Optimizing Satellite Communications with Adaptive and Phased Array Antennas

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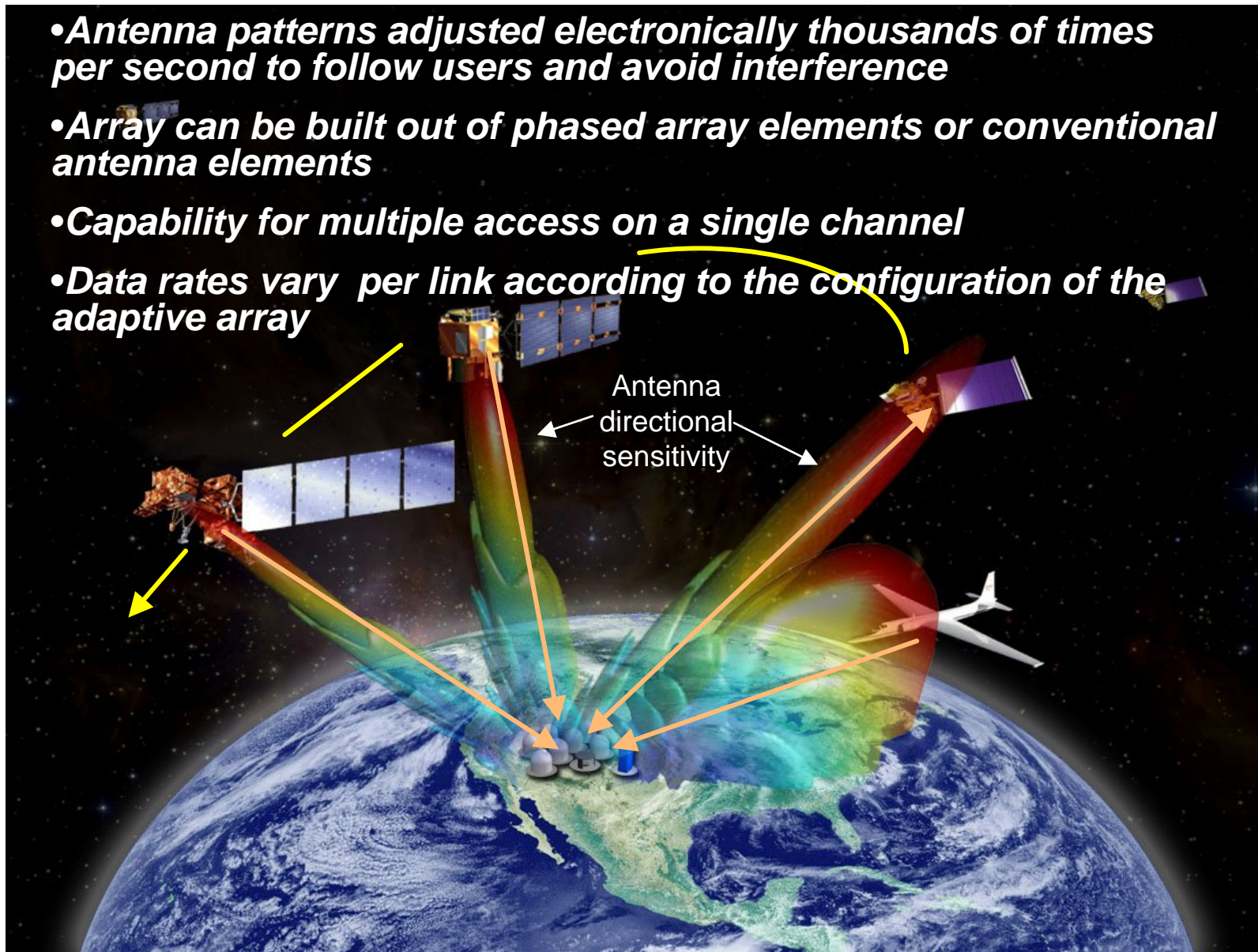
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Agenda

◆ **Smart antenna technology**

◆ **Prototypes**

  – **Adaptive array prototype**

  – **Space Fed Lens front end element prototype**

  – **Reflectarray front end element prototype**
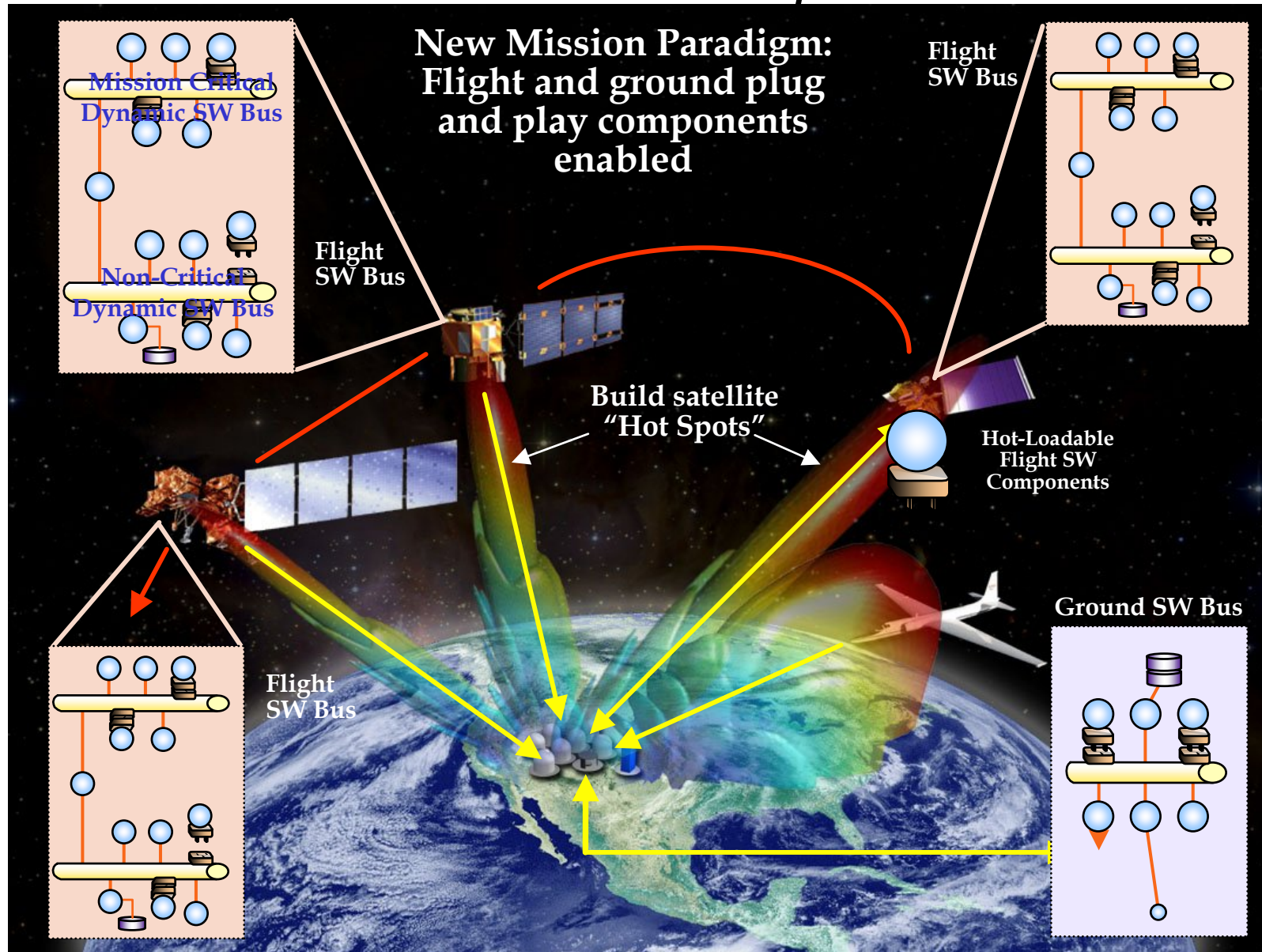
◆ **Conclusion**

- *Antenna patterns adjusted electronically thousands of times per second to follow users and avoid interference*
- *Array can be built out of phased array elements or conventional antenna elements*
- *Capability for multiple access on a single channel*
- *Data rates vary per link according to the configuration of the adaptive array*

Antenna directional sensitivity

New Mission Paradigm: Flight and ground plug and play components enabled

Mission Critical Dynamic SW Bus

Non-Critical Dynamic SW Bus

Flight SW Bus

Flight SW Bus

Build satellite "Hot Spots"

Hot-Loadable Flight SW Components

Flight SW Bus

Flight SW Bus
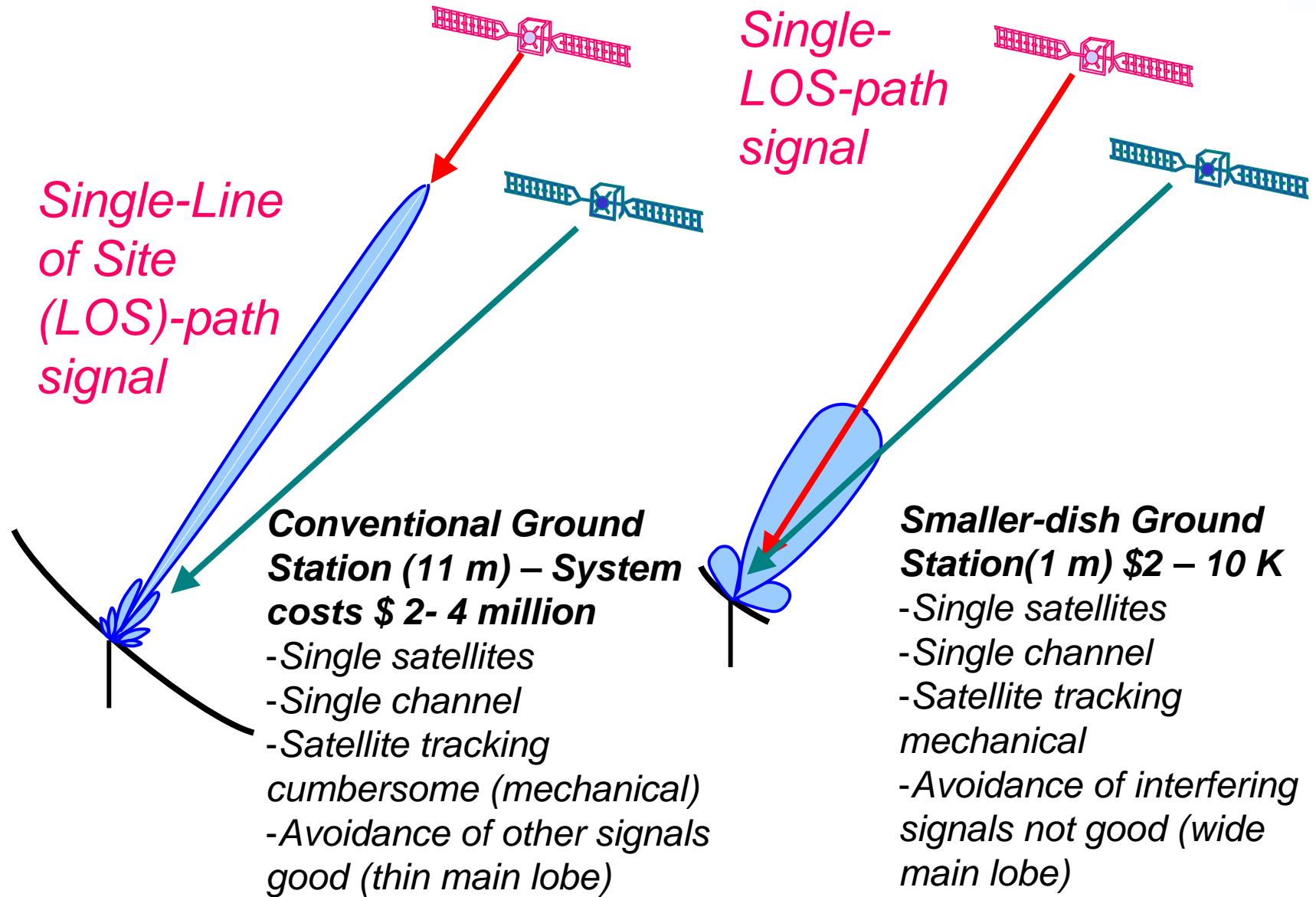
Ground SW Bus

Benefits of Smart Antennas

- ◆ **Smart antennas can shape antenna patterns to null interference and boost desired signals**

  - – *Traditional antenna systems cannot isolate source signals from complex interference environments which include other users/satellites within same system, other signal sources and multipath (source signal bouncing off of things such as buildings to create self-interference)*

- ◆ **Smart antennas can increase the agility of an antenna system thereby tracking moving signals more efficiently than mechanical systems**

- ◆ **Smart antennas will enable more efficient use of the energy spectrum by allowing several users to share the same frequency channel**

  - – *Spatial Division Multiple Access (SDMA) enables the ground system to separate signals that otherwise interfere*

  - – *Enables use of commercial much less expensive components*

- ◆ **Instantaneously able to handle multiple scenarios since electronically reconfigurable**

- ◆ **Increases reliability due to no or minimal moving parts**

- ◆ **Can dramatically lower antenna system costs**

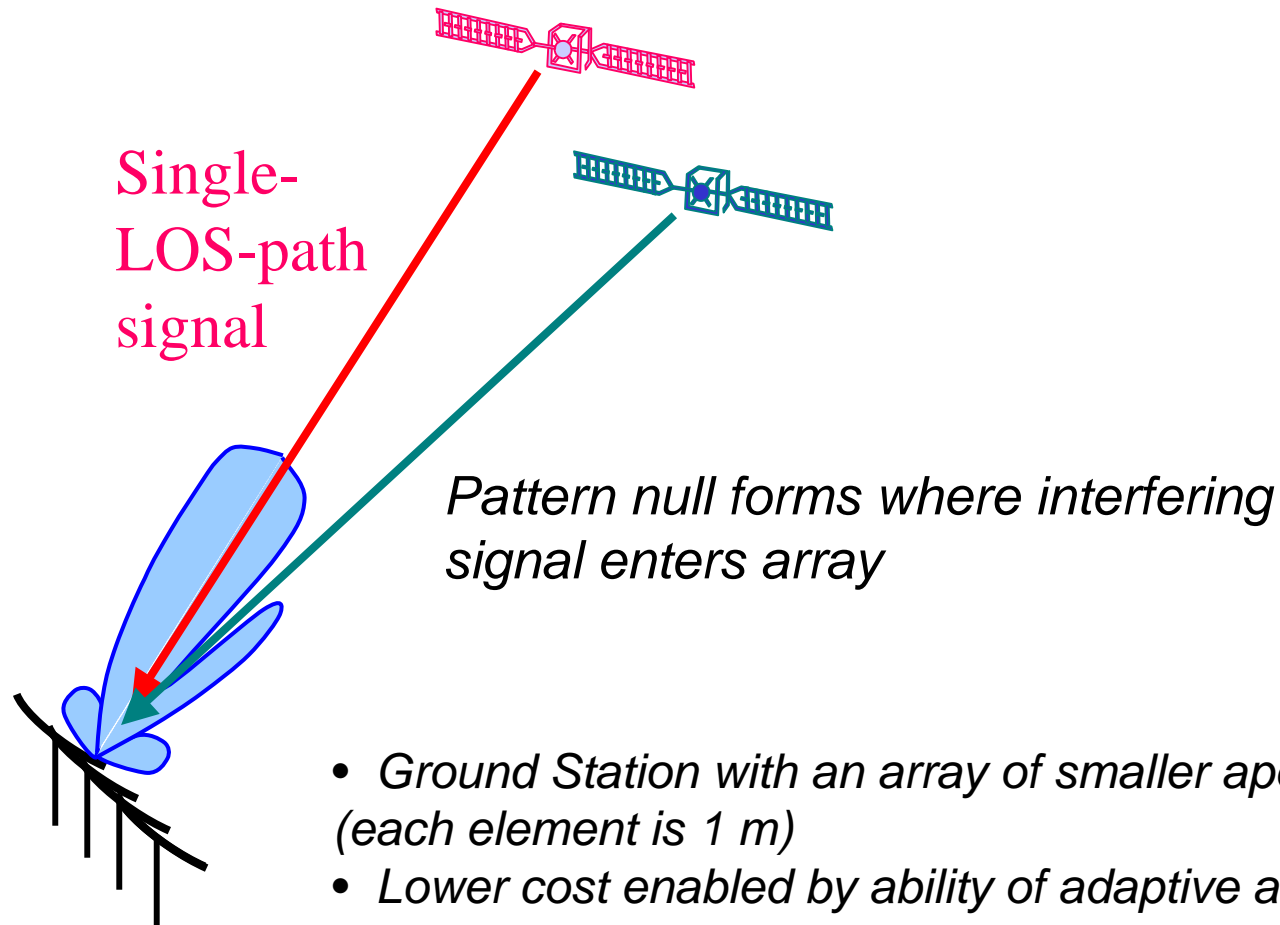# Differences Between Smart Antennas and Traditional Systems

- **Traditional parabolic antennas used for satellites are mechanically steered to track satellite**

    - *Antenna pattern is constant*

    - *Steering performed mechanically*

- **Phased array antennas steer their antenna pattern electronically**

    - *Antenna pattern constant*

    - *One variable (pointing direction) varied to steer the antenna pattern to track satellite*

- **Smart antennas steer the antenna pattern electronically and change the shape of the antenna pattern electronically up to thousands of times per second**

    - *Antenna pattern varies many times per second to self optimize*

    - *Multiple variables (one per element) varied to steer the antenna pattern to track the satellite and vary the antenna pattern to enhance the desired signal and minimize interference.*
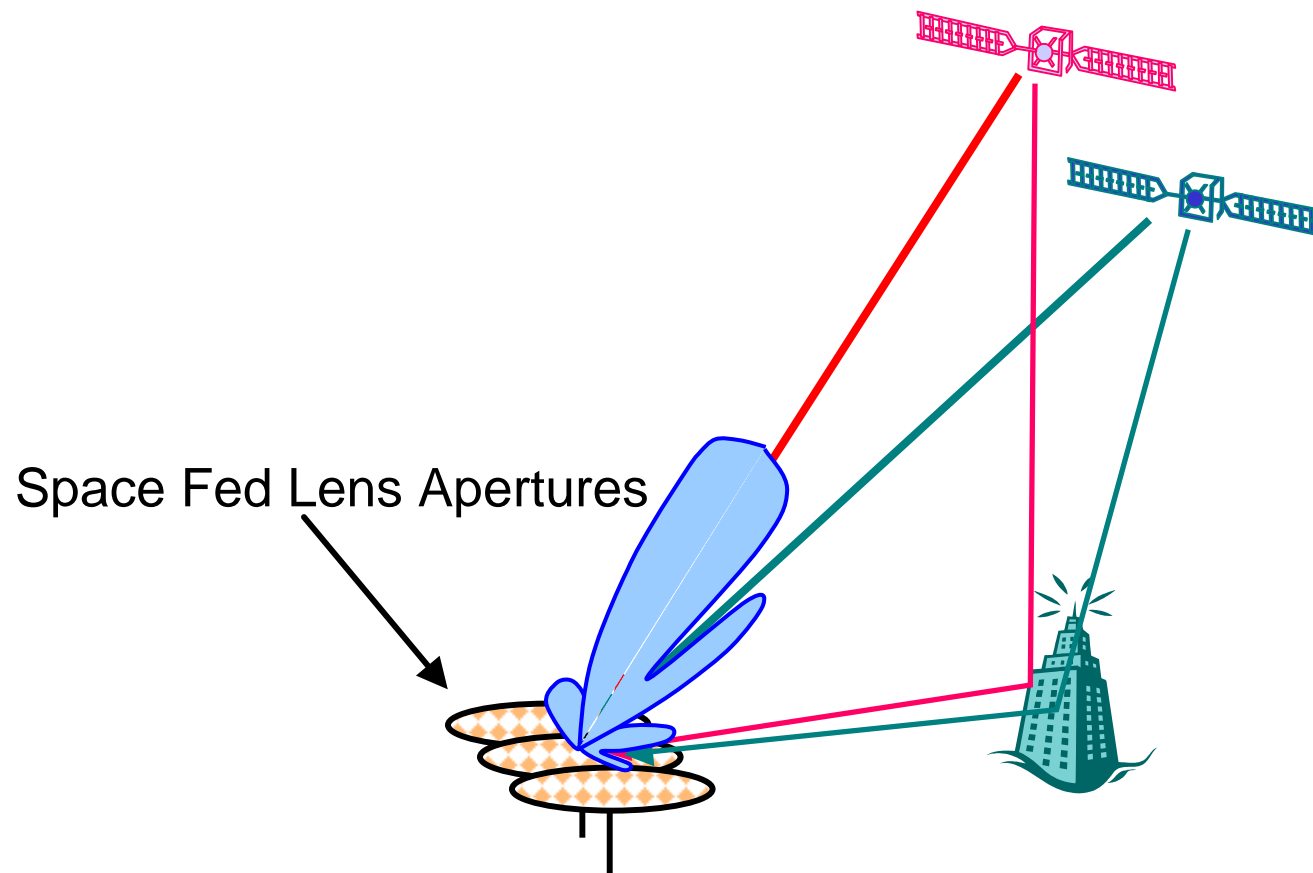
Non-Adaptive Antennas

Single-Line of Site (LOS)-path signal

Single-LOS-path signal

Conventional Ground Station (11 m) – System costs $ 2- 4 million
-Single satellites
-Single channel
-Satellite tracking cumbersome (mechanical)
-Avoidance of other signals good (thin main lobe)

Smaller-dish Ground Station(1 m) $2 – 10 K
-Single satellites
-Single channel
-Satellite tracking mechanical
-Avoidance of interfering signals not good (wide main lobe)

Adapted Pattern for One Co-channel Interferer

Single-LOS-path signal

Pattern null forms where interfering signal enters array

- Ground Station with an array of smaller apertures (each element is 1 m)
- Lower cost enabled by ability of adaptive algorithm to use low cost components and reshape antenna pattern.
- Each aperture is a phased array antenna

Adapted Pattern With Interference and Multipath

Space Fed Lens Apertures

- Ground Station with an array of smaller apertures (each element is 1 m) shapes antenna pattern to null multipath

Multi-satellite Reception With Adaptive Antenna

• Ground Station with an array of smaller apertures (each element is 1 m) can use adaptive combiner to shape the antenna pattern such that for each data stream, the other satellites signal is nulled allowing the processor to extract multiple data streams from the same antenna system

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Adaptive Processor

Research Approach
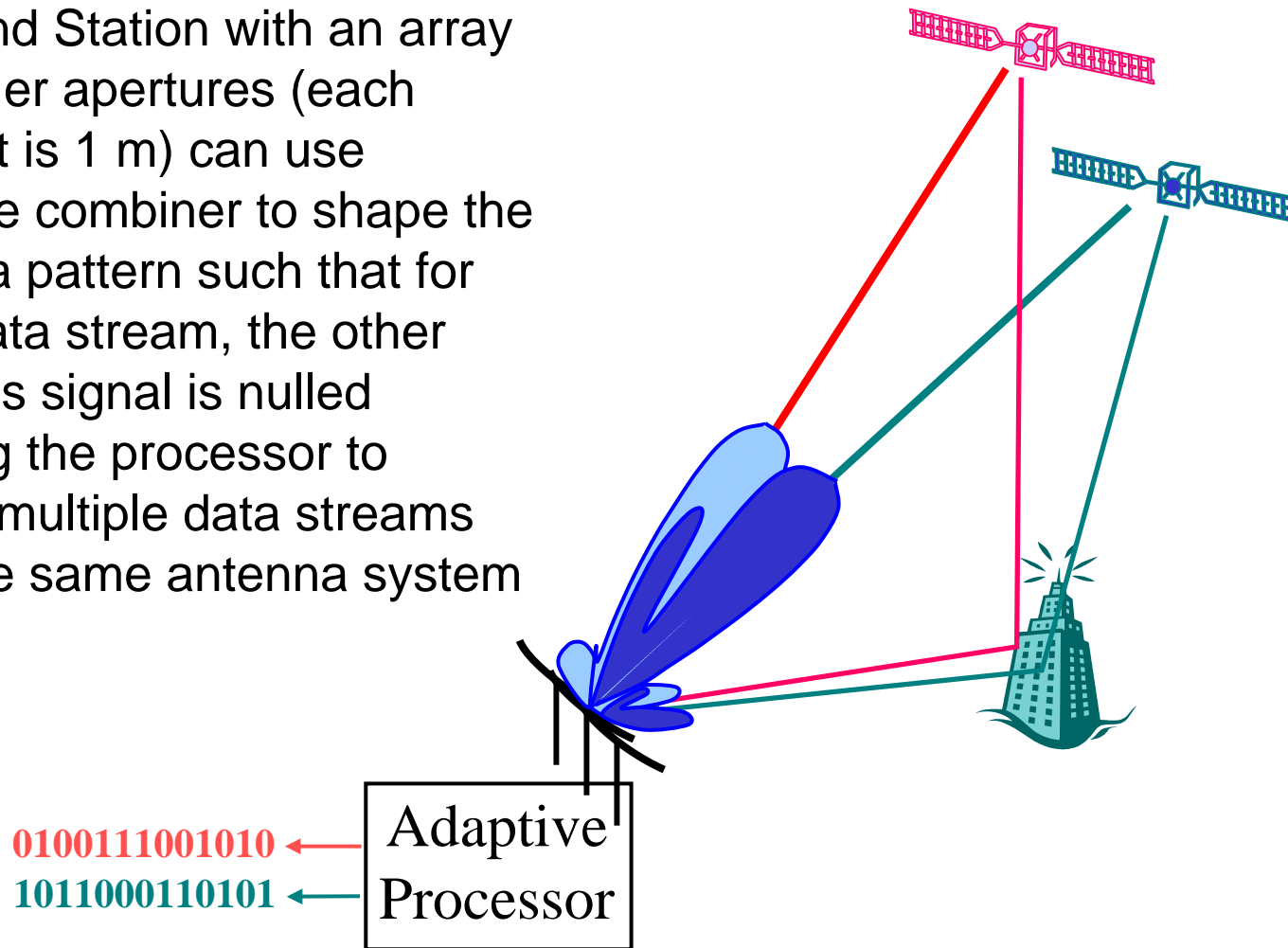
- **Approach**

  – **Explore three technologies**

    – Adaptive beamforming using Digital Signal Processing (DSP) as backend

    – Space Fed Lens front end elements

    – Reflectarrays as front end elements

  – **Manipulate following parameters to minimize cost: aperture size, number of apertures, aperture efficiency and selection of beam forming algorithm**

First prototype experiment July 2003 at Georgia Tech

Field of view of the array (approx 45 degrees)

◆ ***Card cage holds APCOM receivers, A-to-D converters, and digital down-converters***

RF Front Ends

| RFFE | RFFE | RFFE | RFFE |

| APCOM Receiver | APCOM Receiver | APCOM Receiver | APCOM Receiver |

| A/D | A/D | A/D | A/D |

| Digital Receiver | Digital Receiver | Digital Receiver | Digital Receiver |

| FPDP Interface Board | FPDP Interface Board | FPDP Interface Board | FPDP Interface Board |

| Memory Buffer | Memory Buffer | Memory Buffer | Memory Buffer |

Card cage
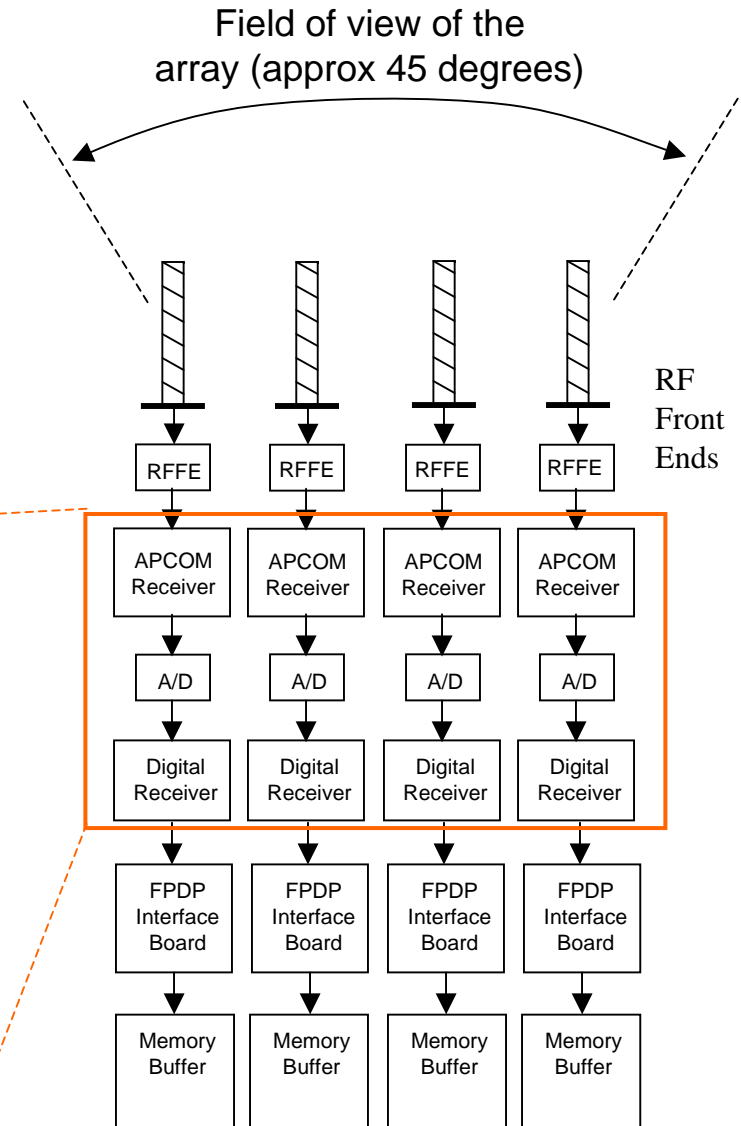
Space Fed Lens Element Being Developed at Glenn Research Center

θ

feed side   radiating side

optical axis   z

FEEDS

α

FOCAL ARC
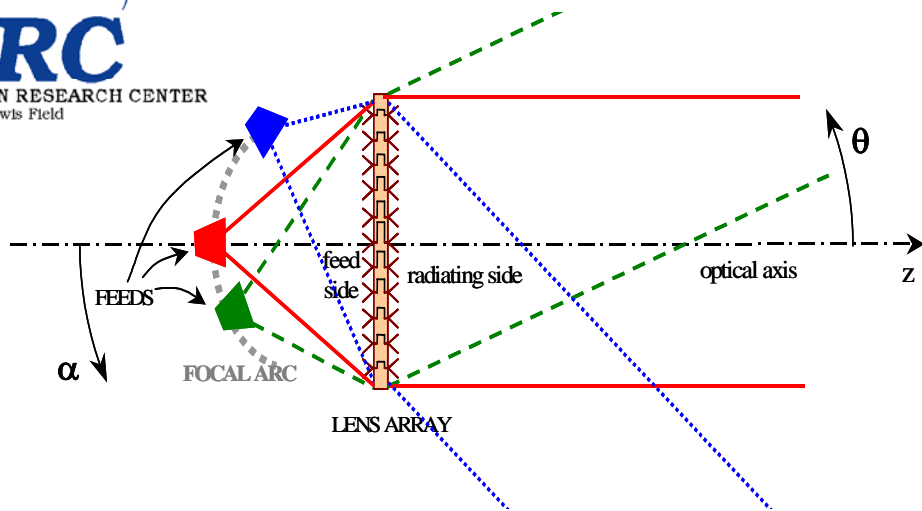
LENS ARRAY
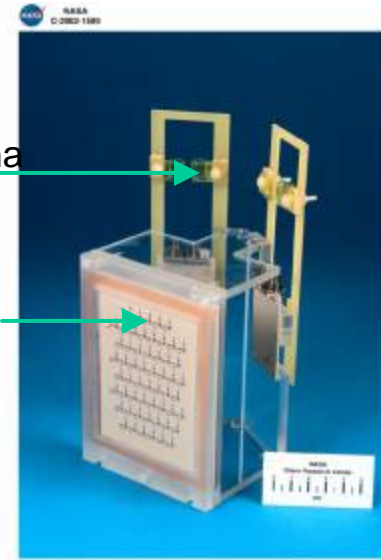
Feed antenna

Lens

Ka-band dual-beam space-fed lens array

Lens array

Feed antenna

Rotating stage

Test setup

26.7 GHz

θ

Measured patterns

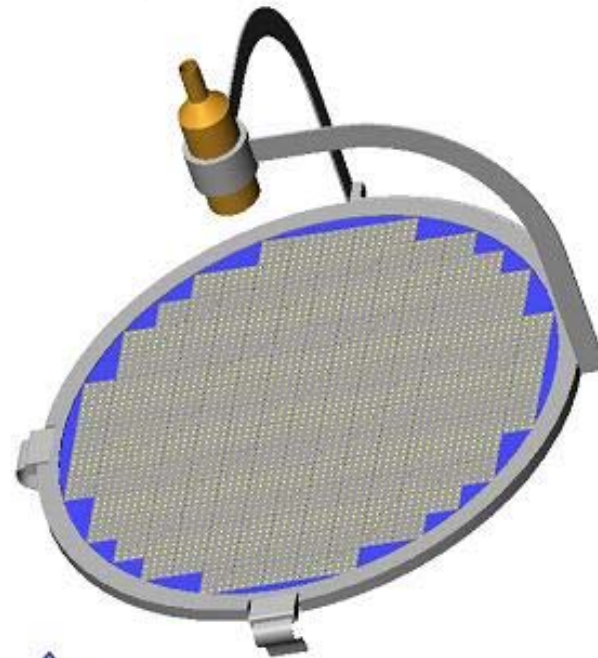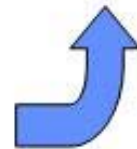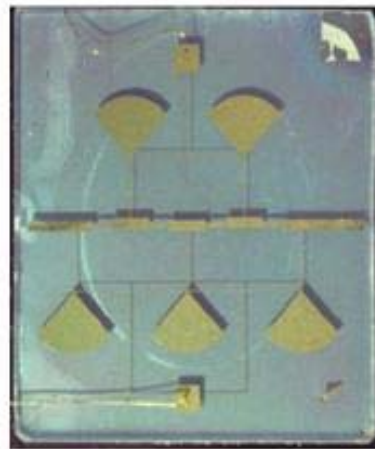## Ground Hybrid Phased Array

Ferroelectric Reflectarray Antenna
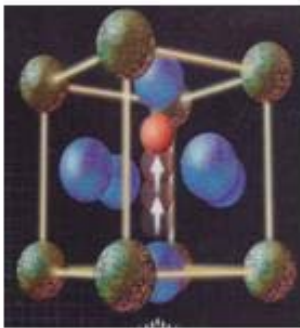
$Ba_xSr_{1-x}TiO_3$ Crystal

Thin Film Phase Shifter

~500 Element Reflectarray

Principle Investigator: R. Romanofsky

Conclusion

◆ *Continuous coverage for low earth orbiting satellites will change the future mission paradigm*

◆ *Adaptive phased array antennas (Smart Antennas) will provide basic building blocks for future flexible cost-effective wireless networks for satellites and continuous coverage*

  – *Same technology being investigated and used for cell and Wi-Fi industry*

  – *Traditional antenna systems cannot isolate source signals from complex interference environments, which include other users/satellites within same system, other signal sources and multipath (source signal bouncing off of things such as buildings to create self-interference)*

◆ *In future, large diverse set of satellites on-orbit will increase complexity of signal transmissions from satellites thus continuing to increase interference*

  – *Drives need for more sophisticated management of signal spectrum that can be provided by smart antennas*