# Satellite 2012

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Washington DC
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Technology Forum
New Methods of Antenna Design

*Antenna Technology at NASA Glenn*

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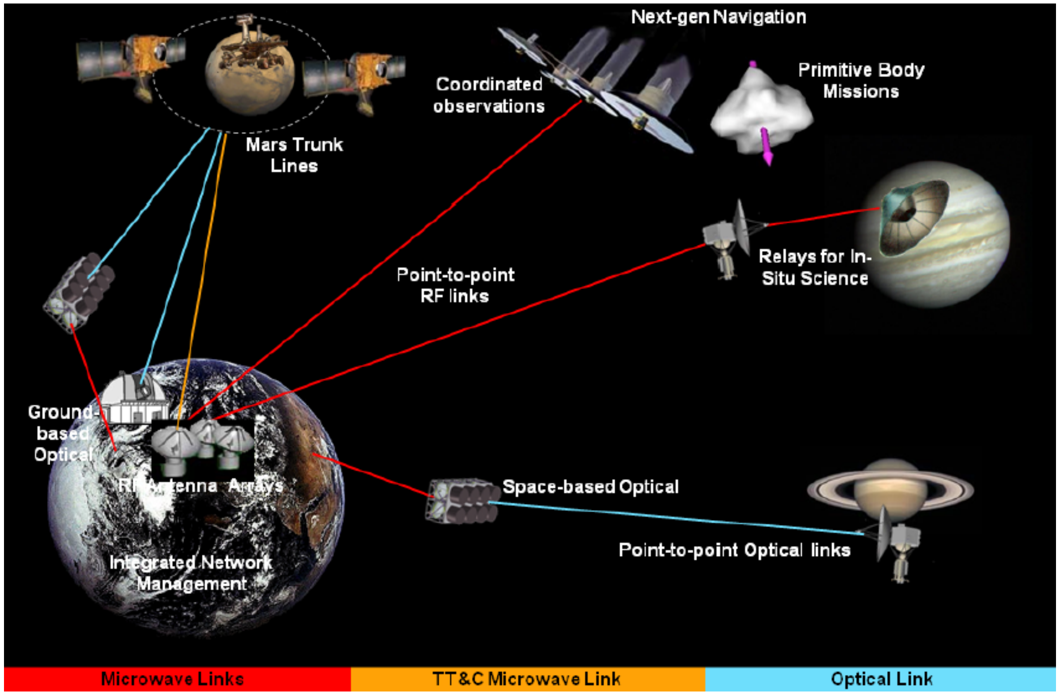
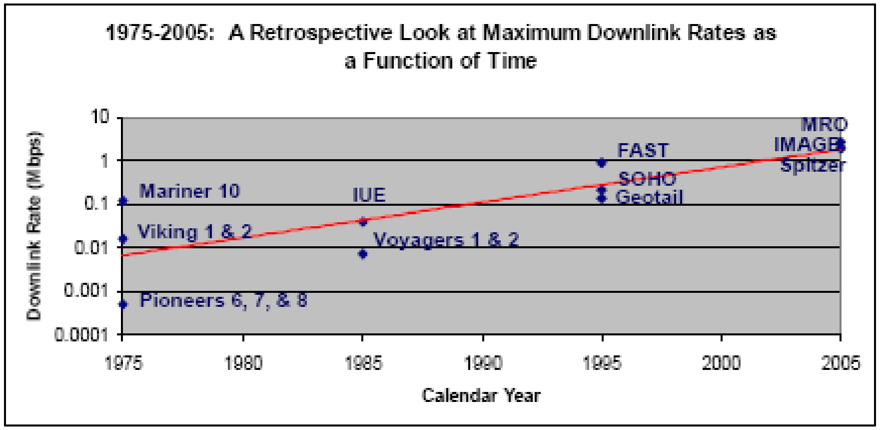
http://aos.grc.nasa.gov/

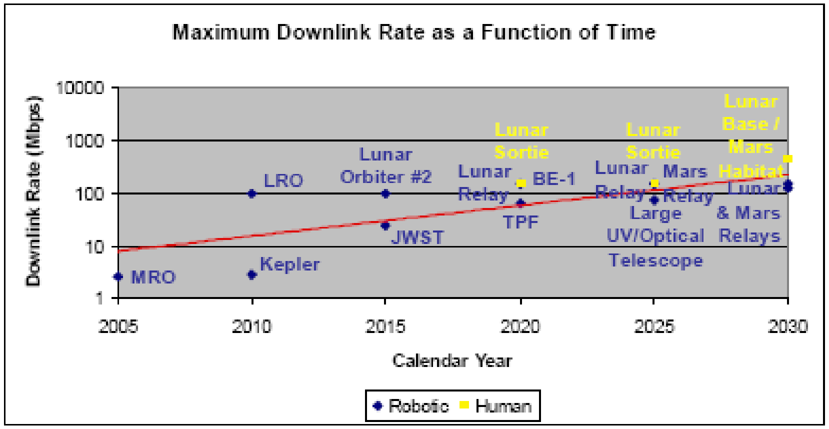
National Aeronautics and Space Administration

# Space Communications and Navigation Project



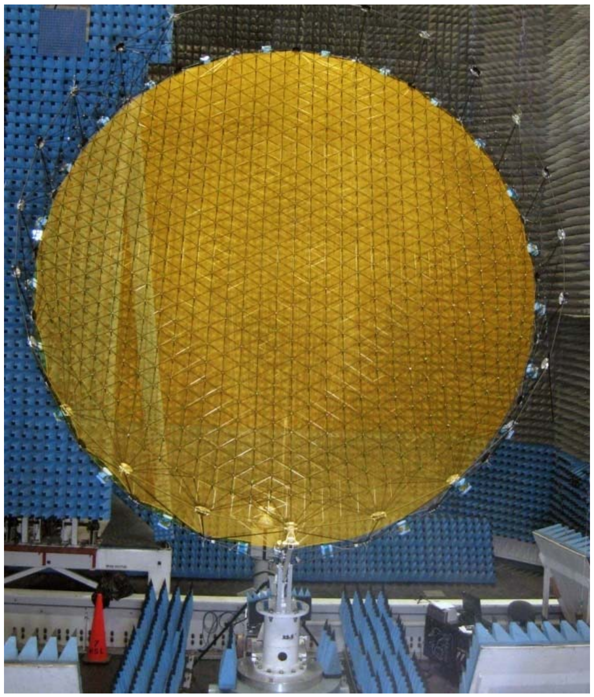




Deep-space communications downlink data rate trend

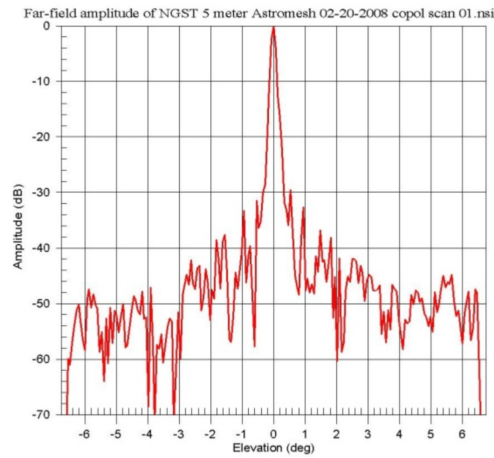



Expected Deep-space communications downlink data rate trend

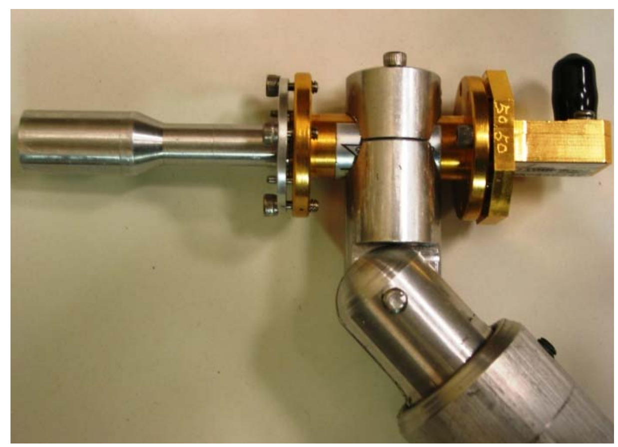
# NGST[1] 5m Reflector Evaluated at 32, 38 and 49 GHz as well as laser radar surface accuracy mapping



NGST 5 m Reflector in NASA GRC Near-Field Range



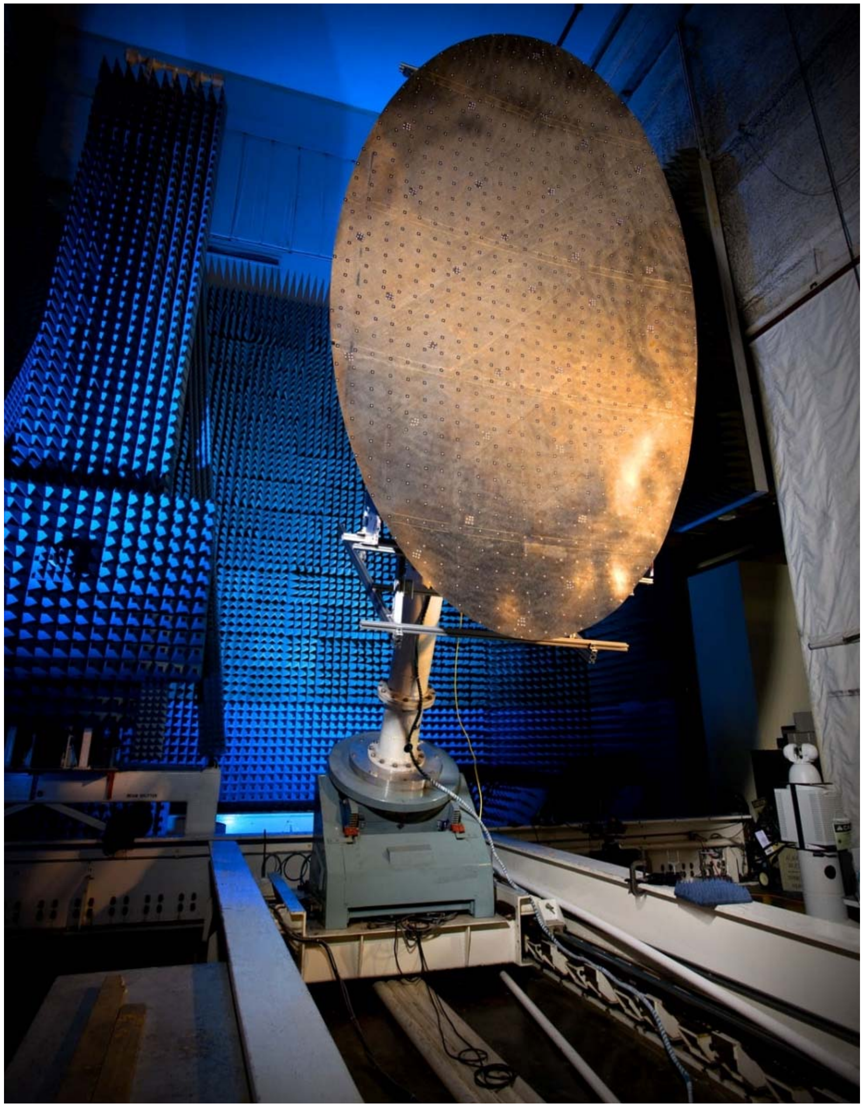

Far Field Elevation pattern at 33 GHz (Directivity = 62.8 dB)



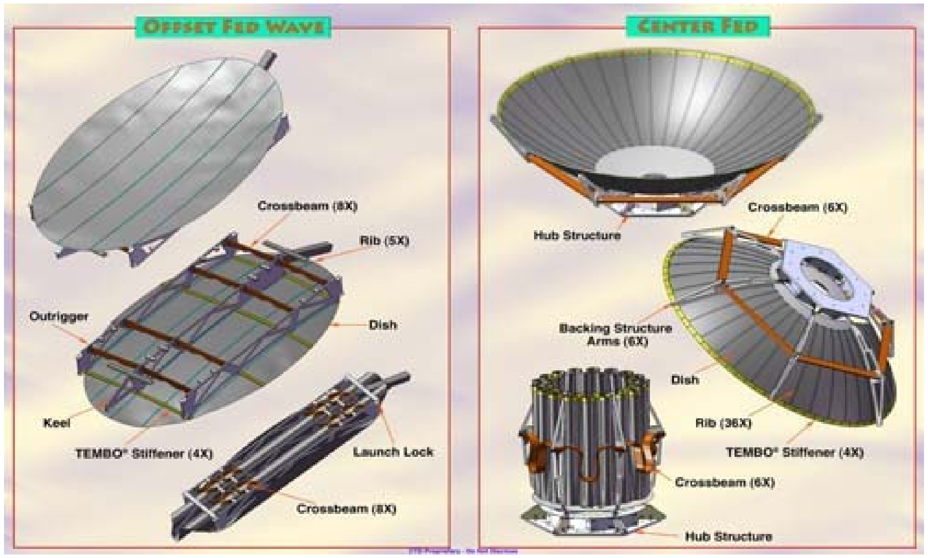
GRC Dual-band feed horn assembly

[1]www.st.northropgrumman.com/astro-aerospace

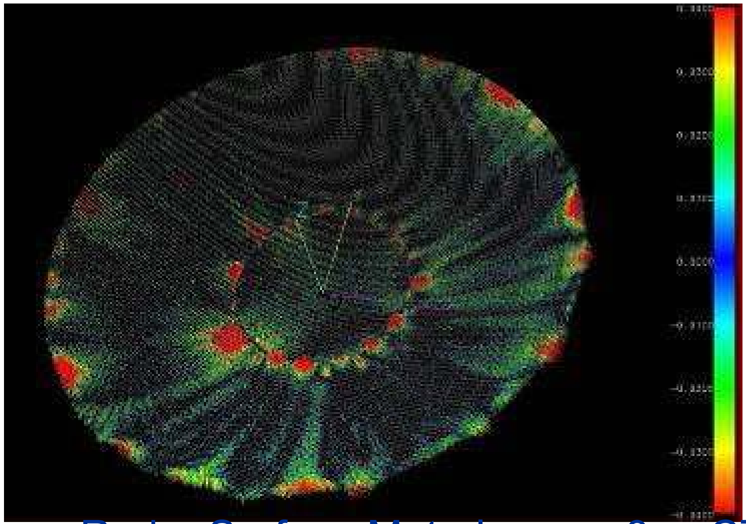
# Shape Memory Polymer Deployable Antenna



4 m X 2.5 m Composite Technology Development Reflector In NASA Glenn Near Field Antenna Range




Deployment Sequence



Laser Radar Surface Metrology on 3 m CTD Reflector at NASA Glenn

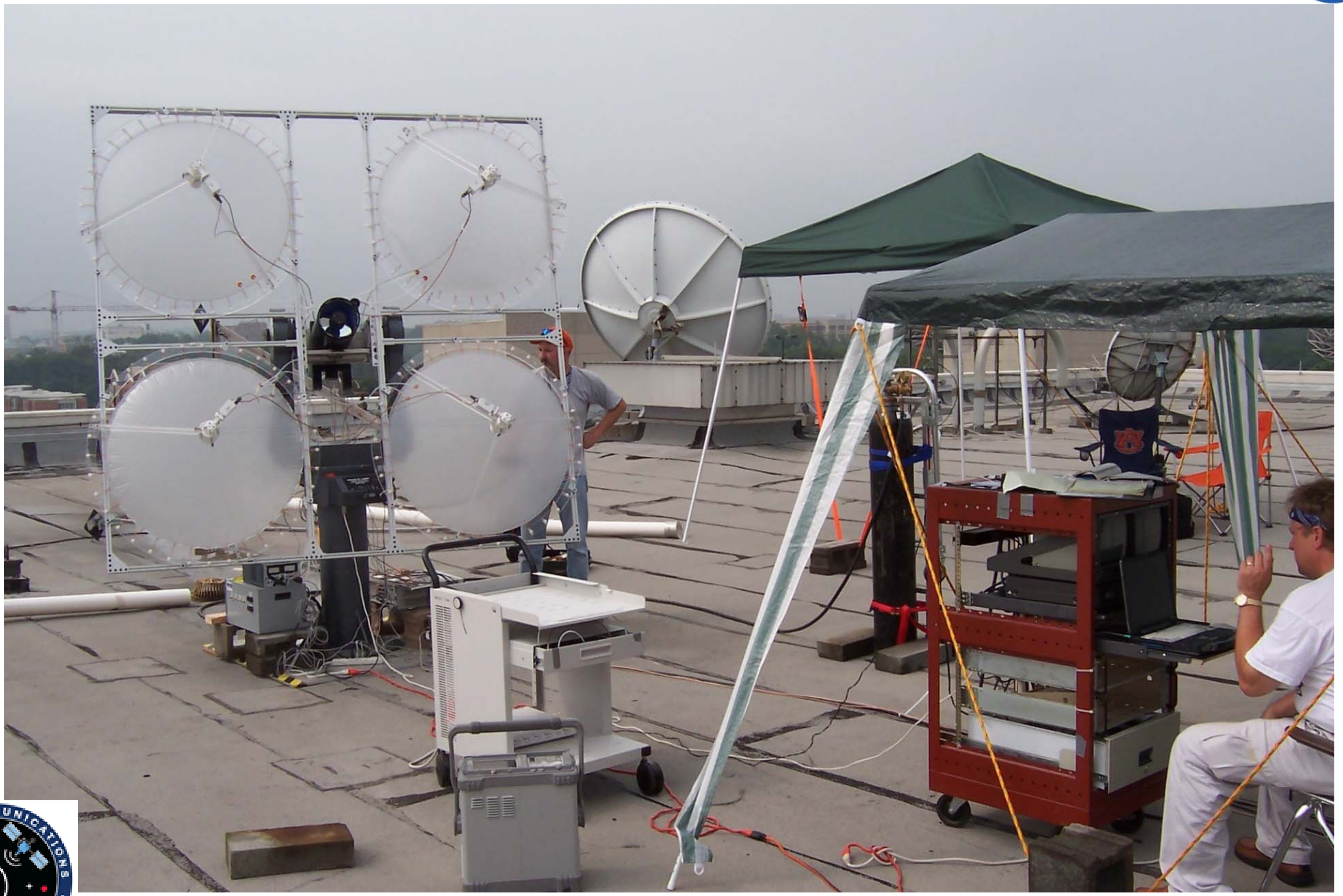
http://www.ctd-materials.com/

# Self-Deploying Gossamer Support Structure

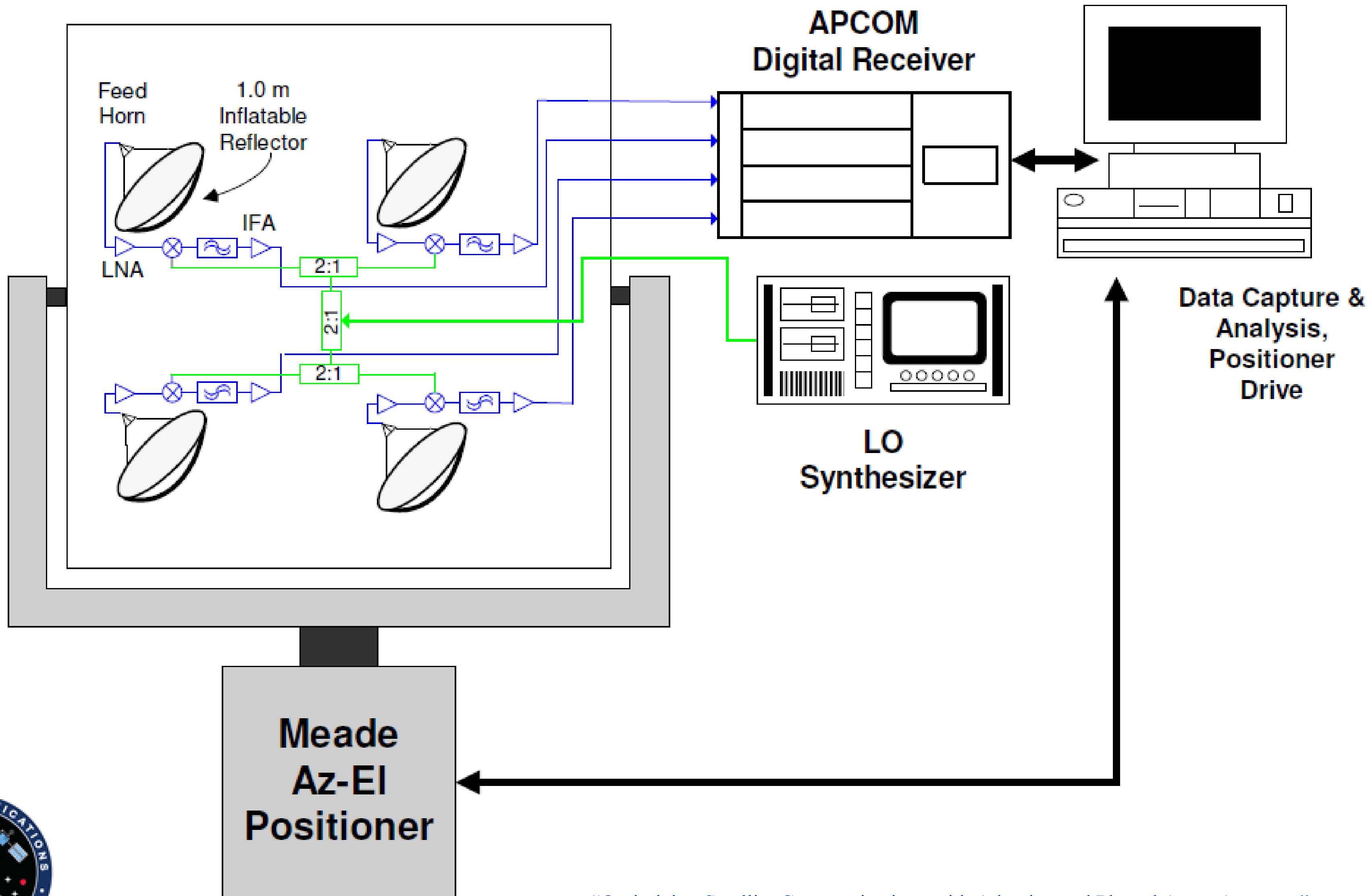
Phase II SBIR NASA Contract NNC06CA10C
Cornerstone Research Group, Dayton, OH

**Activation sequence of early prototype self-deploying truss: one minute duration from compressed (2.5 in.) to deployed (28.5 in.)**

# SAC-C Experiment

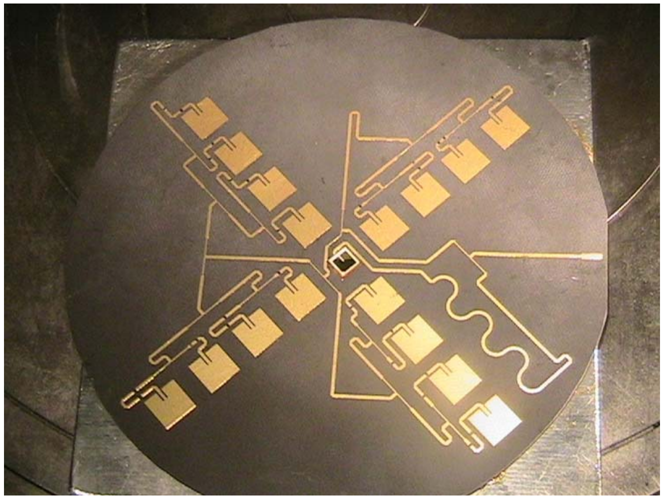


# SAC-C Experiment[1]



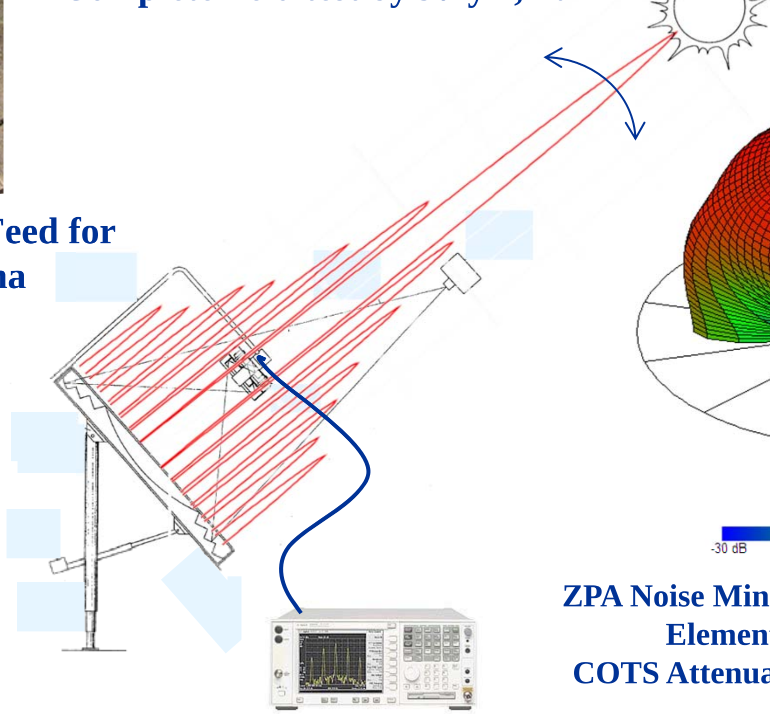

“Optimizing Satellite Communications with Adaptive and Phased Array Antennas”, M. Ingram, R. Romanofsky, R. Lee, et al., ESTC Conference, Anaheim, CA, June, 2004

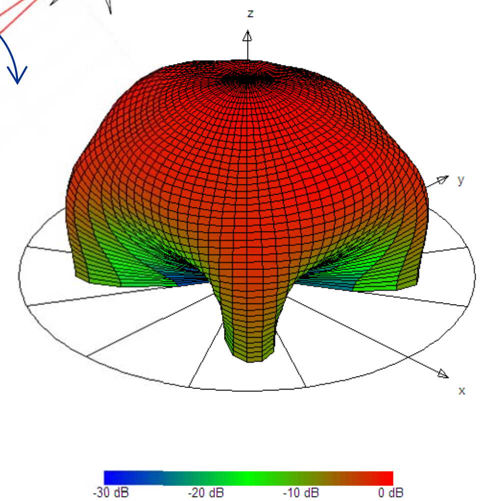
# Investigation of Noise Reduction Properties of the Zone Plate Antenna[1]



**Autocorrelation of white noise at the output of the antenna is a sinc function. Thus for a band-limited system of 400 MHz , for example, the correlation time is approx. 2.5 ns. Since the ZPA induces a delay of 0.27 ns per ring by design, partial correlation of white noise may be present, resulting in some destructive interference of the noise signal**

- **Complete field test by July 1, 2012**






**ZPA Noise Minimization Array Feed 9 + 9 Elements @ 11.7 GHz with COTS Attenuators (Directivity = 7.9 dB)**

**12 cm Uniform Amplitude Taper Array Feed for 150 cm diameter Zone Plate Antenna**

**Array Feed Mounted on ZPA Bridge**

**Conduct solar flux and cold sky measurements and compare with well-characterized results to demonstrate noise cancellation of the ZPA.**

[1]alienworksltd@earthlink.net

# SAA with GATR[1] Technologies since 2006 to develop Inflatable Radome Antenna System

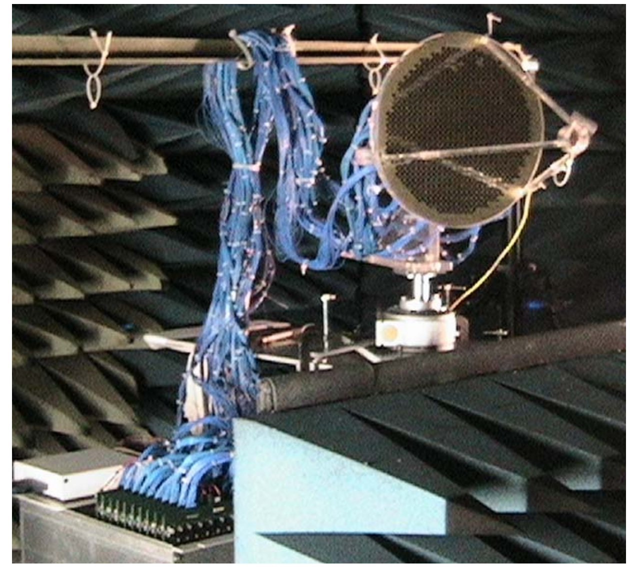
- First-response disaster relief support
  - ✓ *humanitarian aid through support for communications in Haiti following the 2010 earthquake*
- Emergency search-and-rescue support
  - ✓ *The inflatable antenna was used to assist with communications efforts in the search for a missing girl in San Diego, California.*
- Large sports and entertainment venue backup communications
- Homeland security and military communications support
- Federal Laboratory Consortium Award for Excellence in Technology Transfer (2010)
- IR&D 100 Awards (2010)
- Featured in “Spinoff Day on the Hill” (2010)

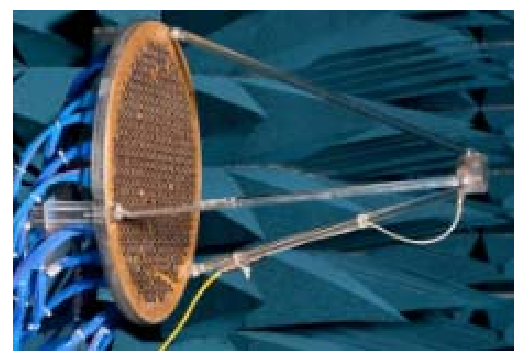
*Officers with the Air Force Special Operations Command set up the inflatable antenna at Hurlburt Field in Eglin, Florida.*

[1]www.gatr.com

# Ferroelectric Reflectarray

- A scanning reflectarray that consists of a flat surface with integrated phase shifters and patch radiators illuminated at a virtual focus
  - The signal passes through the phase shifters and is re-radiated as a focused beam in the preferred / target direction
  - Enabled by unique low loss ferroelectric phase shifters
- Reciprocal surface – the same aperture can transmit or receive so antenna is ideal for two-way communications or monostatic radar
- 2010 R&D 100 Award-winning innovation

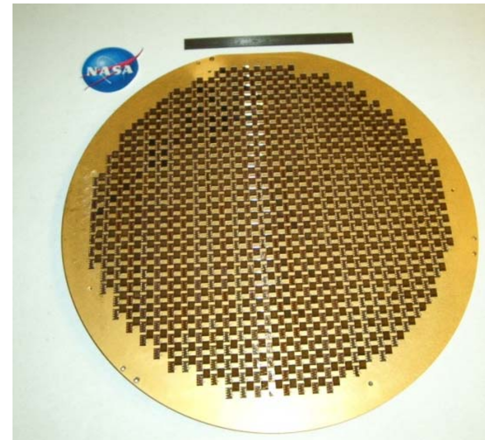




# Ferroelectric Reflectarray

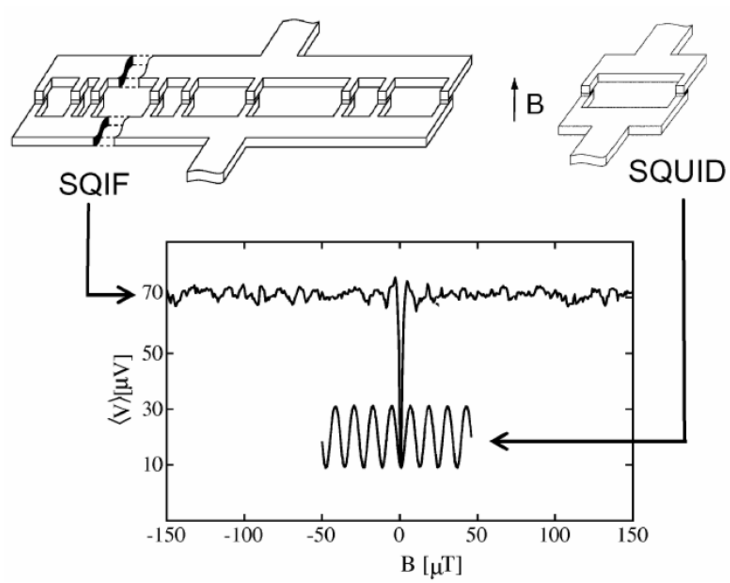
## Key benefits are …

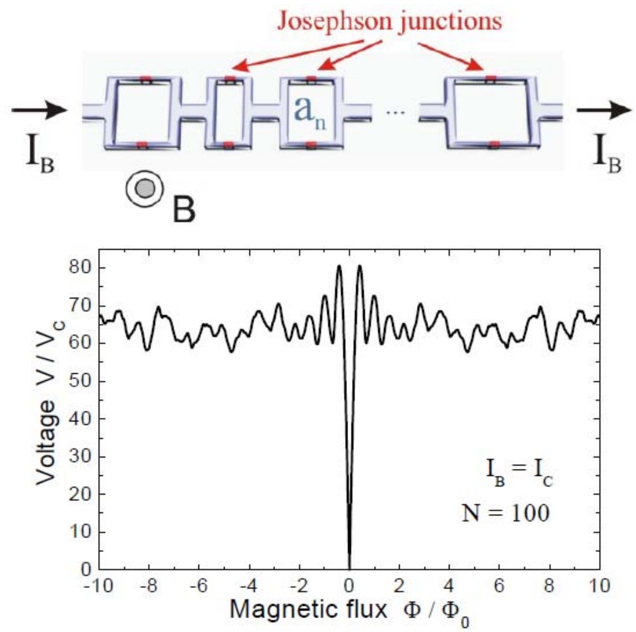
- **Significant cost reduction:** 10X to 100X (at scale) lower cost than direct radiating phased array
- **Unlimited gain:** gain is not limited by a beam forming manifold
- **Efficient:** up to a 5X reduction in power vs. GaAs MMIC array
- **Reliable:** high reliability compared to a gimbaled reflector due to no moving parts
- **Simple construction technique:** only three layers per phase shifter compared to at least five for an MMIC
- **Simple device lithography:** smallest feature size is ~10 μm compared to sub-micron for MMIC devices




~28cm Active Diameter

# Superconducting Quantum Interference Filter Receiver[1]



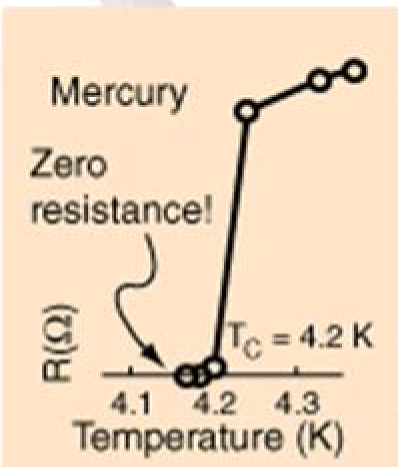

- Comparison between transfer characteristic of conventional SQUID (single loop) and SQIF (multiple-loop device). The amplitude of the peak is a function of the number (N) of SQUIDs in the array.

Sensitivity is a function of the slope and magnitude of the impulse-like response and dynamic range is a function of the linearity.

www.hypres.com

**Table I. Critical Temperature for some key superconductors**

| Superconducting Material | Critical Temperature, $T_c$, (K) |
|---|---|
| Niobium (Nb) | 9.2 |
| Magnesium Diboride ($MgB_2$) | 39 |
| Yttrium Barium Copper Oxide ($YBa_2Cu_3O_7$) | 90 |




Resistance versus Temperature for Hg[1] (perfect dc conductivity below a critical temperature)

- The microscopic origin of this pure *quantum mechanical* phenomenon is the formation of pairs of two conduction electrons having opposite momentum and spin (Cooper pairs)

- In conventional superconductors, electron attraction is generally attributed to an electron-lattice interaction. In the BCS framework, superconductivity is a macroscopic effect which results from "condensation" of Cooper pairs. The attractive interaction between electrons (necessary for pairing) is brought about indirectly by the interaction between the electrons and the vibrating crystal lattice (phonons)

- The spatial extent of the pair correlation can be several orders of magnitude larger than the interatomic distance and is characterized by the coherence length ξ,

- Due to the quasi-boson character of the Cooper pairs, they are allowed to condensate into a common ground state, which can be described by a single macroscopic wave function

[1]http://hyperphysics.phy-astr.gsu.edu/hbase/solids/scond.html

# Semiconductor Receiver versus SQIF Receiver

## $\mathcal{E}$ vs. $\mathcal{B}$

SQUIDs can detect magnetic fields lower than one flux quantum h/(2e)(≈ $10^{-15}$ Wb), $10^{-18}$ Wb reported in the literature

### Conventional Receiver

Mars link at 64 MBPS

- EIRP = 84 dBW (≈2.5 X $10^8$ W)
  - Assumes 100 W TWT, 12 m aperture
  - Range=3.7X$10^8$ km
- Power density at receiver ≈ 2.8X$10^{-16}$ W/m$^2$
  - Electric Field ≈ 4.6 X $10^{-7}$ V/m
  - Displacement flux density ≈ $10^{-18}$ C/m$^2$
- Receive Antenna Aperture
  - QPSK, Block Turbo Code, 3 dB margin
  - Required $E_b/N_o$=4.6 dB

72 meters

### SQIF Superconducting Receiver

Mars link at 64 MBPS

- EIRP = 84 dBW (≈2.5 X $10^8$ W)
  - Assumes 100 W TWT, 12 m aperture
  - Range=3.7X$10^8$ km
- Power density at receiver ≈ 2.8X$10^{-16}$ W/m$^2$
  - Electric Field ≈ 4.6 X $10^{-7}$ V/m
  - Displacement flux density ≈ $10^{-18}$ C/m$^2$
  - Magnetic Field ≈ $10^{-9}$ A/m
  - Magnetic flux density ≈ $10^{-15}$ Wb/m$^2$
- Receive Antenna Aperture
  - Flux Concentrator
  - Mechanical refrigerator at 4K

≈ 1 meter???