A Scalable Deployable High Gain Reflectarray Antenna - DaHGR

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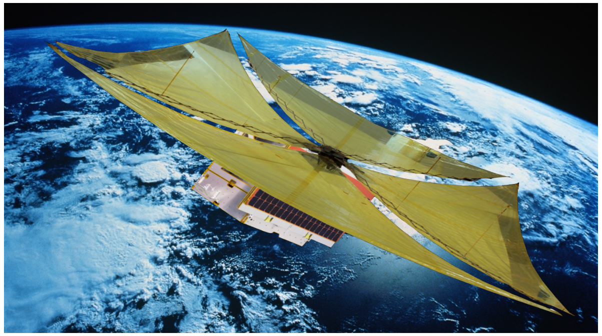
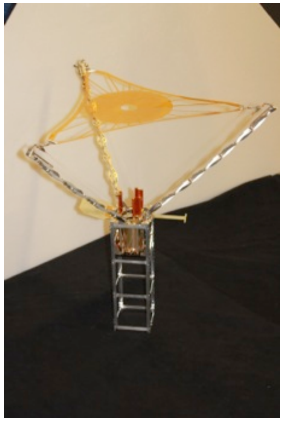
MMA Design LLC

MMA Overview

- Facilities in Boulder County Colorado
  - 10,000 SF facility
  - Cleanroom / Flight Lab
  - R&D Lab
  - Machine Shop
- Business Areas
  - Solar Array Systems
  - Deployable Antennas
  - Deployable Apertures and Structures
- Products
  - HaWK High Performance Solar Arrays
  - DaHGR high gain compact antenna
  - CubeSat Systems
  - dragNET De-orbit Modules

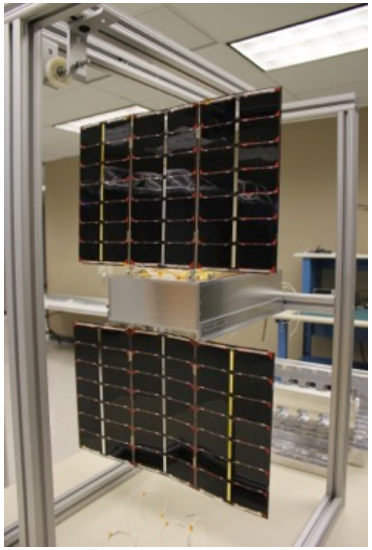


De-orbit System



FalconSat-7 CubeSat

HaWK CubeSat Solar Array



E-HaWK 72W

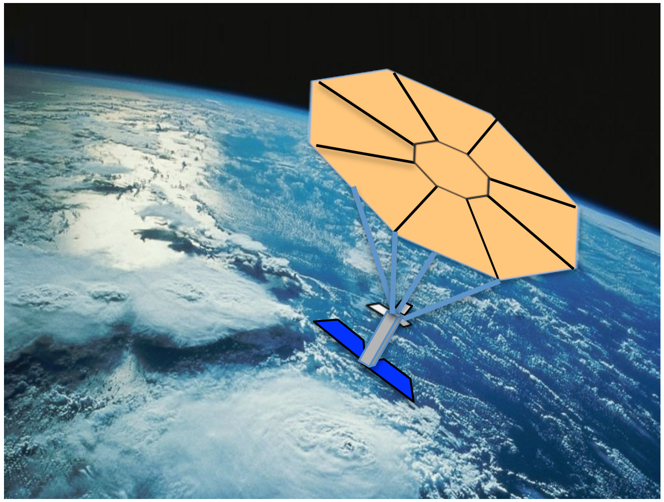
MMA Boulder Facility

Outline

- DaHGR Overview
- What is a Reflectarray?
- Reflectarray Advantages
- DaHGR Performance
- Frequency range and Bandwidth
- Mission Concepts
- DaHGR Heritage/Risk
- Conclusions

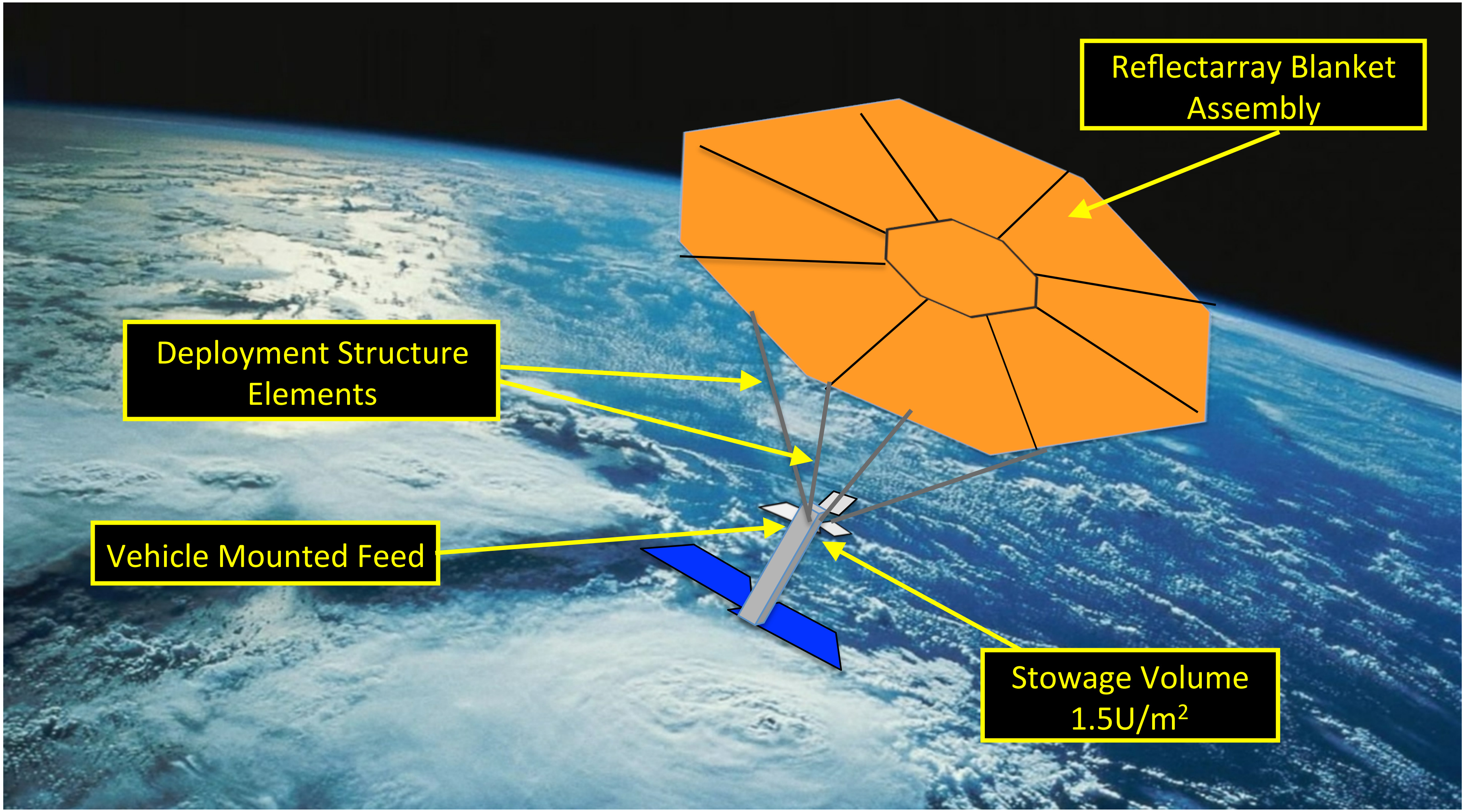
DaHGR Overview

- MMA Design has been developing the DaHGR system under IR&D – multiple patents pending
  - Our RF teams has heritage and world class expertise in reflectarray antennas
  - MMA has world class deployable structures technologies and expertise
  - Three DaHGR 1m to 3m antenna programs started in first quarter 2016
- DaHGR is a product that competes with a parabolic wire mesh reflector high gain antenna
  - Small stowed volume
  - Similar area mass with feed included
  - Fewer parts -**1/3rd the parts**
  - Lower cost -**1/3 the cost**
- Uses thin film reflectarray antenna and membrane technologies
  - High TRL
  - Leverages MMA's TRL-9 membrane deployment experience
    - TRL-9 dragNET De-Orbit system and launch restraints
    - TRL-8 FalconSat-7 diffractive membrane deployment
    - Flight heritage standoff boom composite tapes
  - Multiple frequencies up to Ka-band
- Printed reflectarray technology reduces cost and enables >3m^2 apertures on CubeSats



DaHGR

Deployable High Gain Reflectarray Antenna - DaHGR

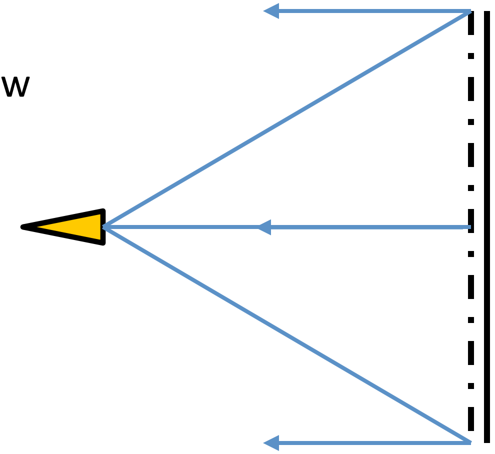


What is a Reflectarray?

- First described in the 1960’s
- 1990’s-2000’s inflatable reflectarrays for space

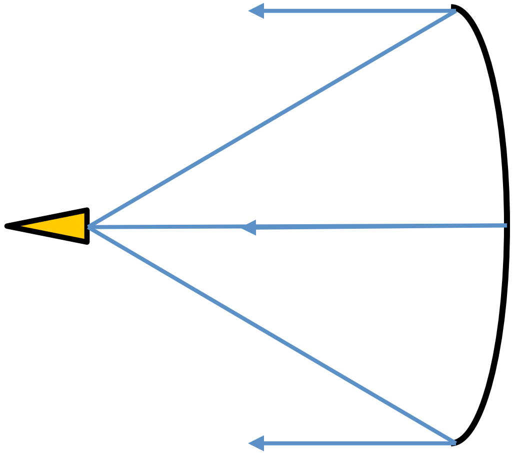
Reflectarray

- Collimation over narrow bandwidth (limited by electrical size, radiator properties, number of layers)
- Single or multiple flat surfaces conducive to small stowed volume



Parabolic Reflector

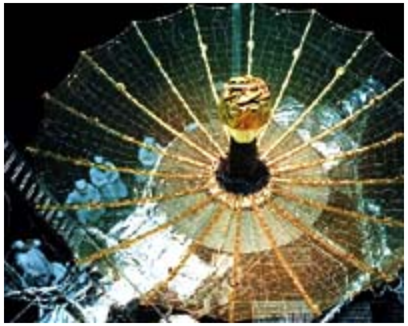
- Collimation over infinite bandwidth (limited by surface roughness)
- Precise parabolic profile requires many physical control features limiting stowed volume/size



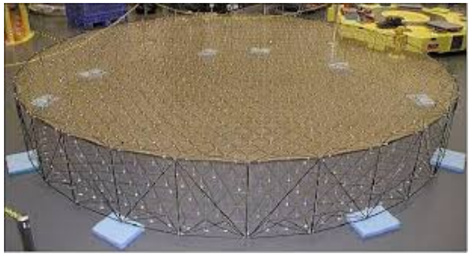
Reflectarrays support any polarization and high power

Thin Membrane Reflectarray Advantages

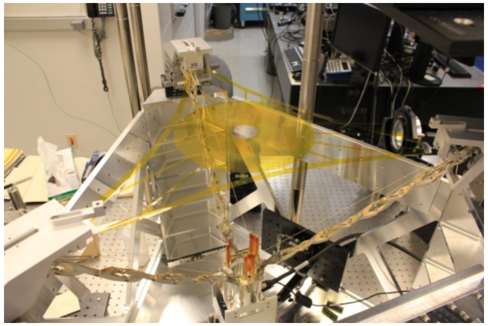
- Cost
  - Less complex mechanical deployment system
  - Lower parts count
  - Less touch labor to assemble
- Small stowed size
  - 1 m diameter aperture in a 0.1m X 0.1m X 0.12m (1U) volume
- Meeting RMS tolerances with flat membrane surfaces is inherently less difficult than mesh/parabola systems
  - Increasing tension improves surface RMS
  - RMS vs Membrane thickness and tension

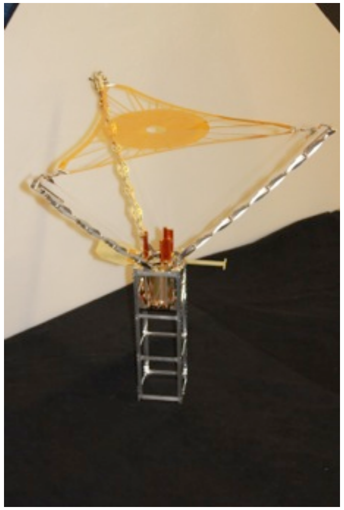


Harris Mesh Reflector



NG AstroMesh





MMA/USAFA FalconSat-7

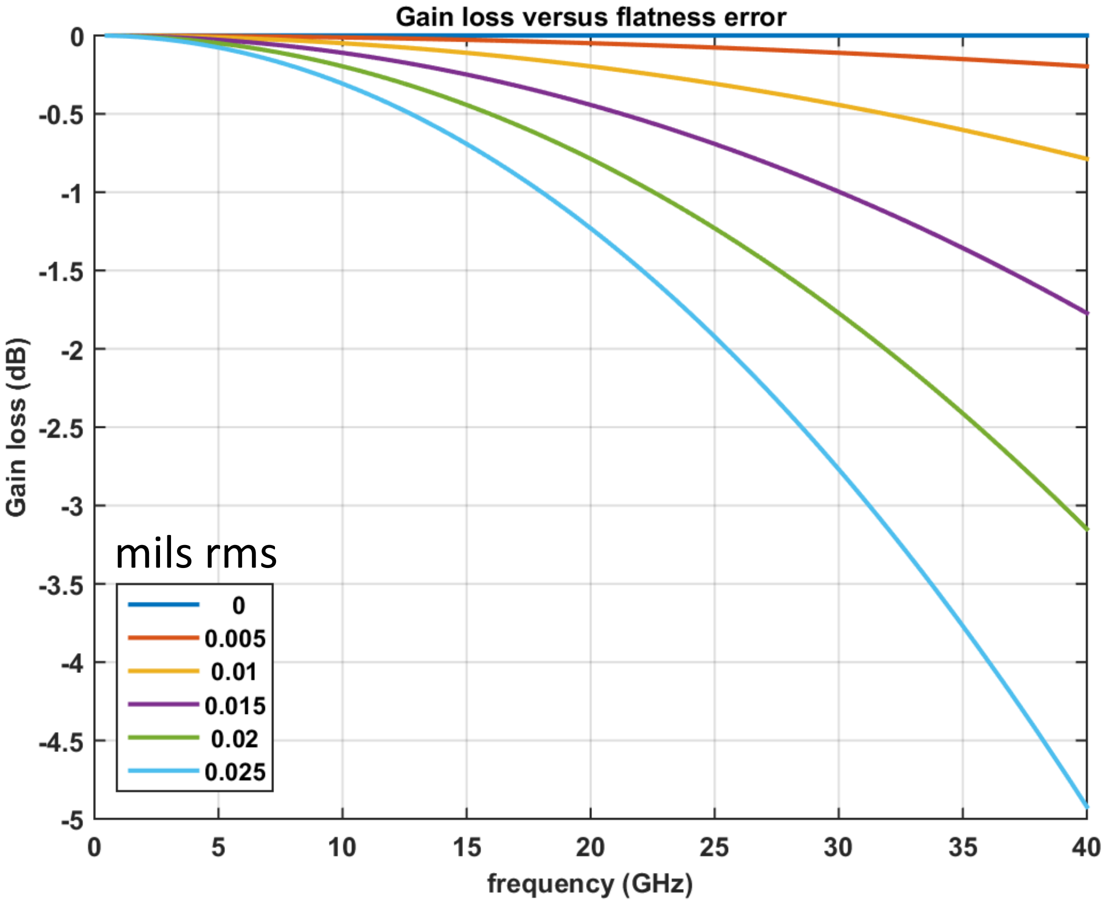
DaHGR Mechanical Performance

- Areal Compaction: approximately 1.5m^2/L
- Mass Density: 1.0kg/m^2 @10m^2 to 1.6kg/m^2 @0.78m^2
- First mode >1 Hz
- Low CTE structure
- On orbit adjustable feed to reflectarray geometry

Frequency Range and Bandwidth for Small Sats

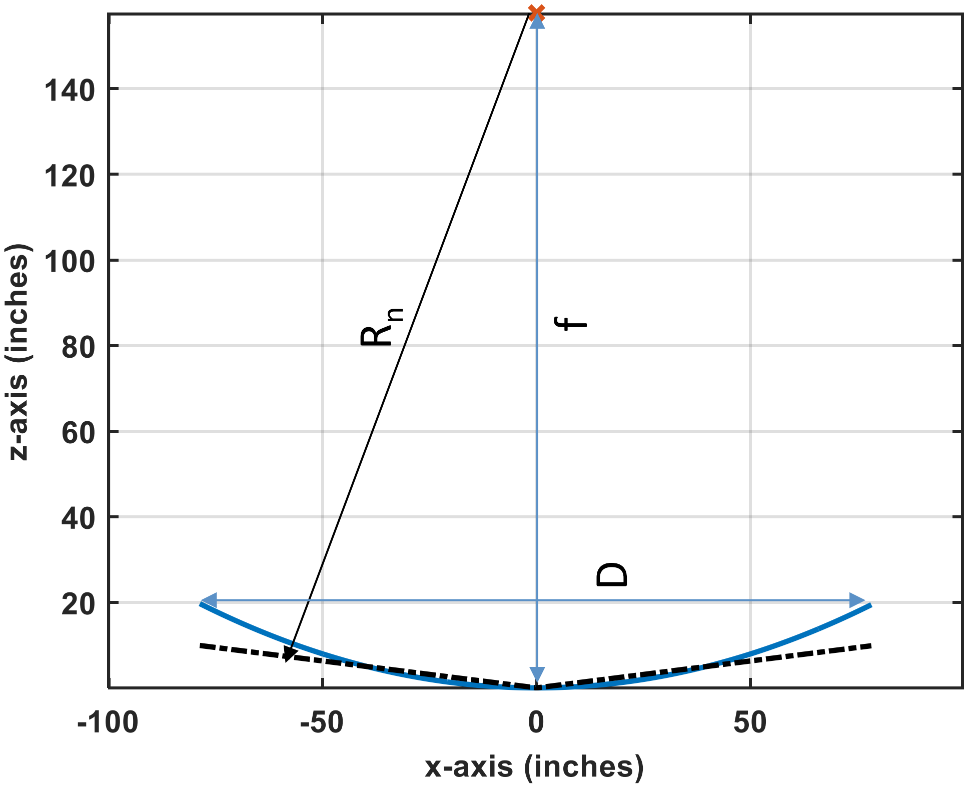
- Aperture sizes in development span 0.8 m to 5 m diameter
- Lower frequency limited by electrical size conducive to spatial feeding with minimal spillover losses (~$D/\lambda > 10$)
  - D=5m, λ=0.5m, lowest frequency is 0.6 GHz
  - At smaller electrical size, the deployment methods described support constrained feed antenna architectures.
- Highest frequency is limited by features controlling deployed flatness and allowance for Gain and sidelobe degradation
- Reflectarrays are inherently band width limited

Ruze's Equation for Reflectors



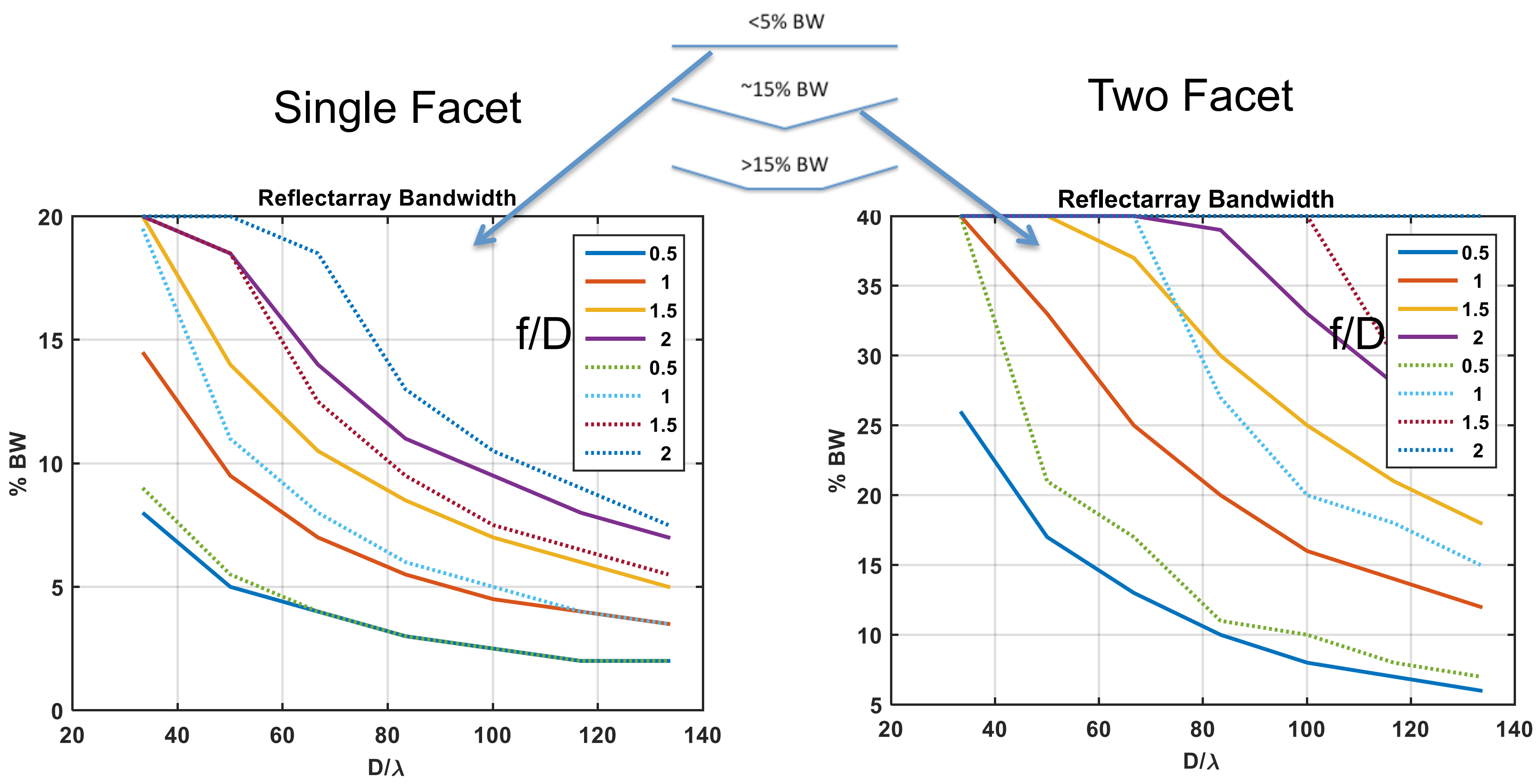
- Active area of research driven primarily by material thickness (membranes and metal).
- Current photogrammetry inspections of surfaces showing better than 25 mil rms.
- Near term work will quantify performance at X-band; we expect Ka band applications to be viable

Bandwidth Analysis Method



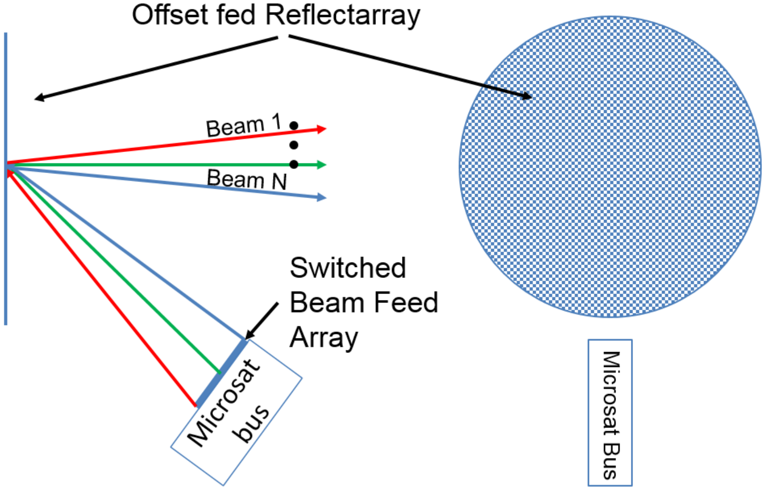
Path length variation (Rn) drives bandwidth of the system

1.0 dB Bandwidth (DaHGR)



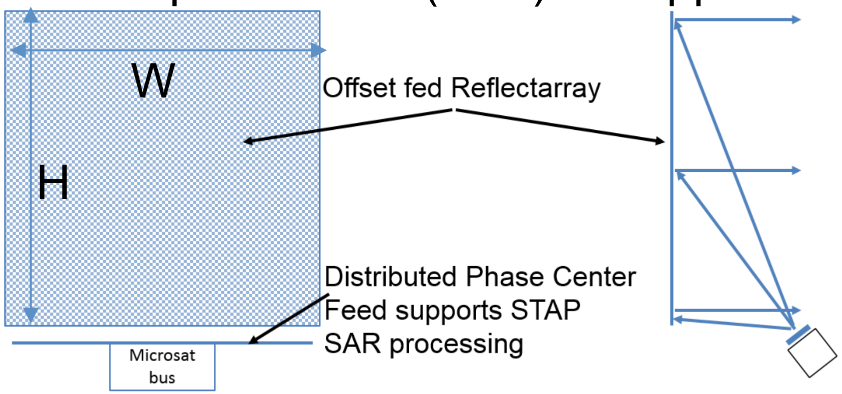
Mission Concepts

SAR/SATCOM

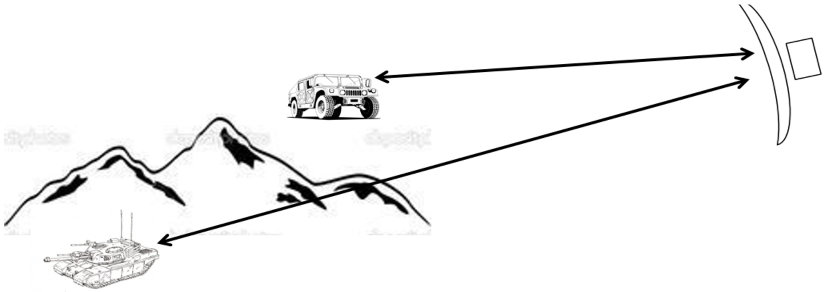


SAR with STAP

Aspect Ratios (H/W)>2 supported

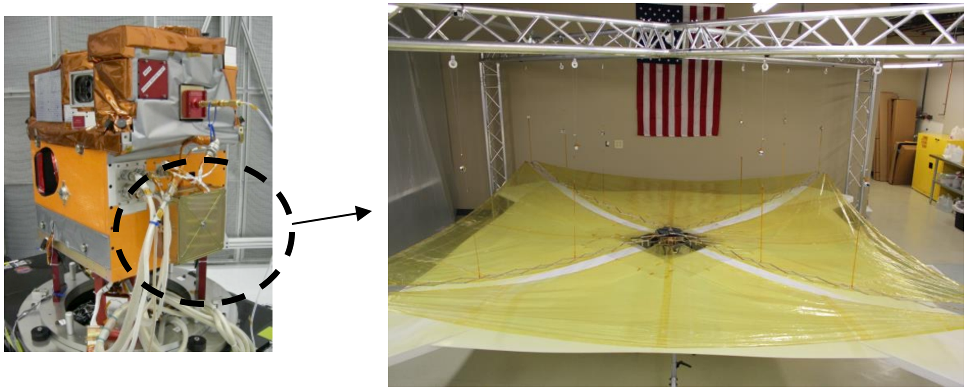


Over the Horizon Comms



DaHGR Heritage/Risk

- Combine two high TRL (9 and 7) to produce a high gain and cost effective antenna
- The deployment system is based on the 14m^2 Flight heritage dragNet de-orbit system
- Deployable thin film Ka and X band reflectarrays have been built and tested by NASA and its contractors
  - They used inflatables to deploy the array
  - The mechanical system in DaHGR is more robust



14m^2 dragNet De-orbit Module

1m X Band

3m Ka-Band Inflatable Reflectarray Antenna (RF Test and Inflation Test)

3m Ka-Band Inflatable Reflectarray Deployment Sequence

3m Ka Band

Conclusion

- Compared to conventional parabolic antennas-DaHGR is:
  - 1/3 the cost
  - 1/5th the volume
  - 1/3 the parts

- Reflectarrays enable new/expanded missions for SmallSats:
  - Expanded GEO communications
    - 2-4x RF aperture
    - Expanded “real estate” for secondary payloads
  - Enable High resolution/SmallSat DoD SAR/SIGINT missions and high capacity communications platforms
  - Launch on ESPA, Minotaur, Pegasus, Taurus, Alasa, SuperStrypi, etc.

- System TRL-9 expected in next 18-24 months on a CubeSat or other mission