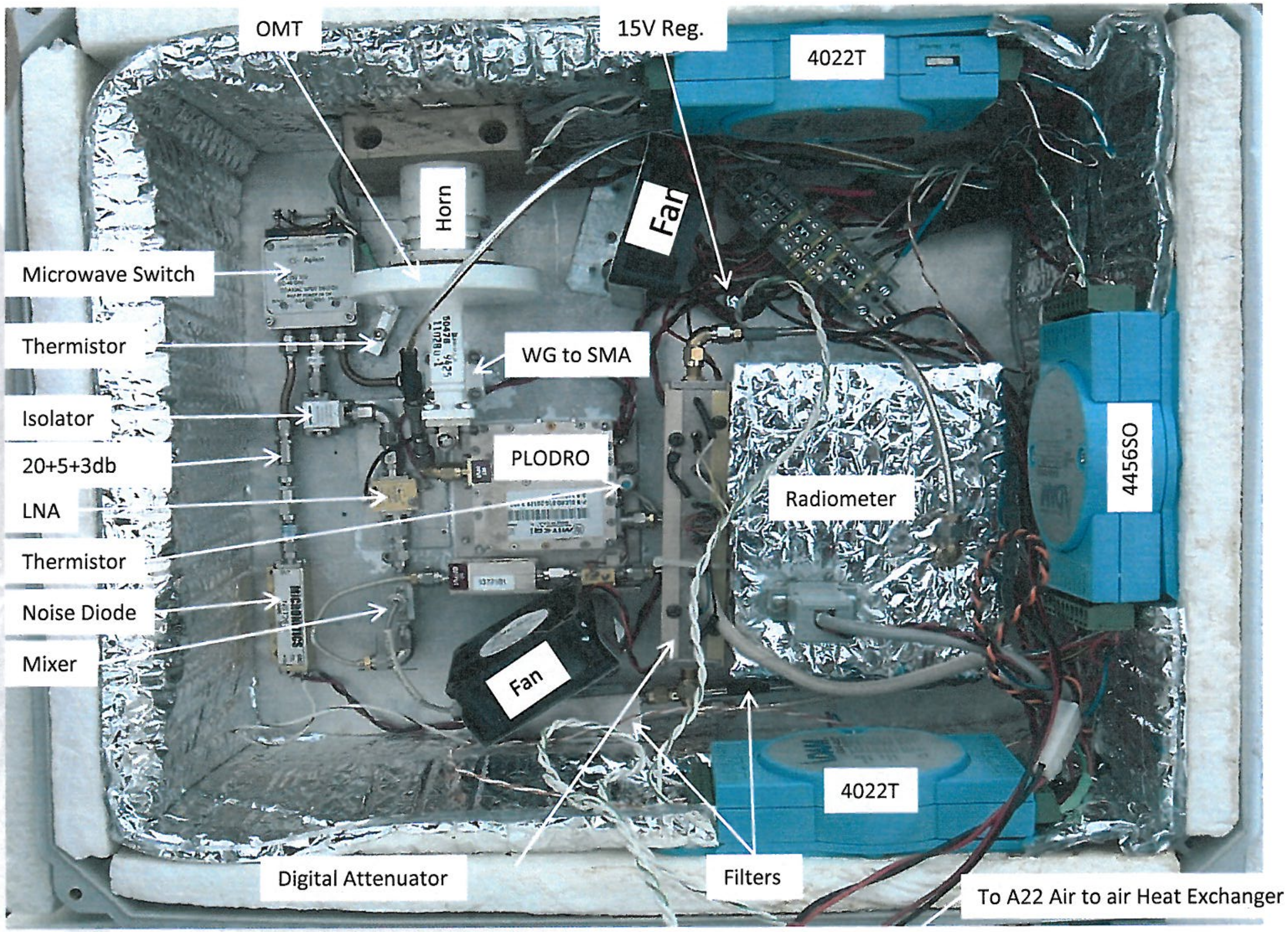
Instrument : Two-Element Ka-Band Interferometer

Data Collection Started : Feb 2009 ✓

GRC Total Power Radiometer

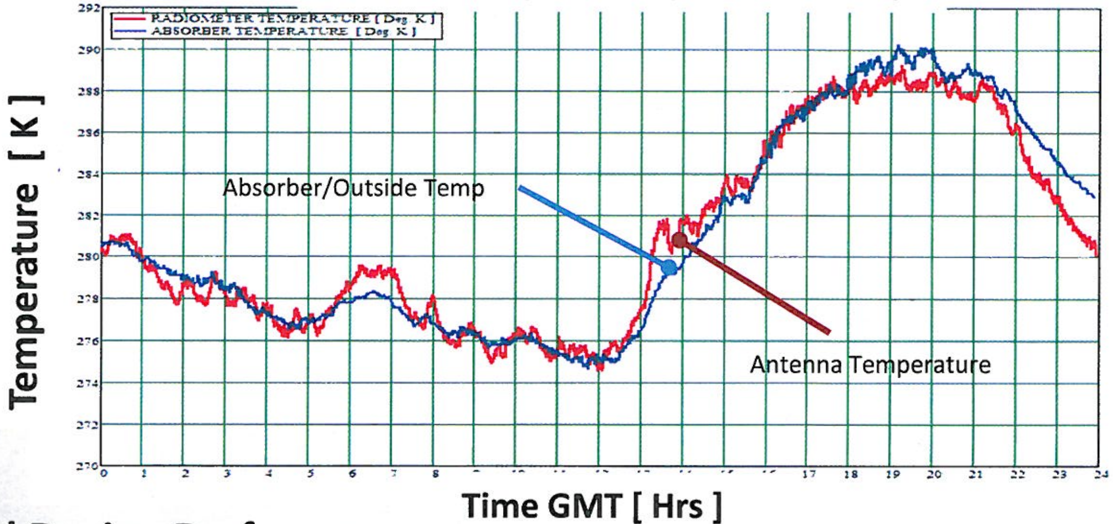
<u>SOLUTION</u> --In-House Developed (Very Low Cost) Ka-Band Single Channel Radiometer

GRC Total Power Radiometer

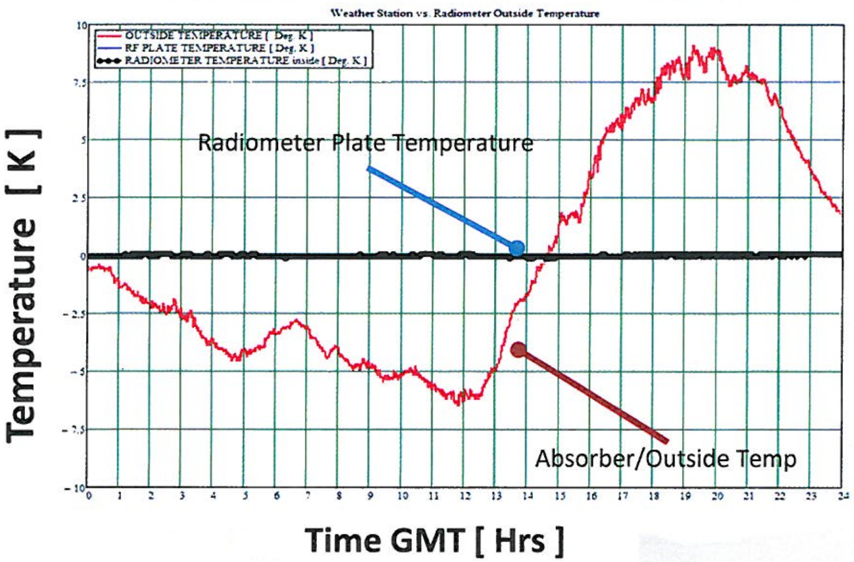


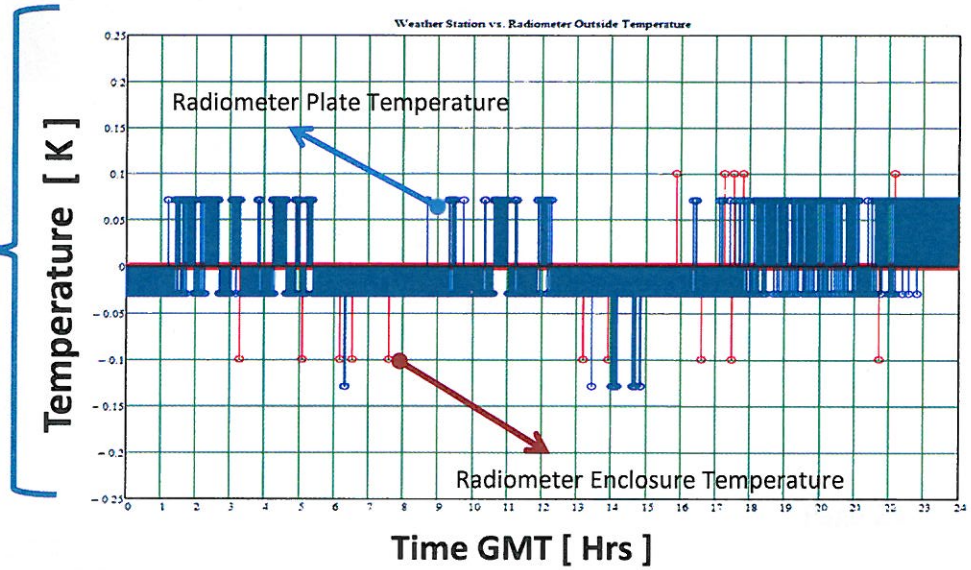
GRC Total Power Radiometer

Antenna Temperature (Absorber Test)



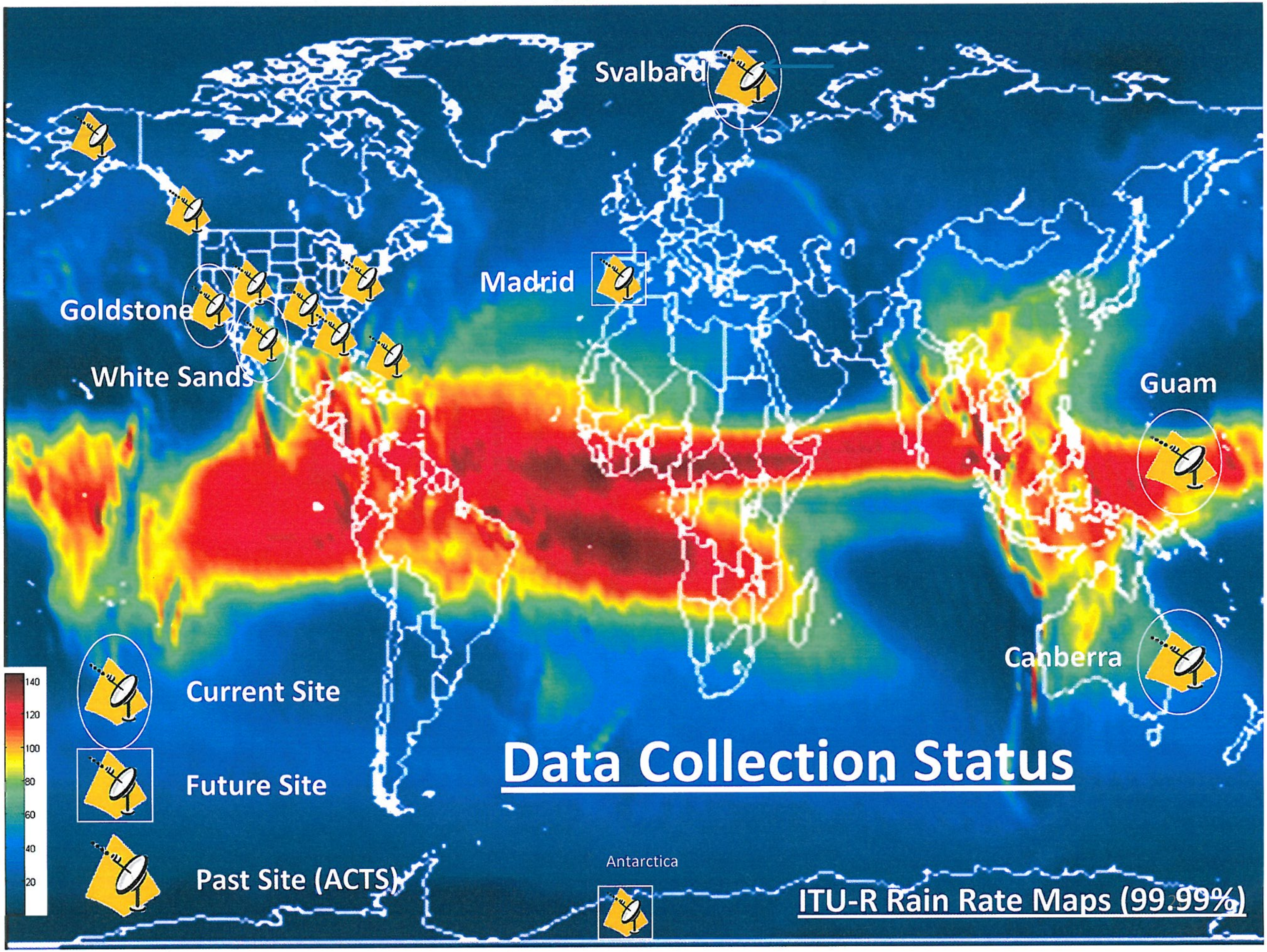
Thermal Design Performance





FIN !!!

Appendix !


Svalbard
Madrid
Goldstone
White Sands
Guam
Canberra
Antarctica
140
120
100
80
60
40
20
Current Site
Future Site
Past Site (ACTS)
Data Collection Status
ITU-R Rain Rate Maps (99.99%)

Physics 101

Attenuation

Rain Rate (measurements or ITU RR MAPS)

Rain

Specific Attenuation (power law relationship)

$$\gamma = k\left(RR_{.01\%}\right)^{\alpha} \quad \text{dB/km}$$

ITU-R

Seminar is about this component !!!

Gaseous

Barometric Pressure

Temperature

Absolute Humidity

Specific Attenuation

$$k_{H2O}(f, P(s), T(s), \rho(s)) \quad \text{dB/km}$$

$$k_{O2}(f, P(s), T(s), \rho(s)) \quad \text{dB/km}$$

Ulaby, et all

Liquid water content of the cloud (gr / m³)

Clouds

Specific Attenuation

$$\gamma = 0.4343\left(\frac{6\pi}{\lambda\rho_d}\right)\text{Im}\left(-\frac{\varepsilon-1}{\varepsilon+1}\right)\rho \quad \text{dB/km}$$

NTIA Report 87-225

How is the data utilized ?

__The data may be used__ differently dependent on which phase of the mission/project the data becomes available to the system engineer.

DESIGN PHASE

Attenuation data :

- The site specific attenuation data will be used by the system engineer (link designer) to create cumulative distribution functions of the amplitude /attenuation to establish the minimum service margin (goal: avoiding overdesign) to provide the required or design system availability (e.g. 90%) due to rain or weather outages.
- The site specific attenuation data will be used by the system engineer (link designer) to effectively design and implement adaptive rain fade techniques to increase system availability and link reliability.

Phase data: The site specific phase data will be used by the system engineer (link designer) to create cumulative distribution functions of the phase decorrelation to determine the extent to which a particular site (e.g., Guam, White Sands, Goldstone, etc.) is capable of supporting widely distributed antenna systems for future NASA Ka-Band communications. The phase data currently collected at White Sands and Goldstone will enable the SCaN system planning office in determining if arraying of antennas (e.g. 34 m) for uplinks is feasible.

How is the data utilized ?

The data may be used differently dependent on which phase of the mission/project the data becomes available to the system engineer.

OPERATIONAL PHASE

Attenuation data :

•Assuming that the system design was not good enough to overcome most of the rain outages or if it is desired to increase the service availability due to rain, the attenuation data will be used by the system engineer (link designer) to effectively design and implement adaptive rain fade techniques to increase system availability and link reliability.

- ***COST SAVINGS LESSON LEARNED: The ACTS system was a test-bed for testing rain fade compensation techniques. The following techniques were shown to be very effective in mitigating medium to severe rain fades at 99.99 % of the time.***
  - *a. Adaptive uplink-power control*
  - *b. Adaptive data rate*
  - *c. Ground feed radomes*