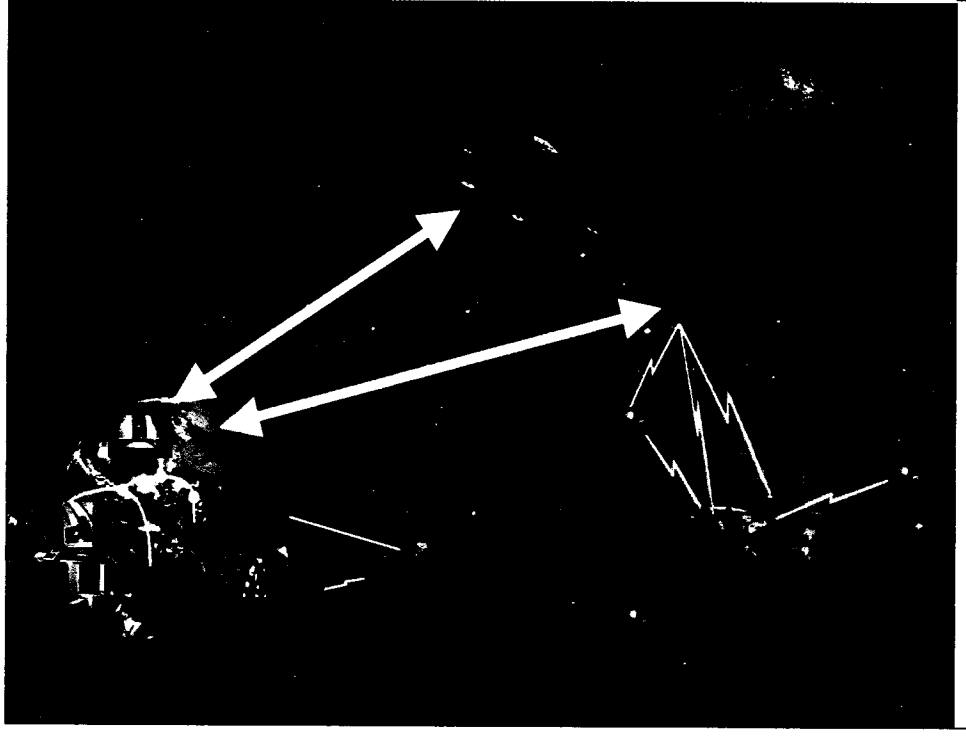
JPL

NASA

A View of the Future of NASA's Deep Space Network and Associated Systems



Bill Weber

October 10, 2002

Space Ops 2002

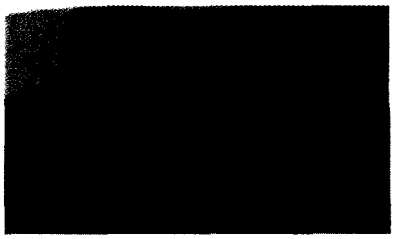
Outline

- **Current Obstacles & Challenges**
- **Vision & Goals**
- **Existing Systems & Near-Term Investments**
  - DSN Extensions
  - Flight Systems
- **Optical Communications**
- **Arraying for Large Aperture Synthesis**
- **Planetary Area Networks (Mars Network)**
- **Role of Standards & Protocols in Networking**
- **Precision Navigation**
- **Public Involvement**
- **Reaping the Rewards**

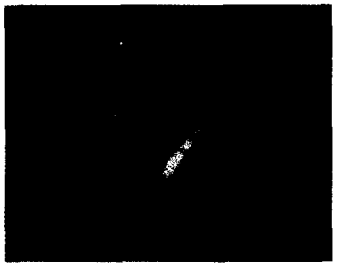
Note: Recommendations and proposed initiatives presented herein are pending Agency approval

Space Ops 2002

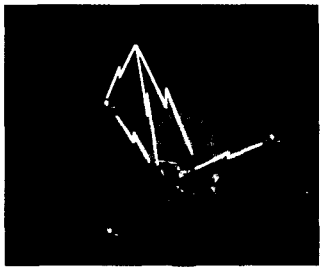
Overcoming Today's Obstacles and Bottlenecks, Increasing Mission Value



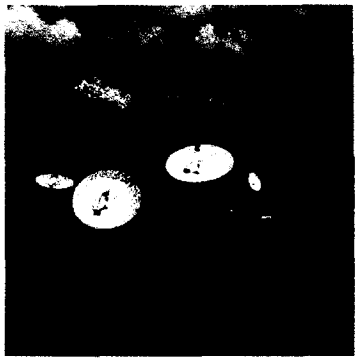
Little or no communications during many critical events



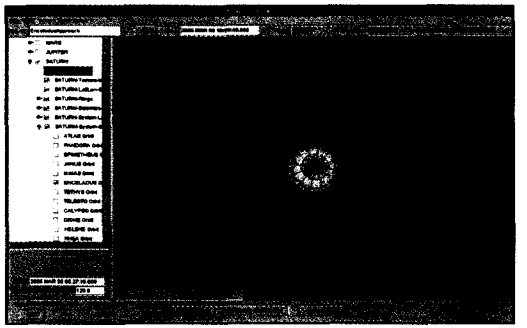
Very low data rates from planets: Mars orbiters image about 1% of planet at high resolution; can't use many high-rate science instruments *



Mars science orbiters can provide only limited relay communications for surface vehicles



Deep Space Network congestion, like '03/'04, compromise science return and add risk to all missions



Deep space mission operations is arduous and expensive

Scientists spend more time on operations than science; public participation is a fraction of what it could be

More Challenges: NASA's Deep Space Problems are Unique and Difficult

- **Extreme Distance**
  - Communications performance scales as $1/R^2$
  - Communicating at Neptune (30 AU) is ~*10 billion* times harder than at a commercial GEO satellite distance
  - **(The received energy from Voyager at Neptune, if integrated for 300 million years, would be just enough to set off a small photographic flashbulb!)**
- **Long Round Trip Light Times**
  - Over 8 hours round trip light time at Neptune -- No "joy-sticking" possible
- **Unique Navigation Scenarios**
  - Small body ops, gravity assist trajectories, aerocapture/aerobraking, electric propulsion, Lagrange point missions, formation flying
- **High Launch/Delivery Cost per Unit Payload Mass**
  - Drives need for low mass, low power flight systems

NASA

Goals

- **An integrated deep space communications network with mission operations and user applications**
  - No "bottlenecks and obstacles"
  - Breakthrough communication rates on interplanetary links
  - Efficient, miniature short-range and in situ communications systems
  - Seamless end-to-end information flow across the solar system
  - Layered architecture and protocols for evolvability and interoperability
  - Integrated communications, navigation, and operations services
  - User software tools for analysis and visualization

Major Elements Start with Existing Systems

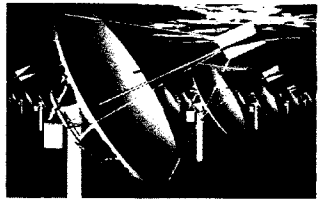
- **An integrated deep space communications network**
  - NASA's Deep Space Network and other earth-based assets
  - Mars Network and other space-to-space communications links and networks
  - Unifying network architecture, operations, standards, and protocols
- **Mission operations applications and infrastructure**
  - Applications using the communications network for efficient mission operations and information transfer
  - Highly automated and transparent mission and network operations (invisible to the end-user)
- **End-user applications**
  - "Killer applications" for scientists and the public to take full advantage of the investments in each mission
    - Creation of "virtual observatories"

Space Ops 2002

Major Network Investments (< FY10)

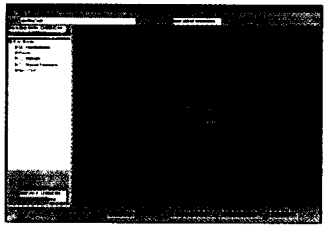
- **Upgrade the current Deep Space Network**
  - Antenna refurb., 1 new antenna, Ka-band, automation
  - Advanced spacecraft radios, amplifiers, and antennas

- **Demonstrate deep space optical communications**
  - Work with synergistic DoD efforts
  - Space station demo, followed by deep space demo



- **Prototype large arrays of small (10m) antennas**
  - Build equivalent of one 70 meter antenna
  - Understand technology, costing, operations, extensions
  - Use prototype as operational DSN element

- **Expand Mars network with comsats about Mars**
  - H/W & S/W for relay, store/forward, micro-com
  - Dedicated orbiters, followed by one or more stationary orbiter(s)



- **Develop new mission and network operations tools and user tools**
  - Automation tools for operations
  - Applications for science and the public

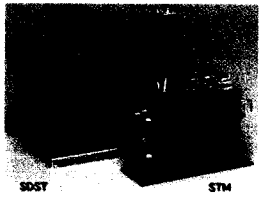
Extending the DSN

- DSN Enhancements
  - 70m life extension
  - Ka-band completion
  - Beam Wave Guide "completion" (1-3 BWGs)
  - High rate uplink
  - High rate downlink (turbo decoders, etc.)
  - Multiple spacecraft per antenna
  - Alternate assets; standards for interoperability
  - Automation; self-monitor and control
  - High capacity ground distribution

Space Ops 2002

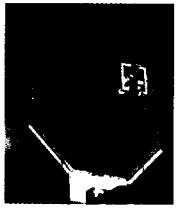
Spacecraft Communications Technologies

Example Radios

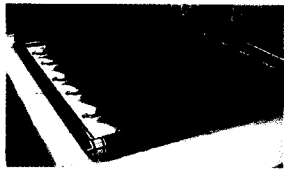


- *Small Deep Space Transponder (SDST) exists today*
- *Space Transponding Modem (STM) by FY'07*

Example Antennas



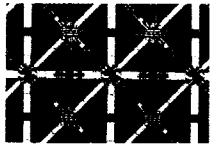
- *3m X/Ka-Band Inflatable Lens Antenna by FY'10*



- *3.5m X/Ka-Band Reflect-Array Membrane design by FY'08*
- *5-7m design by FY'12*

Example Amplifiers

- *35W Ka-band TWTA enables 4x improvement over X-band by FY'03*
- *100W X-band TWTA by FY'04*
- *100W Ka TWTA by FY'07*
- *High power amp by FY'09*



- *Grid amplifier by FY'11*

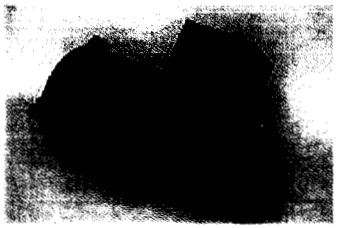
Potential performance improvements from these components:

- ~25x from antenna developments
- ~5x from Ka-band power amplifiers

Space Ops 2002

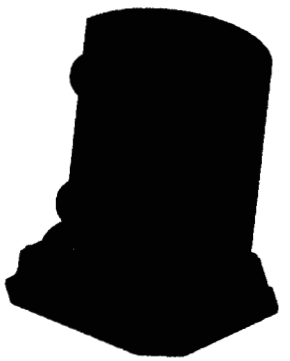
Optical Communications

- Potential for orders of magnitude greater downlink performance
- Initial technology and demonstration steps have been taken
- Need for deep space operational demonstrations
  - Space Station-to-earth first; then deep space
- Strong collaborations and synergy with DoD space communications efforts
- Synergism with Code Y and near-Earth, high-rate applications



Optical Comm Demonstrator
- 10 cm telescope
- Fiber-coupled laser

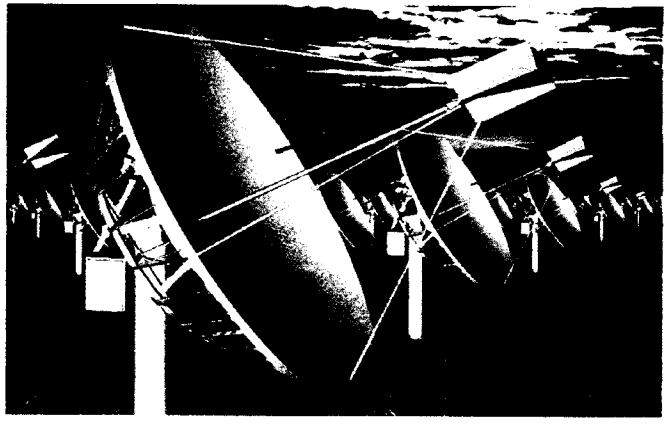
1-m OCTL Facility (under construction)

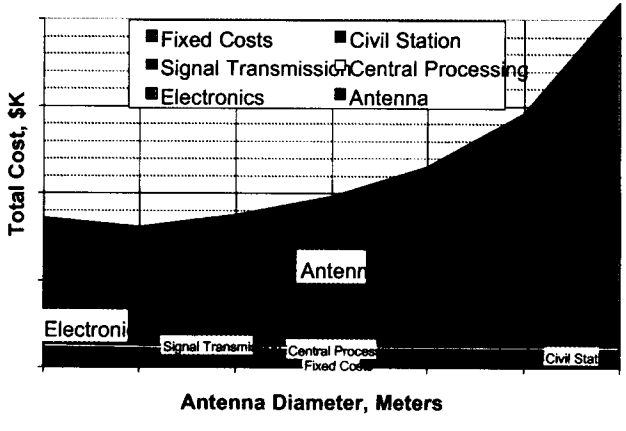


30-cm Optical Comm Terminal with Hi-Res. Imaging and Laser Altimeter

Space Ops 2002

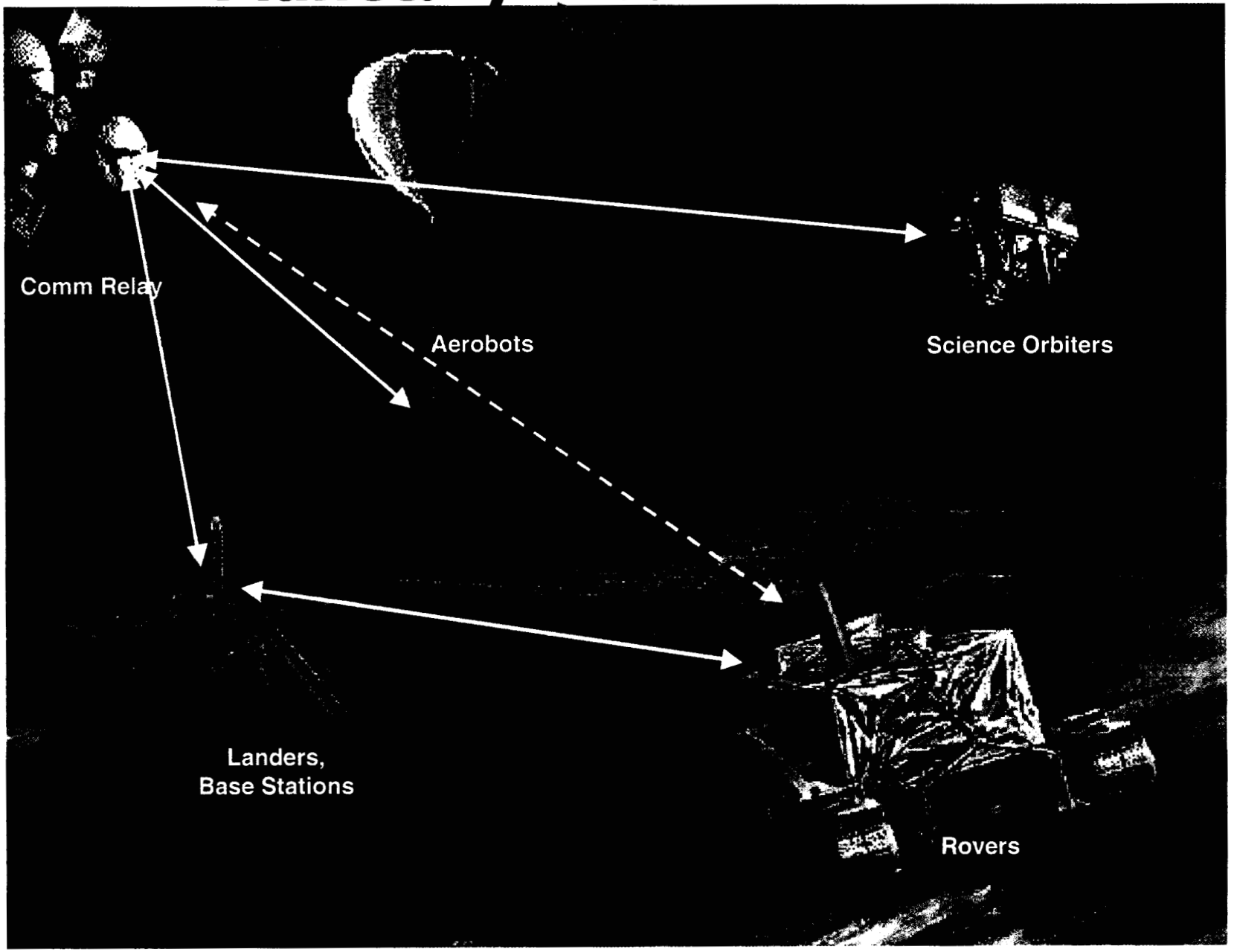
Arraying Technology -- Synthesizing Large Antenna Apertures



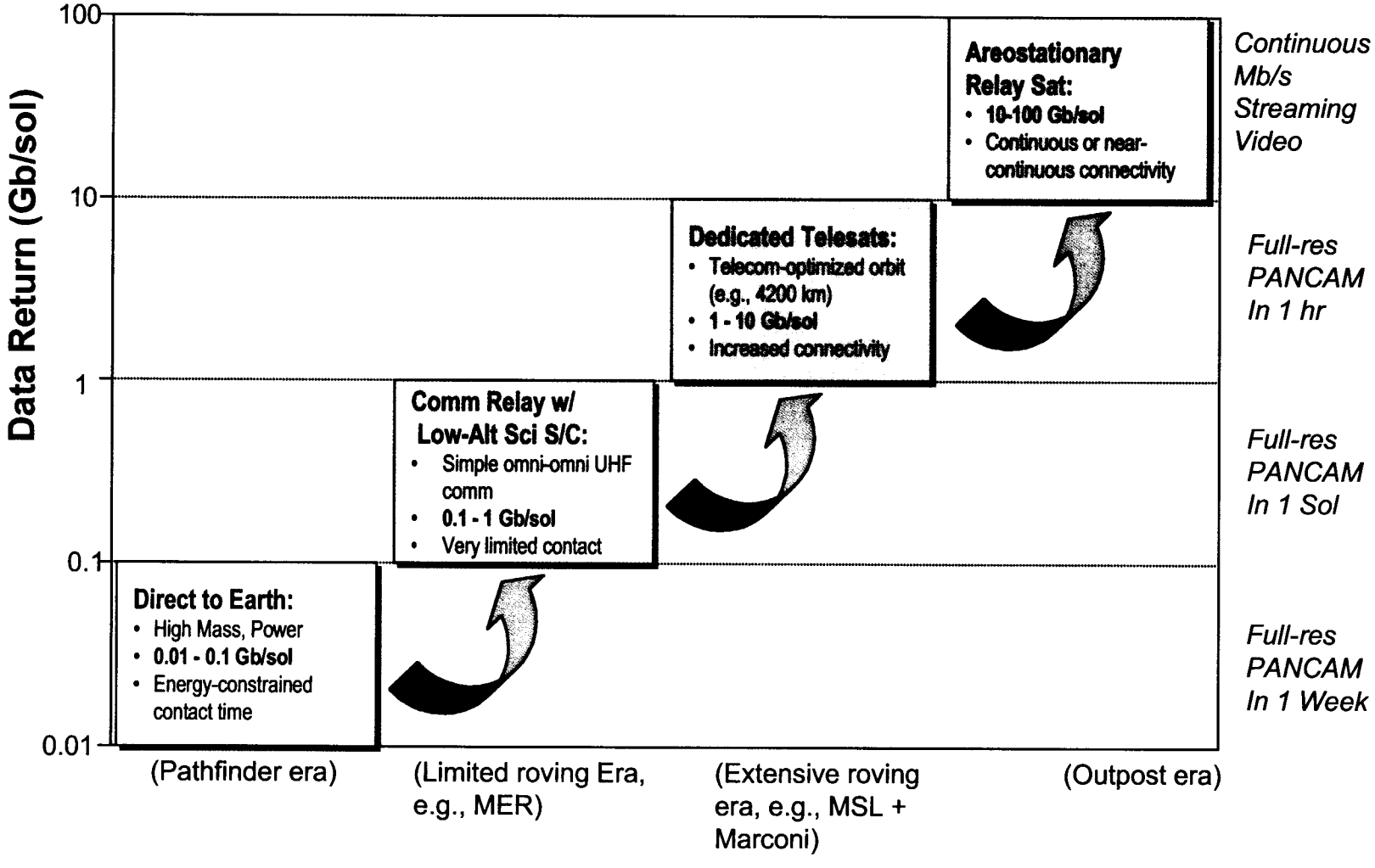


- A new paradigm for microwave, large-aperture synthesis
  - Arrays of 100's of 10 meter antennas
- Requirements:
  - Low cost, high performance antennas
  - Low cost, low noise amplifiers
  - Low cost, reliable, cryogenics
  - Mass production efficiencies
- Need for a prototype array to demonstrate technologies, costs, and operational characteristics
- **Potential order of magnitude lower cost than current large microwave antennas**

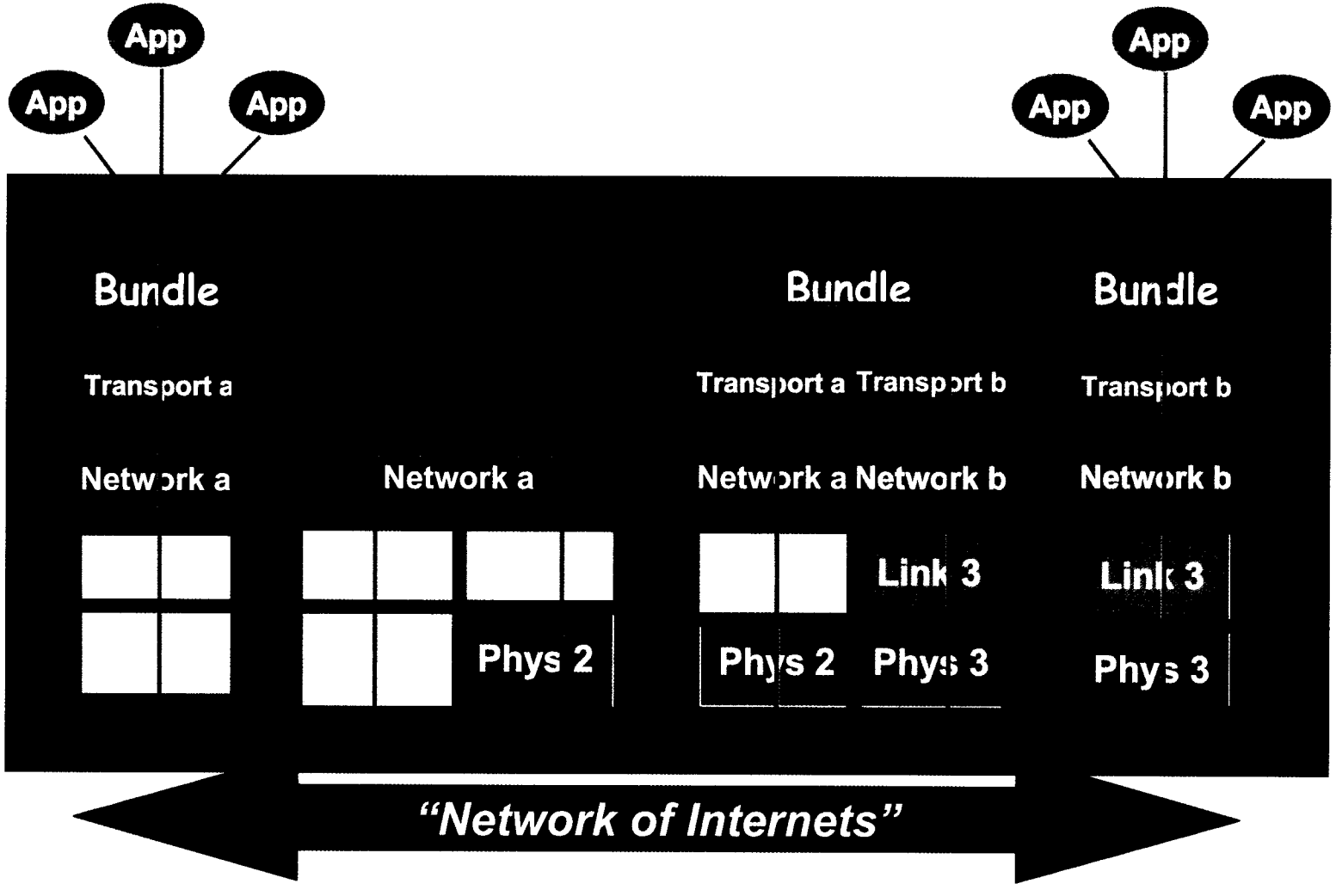
Mars Network: A Prototype for "Planetary Area Networks"



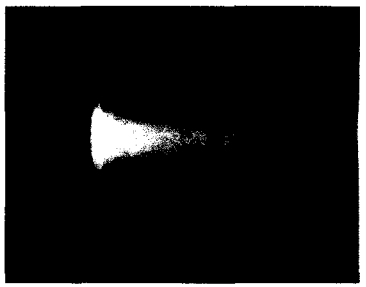
Evolution of Mars Telecommunications Capability



Networking Concepts and Protocols



Enabling Precision Navigation



Low-Thrust Guidance & Navigation

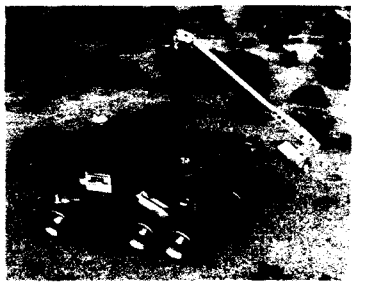
Mercury, small body, and outer planet missions

Aerocapture

Missions going into orbit about Venus, Mars, Saturn/Titan, Uranus, Neptune

Precision Landing

Landing on small bodies, terrestrial bodies, or planetary satellites



***In-Situ* Vehicle GN&C**

Rovers, balloons, submarines, and aircraft on planets, satellites, and small bodies

Rendezvous & Docking

Sample return missions to terrestrial planets, small bodies, and planetary satellites

Flight in Irregular or Multi-Body Gravitational Environments

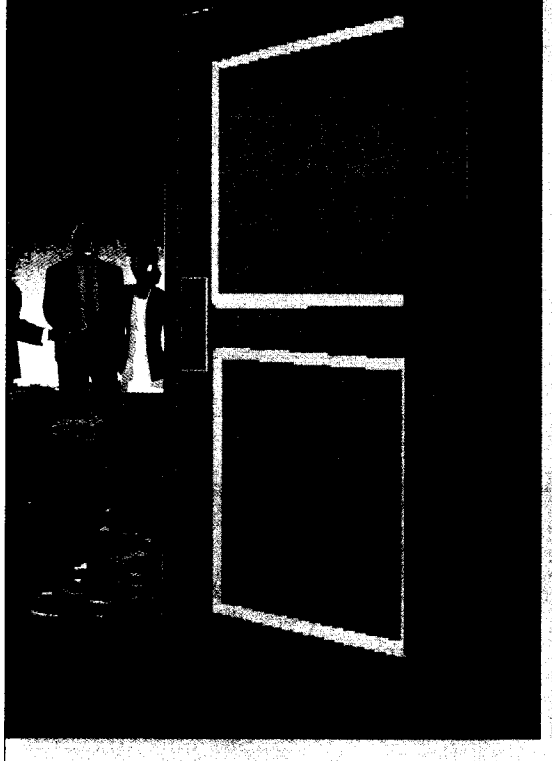
Small body and libration point missions

Multi-Vehicle GN&C

Terrestrial Planet Finder, constellations, etc.

An opportunity for Commercial and University Partnering to Develop Applications

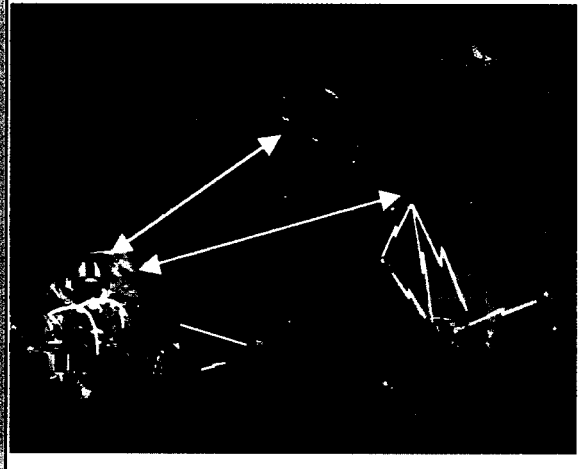
Gateway to Exploration
For Education and the Public



- Virtual reality
- Publicly accessible databases
- Games
- Amateur astronomy via the Internet
- Teaching aids; learning programs

Space Ops 2002

Return on Investment



- **More science for the scientist**
  - 100 times or greater increase in science data
  - Huge increase in science return for every mission's investment
- **Safer, cheaper, and more capable space science missions**
  - Continuous, ubiquitous, and reliable communications for all mission events
  - Precision navigation
  - Multi-mission, "plug and play" H/W and S/W components
  - Standard, automated mission operations tools
- **Telescience, telepresence, and a real sense of participation by the public**
  - Applications to enable scientists to do science more easily
  - Applications for exploration and discovery by the public -- virtual observatories

Enabling NASA's Mission