National Aeronautics and Space Administration

Advanced Antennas and Propagation Research

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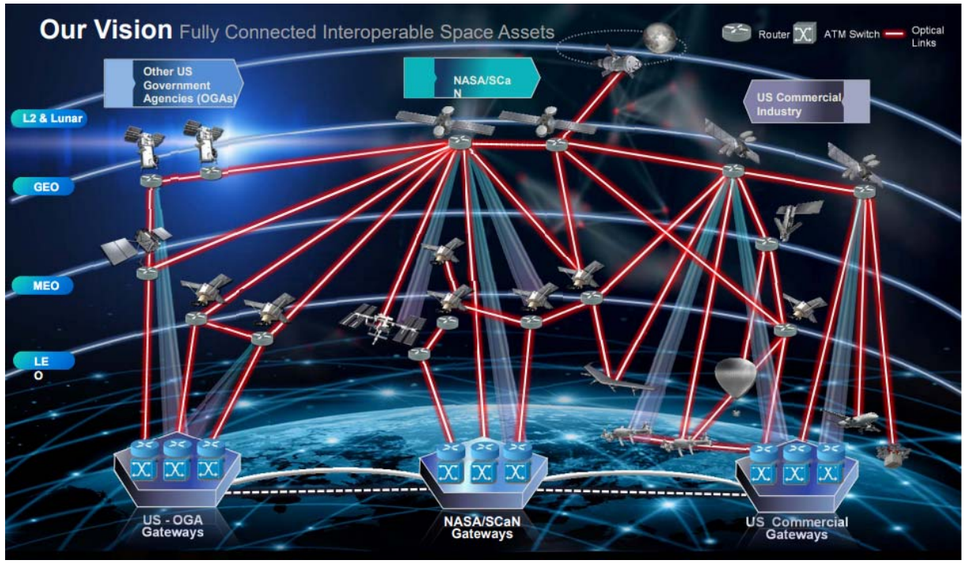
Outline of Presentation

- Advanced Antenna Technologies Development Overview
  - *Conformal Antennas for Aeronautics Applications*
  - *Cognitive Antennas for Space Applications*
  - *SmallSat Ka-band Operations User Terminal (SKOUT)*
- Advanced Antenna Testbed Development
  - *The Multiple Access Testbed for Research in Innovative Communications Systems (MATRICS)*
- Propagation Studies

Overview of NASA GRC Objectives in Communications

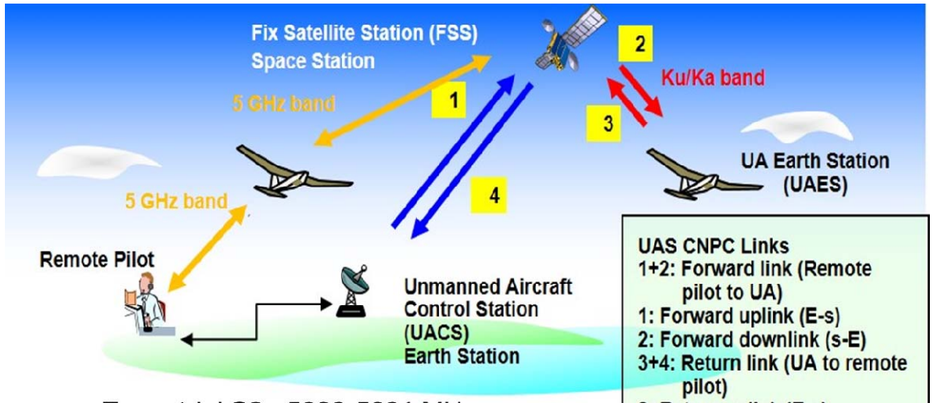
Space Applications

- *Next Generation Near Earth Relay Capability*
- *Primary targets: Ka-band/Optical*



Aeronautics Applications

- *Lightweight, conformal antenna technologies*
- *Primary Targets: Ku/Ka-band*

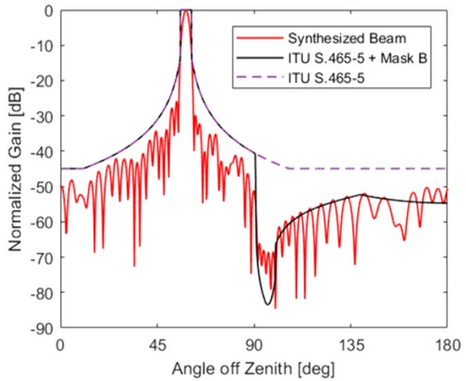


- Terrestrial C2 - 5030-5091 MHz
- Satellite communications C2
  - 5030-5091 MHz (no satellites exist)
  - Ku Band (11/14 GHz) – many Commercial FSS
  - Ka Band (20/30 GHz) – some Commercial FSS

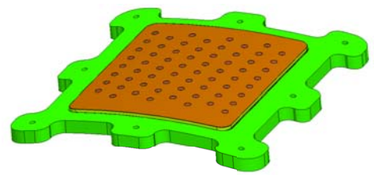
Advanced Antenna Development

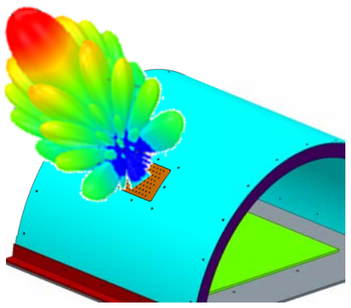
Conformal Antennas

- **New satellite bands were provisionally allocated at WRC-15 Satellite Communications**
  - Meeting interference criteria (UAS into co-primary terrestrial systems) will be very difficult
- **Phased array antenna may provide a solution via beam synthesis approaches**
- **New, lightweight, conformal phased array antenna is being developed and tested for this application**
  - Based on Aerogel substrate materials which are 90% air, flexible, and leading to 50% reduction in mass of antenna
- **Flight testing with Global Hawk to occur in February 2019**



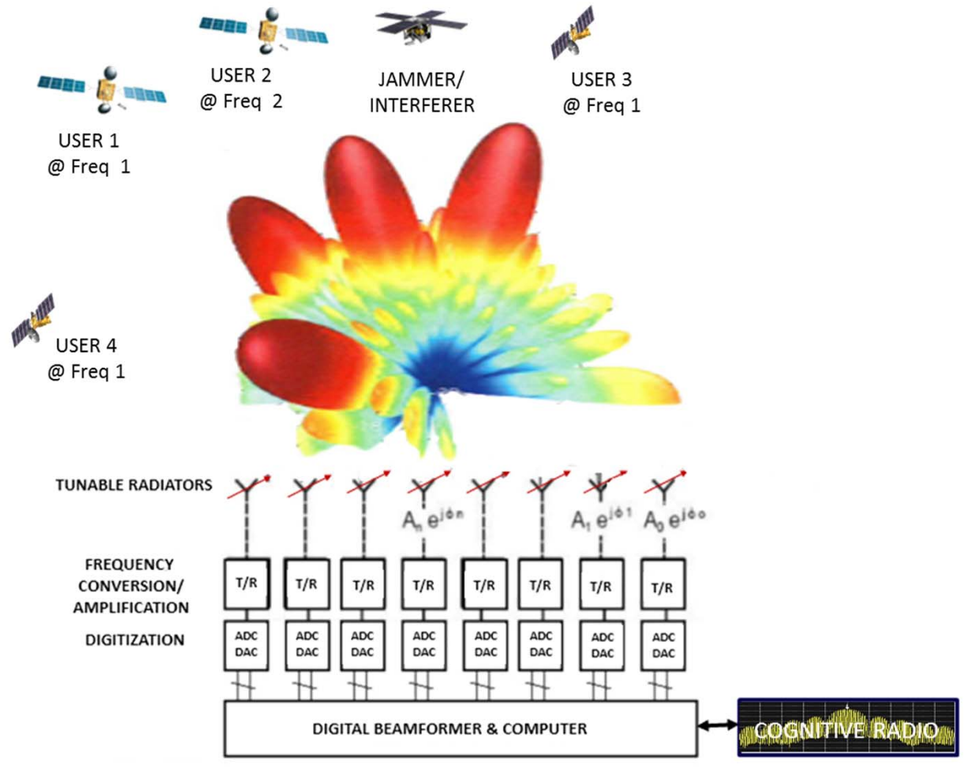
Conformal Prototype Array for Flight Test





Advanced Antenna Development

Cognitive Antenna Systems

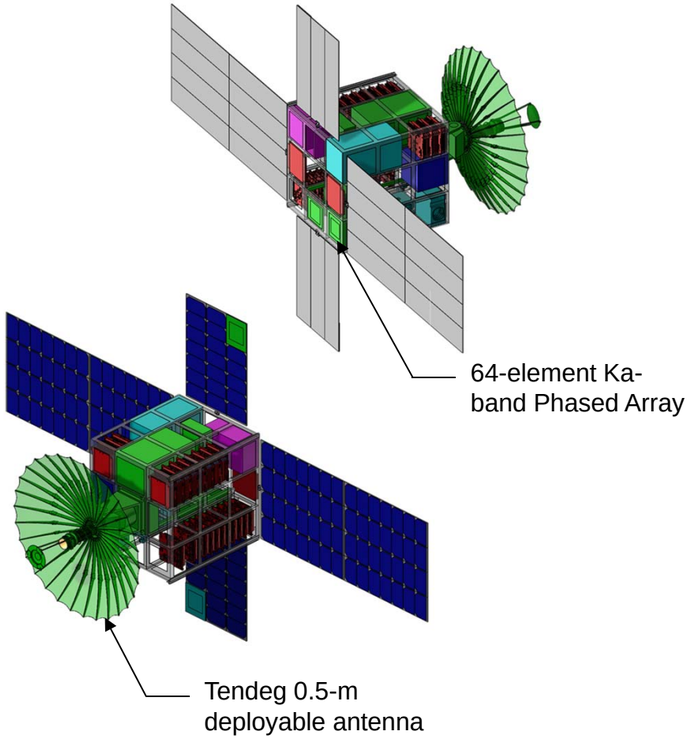


A Ka-Band Antenna with the Following Knobs and Intellect Does Not Exist:

- Tunable anywhere from ≈20 GHz to 33 GHz
- Adjustable bandwidth 10 MHz to 200 MHz
- Arbitrary beamwidth
- ≈Hemispherical coverage
- Multiple (>4) independent beams
- Variable EIRP
- Directional nulling
- Low power per channel (< 500 mW)
- Interactive with cognitive radio
- Wideband spectral and hemispherical spatial sensing and narrowband directional transmit

Advanced Antenna Development

SmallSat Ka-band Operations User Terminal (SKOUT)

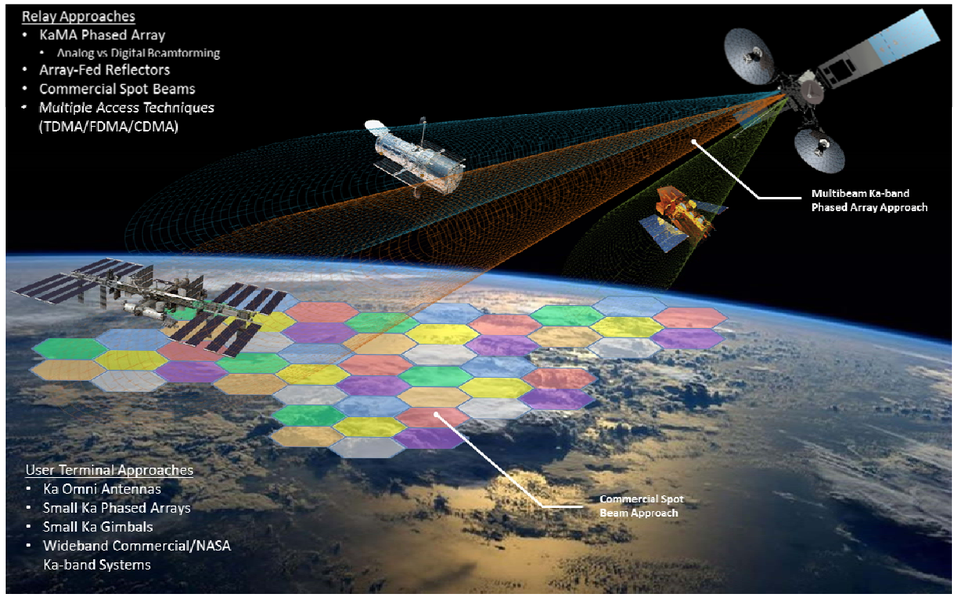


Mission Communications Summary

- A Ka-band communications system for future NASA mission spacecraft that operates with both NASA and commercial relay satellite constellations in GEO (and potentially LEO) as well as direct-to-ground (DTG) networks
- A compact modular system compliant with CubeSat standards (e.g. 6U) that is also applicable to SmallSats (<180kg) and larger mission spacecraft needing high capacity data return (Terra-bits per day!)
- Demonstrator Mission provides opportunity to demonstrate:
  - Ka-band communications with commercial spot beam architectures
  - Ka-band direct to earth phased array communications demonstration
  - Ka-band phased array to commercial LEO/TDRSS communications demonstration

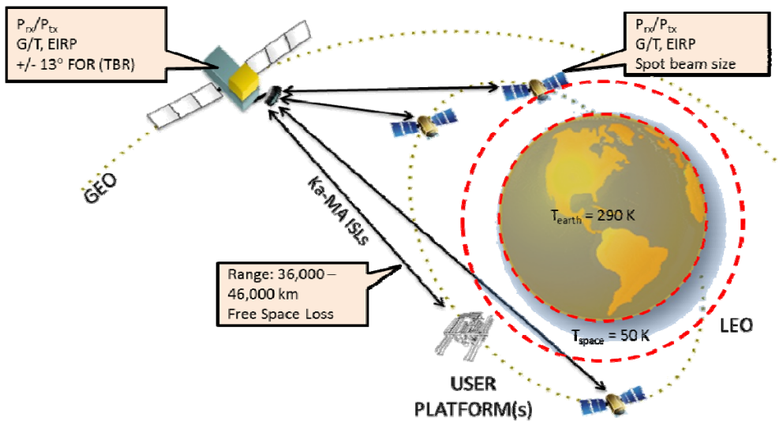
The MATRICS

- Provide a system-level architecture assessment tool for candidate next generation Ka-band relay and user terminal solutions.
  - Develop unique capability within NASA to support the demonstration and testing of proposed technologies, architectures, and CONOPS for an evolving next generation relay platform in realistic link scenarios.
  - Provide an opportunity to develop/demonstrate novel approaches to next generation architecture solutions.
  - Validate NASA/Industry solutions for next generation Ka-band architecture (e.g., Pathfinder RFI responses)



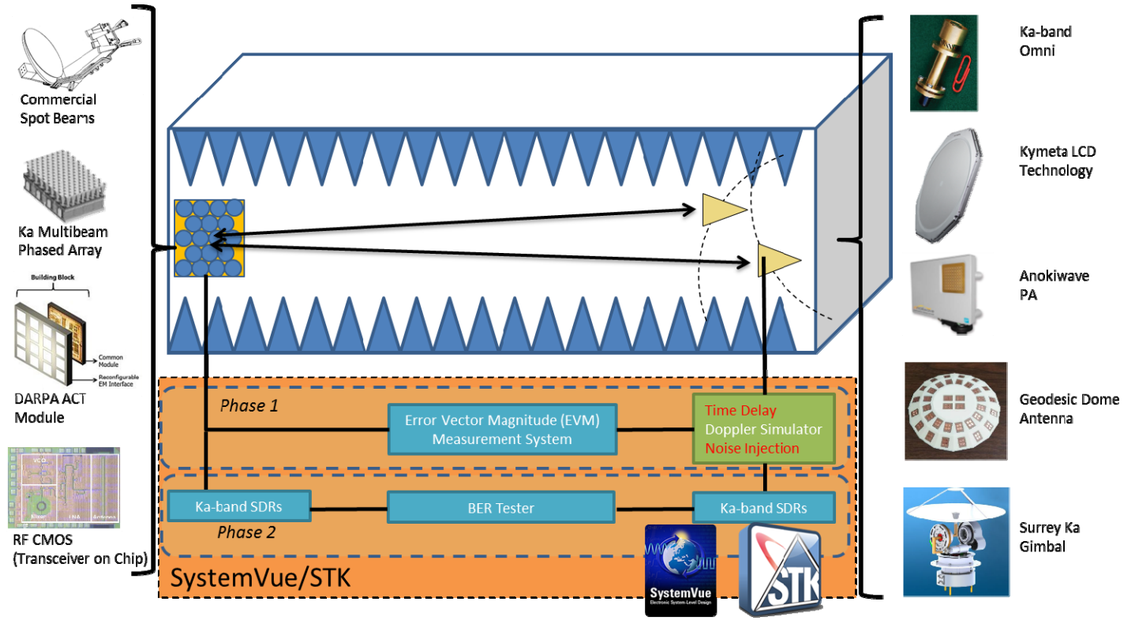
- Mitigate pre-flight risk via enhanced testing in a realistic emulation environment
- Provide NASA with a high fidelity assessment of user terminal and multiple access technology capabilities for the next generation relay.

The MATRICS



TDRSS Ka Forward Service	
EIRP	63 dBW
Free Space Loss	~210 dB
Bandwidth	50 MHz
Modulation	BPSK/UQPSK
Data Rate	300 kbps – 25 Mbps
Max. User Rx Power (before antenna)	-117 dBm

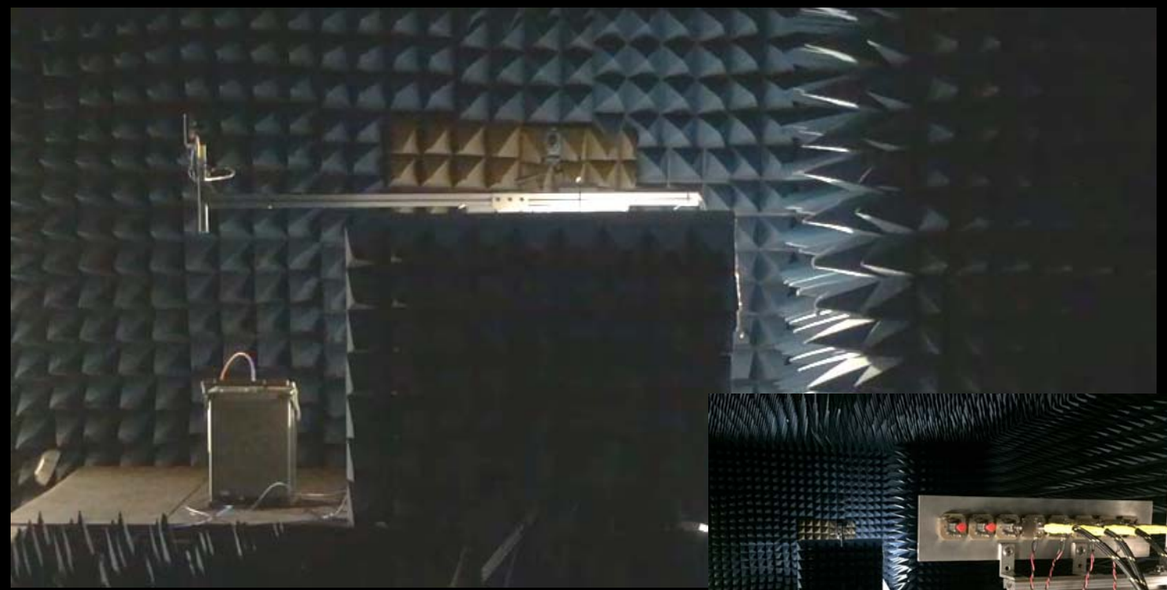
TDRSS Ka Return Service	
G/T	26.5 dB/K
Free Space Loss	~210 dB
Bandwidth	225 - 650 MHz
Modulation	BPSK/UQPSK
Data Rate	300 Mbps

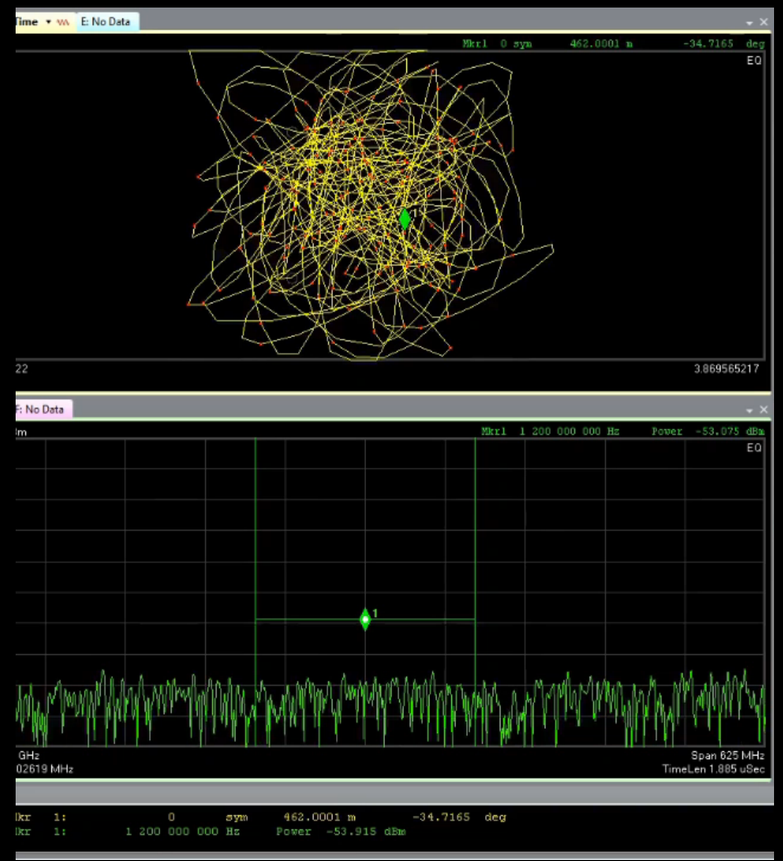


- **<u>Approach</u>**: *Scale LEO-GEO relay links into a controlled, emulated environment to perform CONOPS, architecture trades, and technology assessments for various relay/user terminal technologies.*
- Flexible platform to test/demonstrate various relay and user terminal technologies and CONOPS

The MATRICS

Dynamic Phased Array Testing



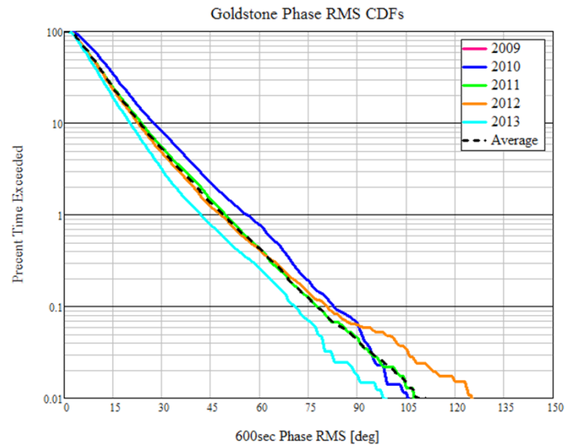


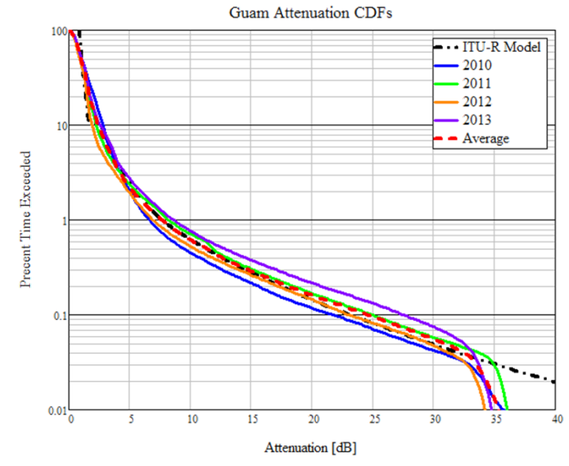
MATRICS Test Parameters

- ISS LEO orbit configuration
- Anokiwave 64-element COTS phased array
- 26 GHz return service link
- Characterize EVM through entire LEO-GEO link pass

Propagation Studies

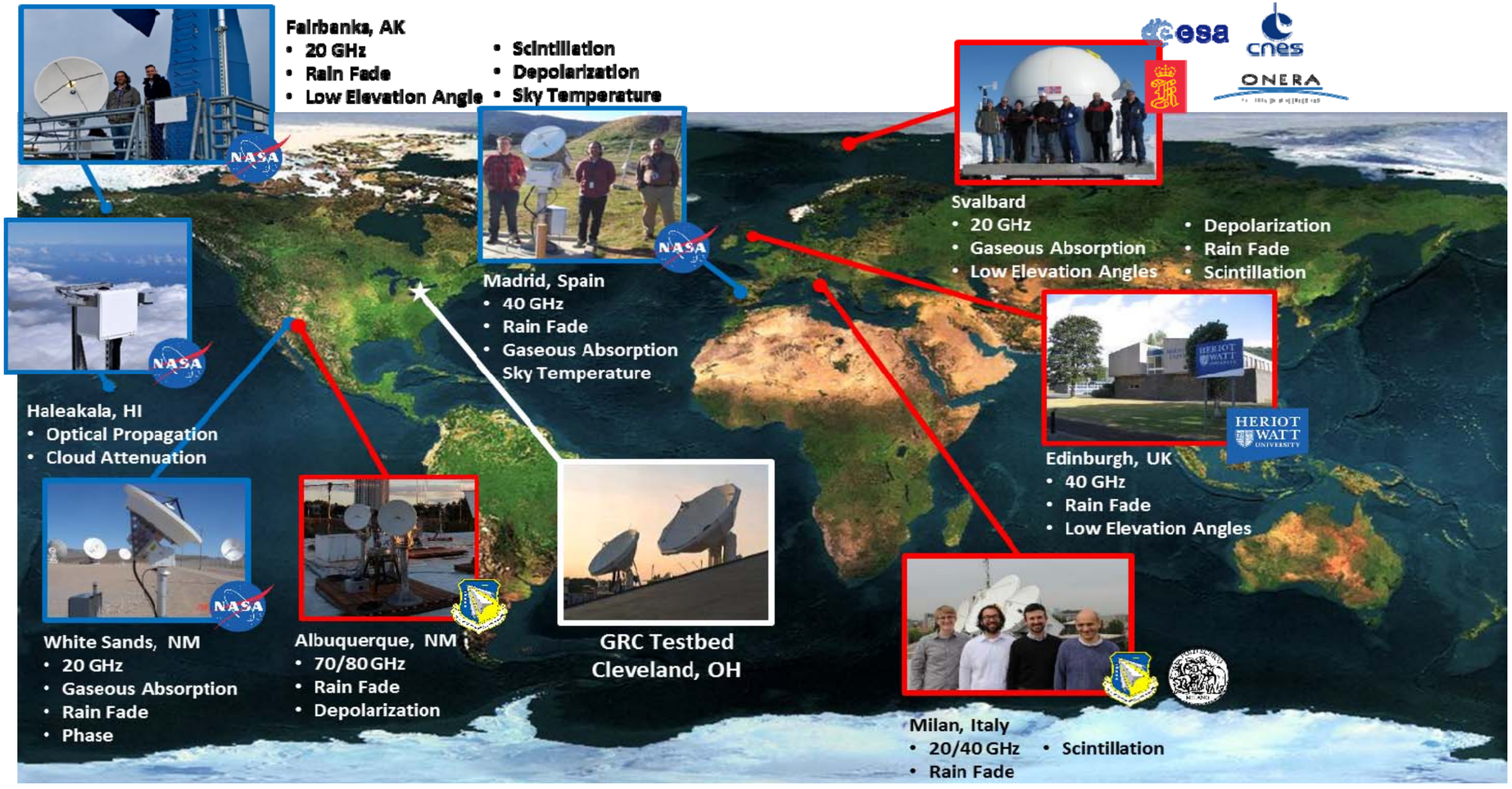
- Glenn Research Center is the lead NASA Center for propagation studies and world renown as subject matter experts in the field
- Primary interests have been in Ka-band and millimeter wave propagation through the troposphere, but moving into optical propagation for NASA's next generation architecture
- Since the 1990's, have collected over 200 station years of data on rain attenuation in the Ka and above frequency bands at sites around the world.





Propagation Studies

Ongoing Measurement Campaigns



Propagation Studies with AFRL

W/V-band Satellite Communications Experiment (WSCE)

- Presently involved in successful collaboration with AFRL/RV (Space Vehicles Directorate) to initiate ACTS-like propagation campaign for the characterization of atmospheric effects on W/V-band (81-86/71-76 GHz)
- Developed W/V-band Terrestrial Link Experiment (WTLE) for pre-WSCE propagation measurements and ground compatibility testing
- Developed prototype design for ground station hardware/ digital software for WSCE