A Cost-Effective Array-based DSN (DSAN)

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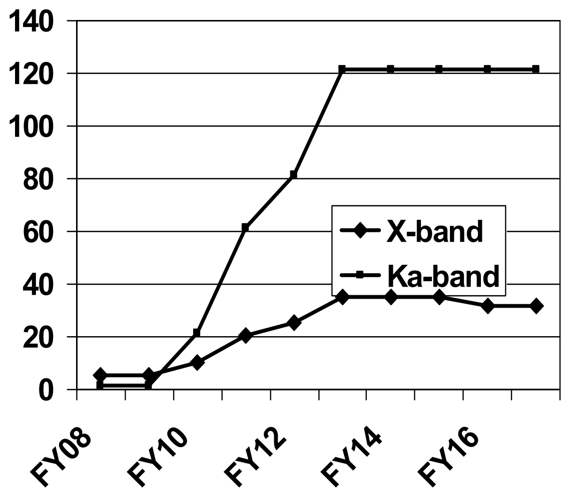
(with contributions from B. Geldzahler, L. Deutsch, and R. Preston)

7/29/2004

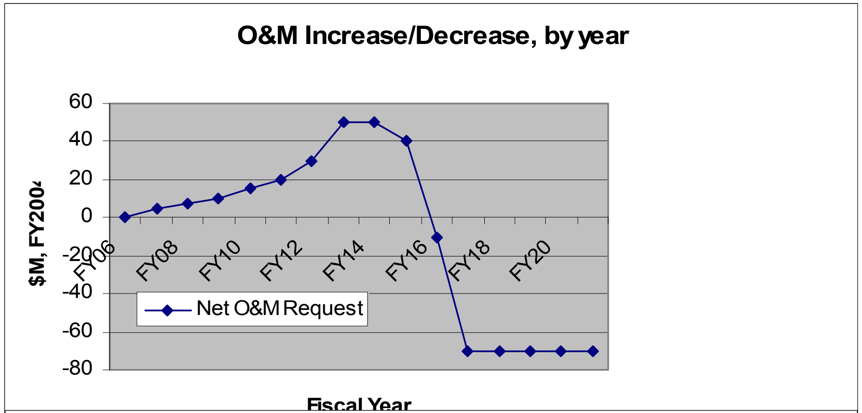
WHY DSAN?

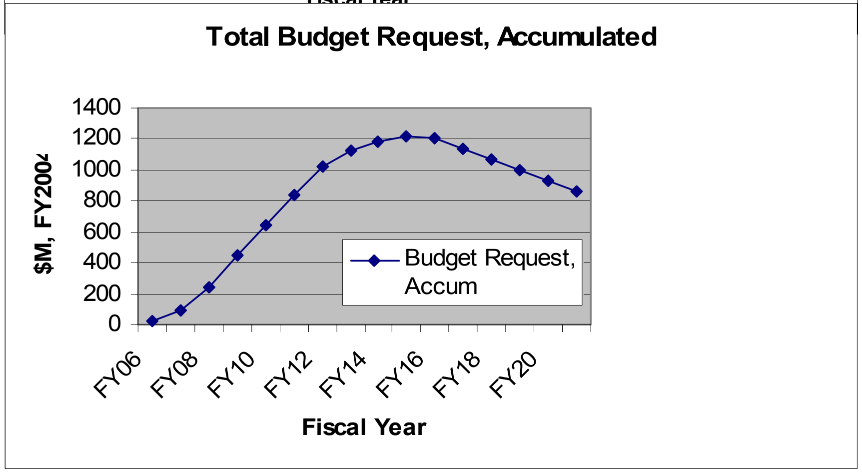
More Capacity!



This chart shows the equivalent G/T, in units of 70-m X-band G/T.

More Cost-Efficient!





The Concept of Operations will facilitate efficiency, primarily by reducing O&M cost (numbers are preliminary, PCAT study is underway)

The BIG Picture: A Combined Optical/RF Strategy

<u>The Challenge</u>: **Capabilities are needed in deep space communication that will accommodate orders-of-magnitude increase in science data and at least a doubling of the number of supported spacecraft over the next 30 years**

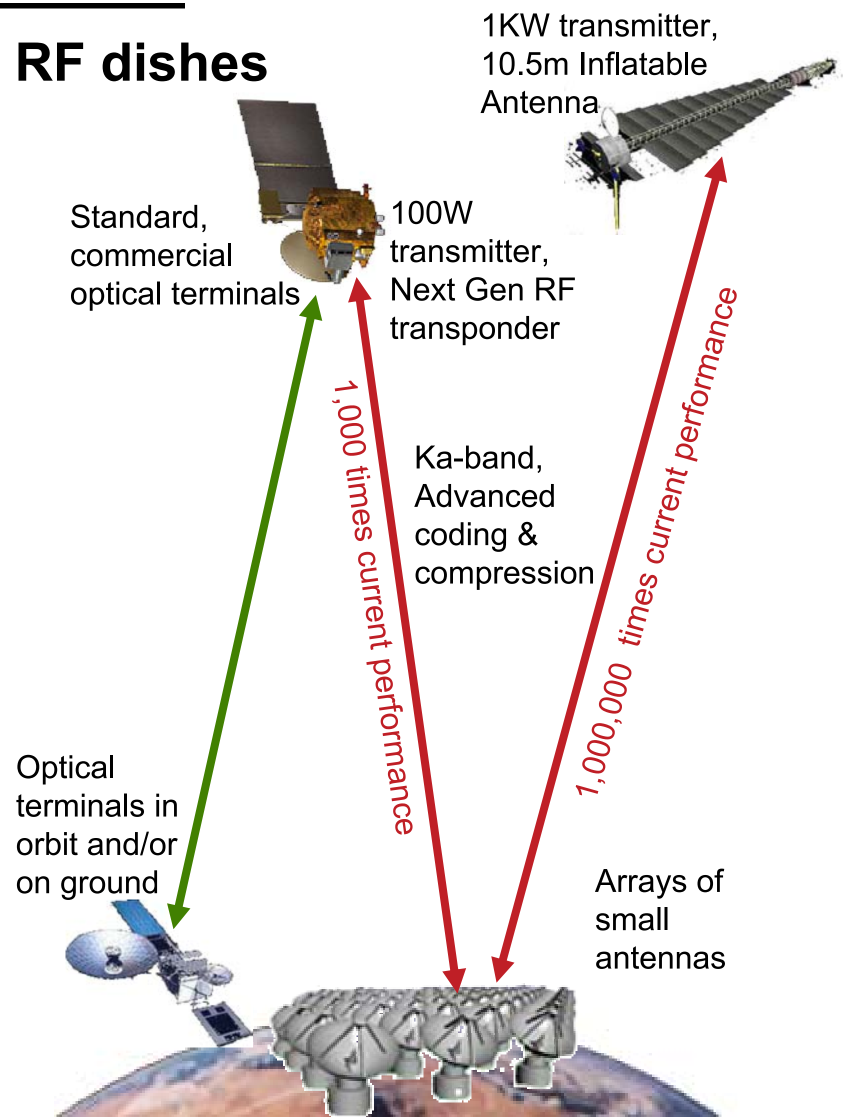
- The present DSN architecture is not extensible to meet future needs in a reliable and cost-effective manner
- Optical communication, which will take at least another decade to mature and two to be operational, has development risk and may not be appropriate for all missions or mission phases
- NASA must develop a comprehensive strategy for deep space communications that meets the forthcoming dramatic increase in mission needs in a reliable and cost effective manner

The BIG Picture: A Combined Optical/RF Strategy (cont.)

Proposed Solution for the Next Generation DSN:

Optical links plus arrays of small RF dishes

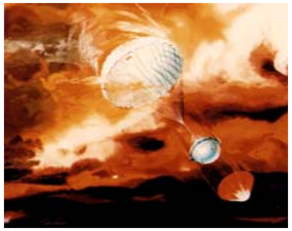
- This is a true end-to-end solution
- Optical and radio array links would be complementary: Optical links could handle high-rate communications from telecommunications orbiters and special missions, while the radio array links would benefit all missions large and small, new and old, as well as reducing mission risk by providing communications redundancy
- Radio arrays will be very reliable while the implementation cost will be relatively small compared to expansion of the current DSN architecture
  - Costs will be recovered over time through reduction of DSN operations and maintenance costs
  - Technology is mature and low-risk



Why is Change Needed?

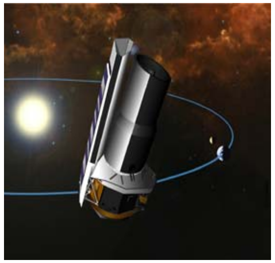
- MRO will only map about 1% of Mars surface – limited by communications
  - Selection of “prime sites” to observe is the worst kind of data compression because it introduces biases
- Future planetary missions will be more like Earth science missions

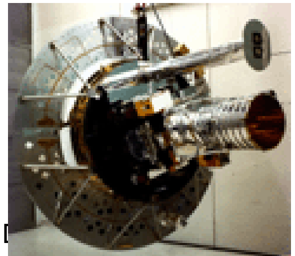
Preliminary solar system reconnaissance via brief flybys. → Detailed Orbital Remote Sensing. (e.g., MRO, JIMO)



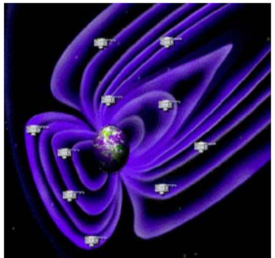
In situ exploration via short-lived probes. → *In situ* exploration via long-lived mobile elements. (e.g., MER, MSL)

Low-Earth-orbit solar and astrophysical observatories. → Observatories located farther from Earth. (e.g., SIRTF, JWST)



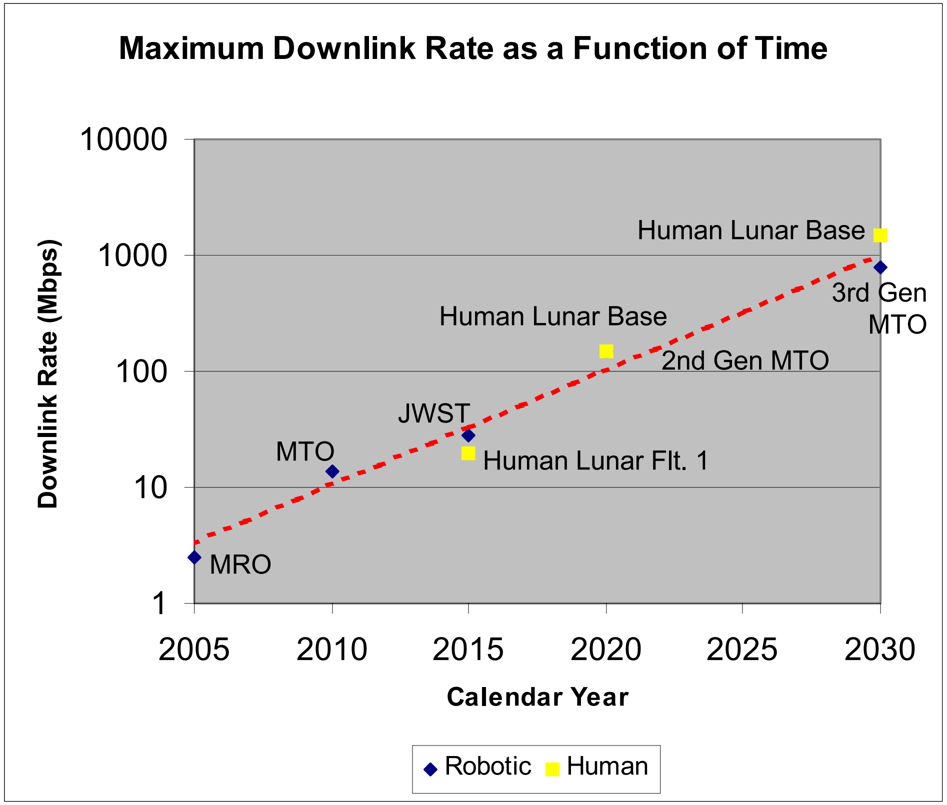


Single, large spacecraft for solar and astrophysical observations. → Constellations of small, low-cost spacecraft. (e.g., MMS, MagCon)

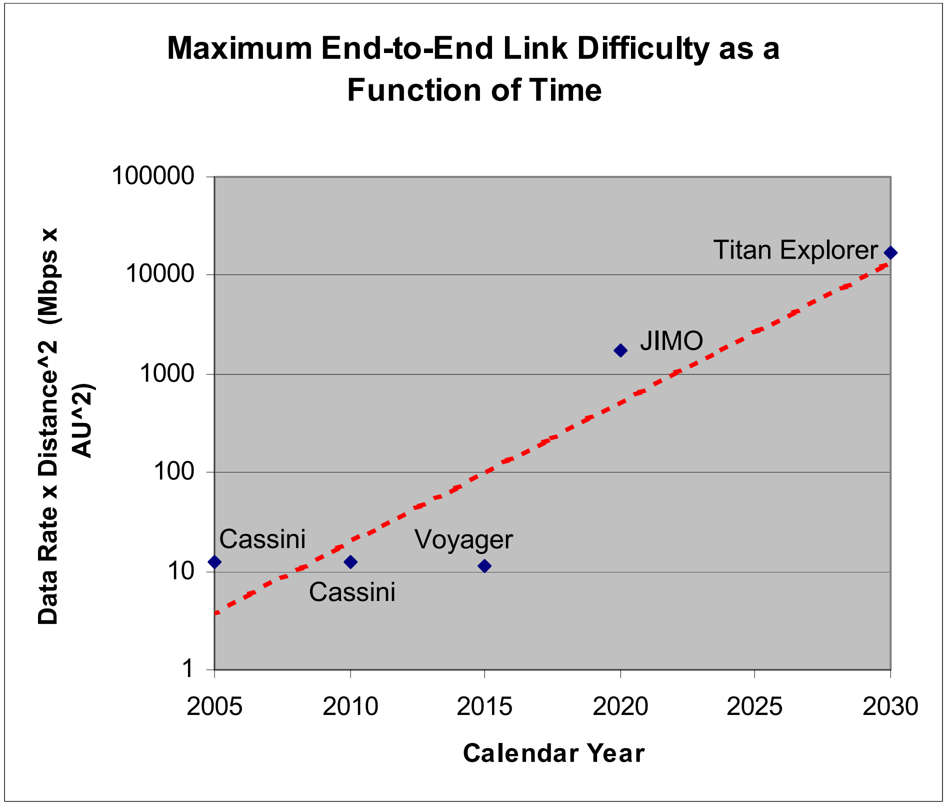


Predicted Growth in Deep Space Mission Downlink Requirements (2005-2030)

Data Throughput



Link Difficulty



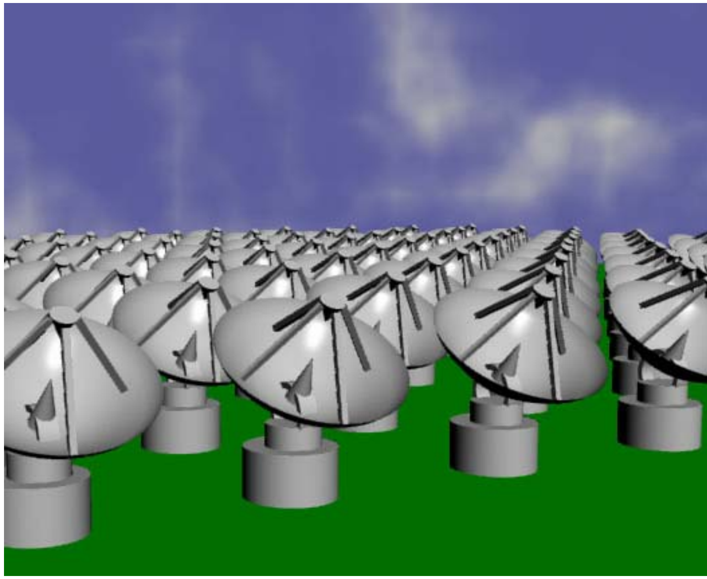
- Mars robotic and lunar human missions drive maximum data rates up by almost 3 orders of magnitude over next 25 years – probably an underestimate.
- Robotic missions to Jupiter and Saturn drive up difficulty of attempted link by a over 3 orders of magnitude over next 25 years – probably an underestimate.

The Next Generation RF DSN: Arrays of Small Antennas

- The current architecture using large antennas is not sufficient for NASA's future
  - Will not meet the needs of NASA future mission set (sensitivity and navigation)
  - Is expensive to maintain and operate
- A new approach is needed: Arrays of small antennas

Reliable:

– Provides graceful degradation in performance in case of antenna or receiver failures – less single-point-of-failure



Science Data Return:

– Meets the science data rate requirements of most future missions
  - Code S is investing in more capable science instruments to enhance high-power missions

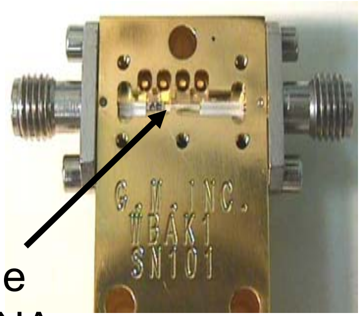
– The architecture is easily scalable when growth is required

– Accommodates significant growth in the number of s/c since an array could service several missions simultaneously, each with just the required aperture

Cost Effective

– Substantially reduces operations and maintenance costs: Plug-and-play components with longer lifetimes

Array Technology



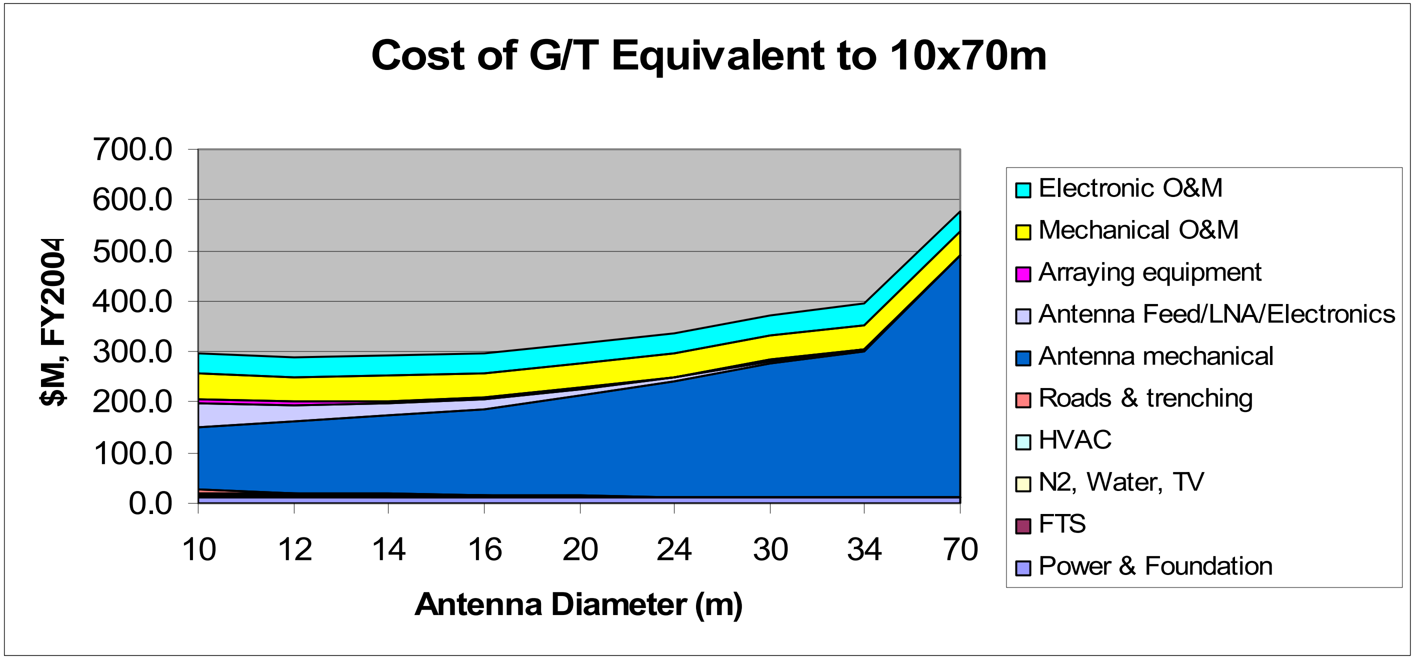
Single chip LNA

Advances in the following areas are making <u>much larger</u> arrays feasible

- Low cost, high performance, parabolic antennas
  - Fueled by the home satellite TV industry
- Low cost, low noise, wide bandwidth RF amplifiers
  - Breakthroughs in MIC/MMIC technologies
- Low cost, reliable, cryogenics
  - Developed for the next generation of computers and communications
- Long-distance, wide-bandwidth data transmission
  - Huge investments in fiber optics by telecom industry and DoD
- Faster, less expensive computers for automation and operations
  - Moore's law

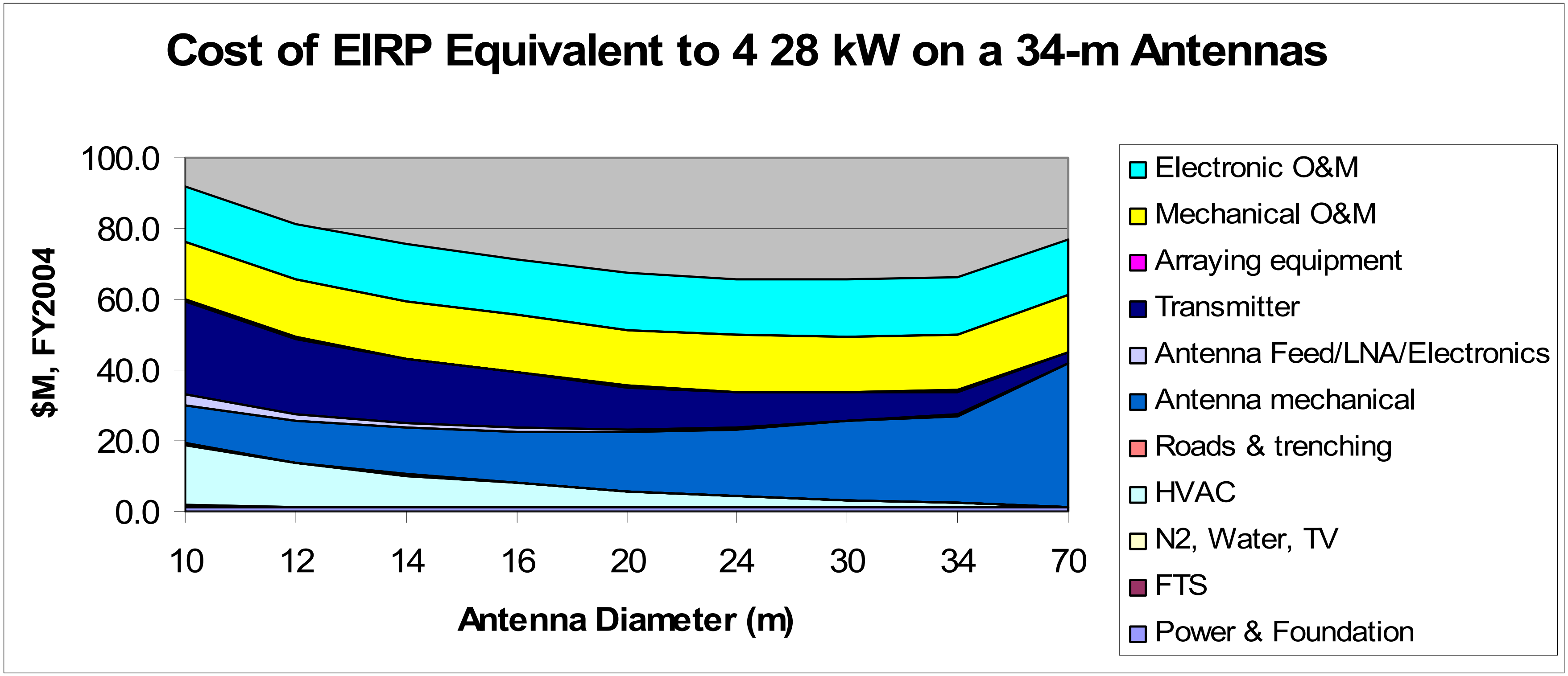
Downlink Life-Cycle-Cost (preliminary)

Optimal diameter is around 12 m



Uplink Life-Cycle-Cost (preliminary)

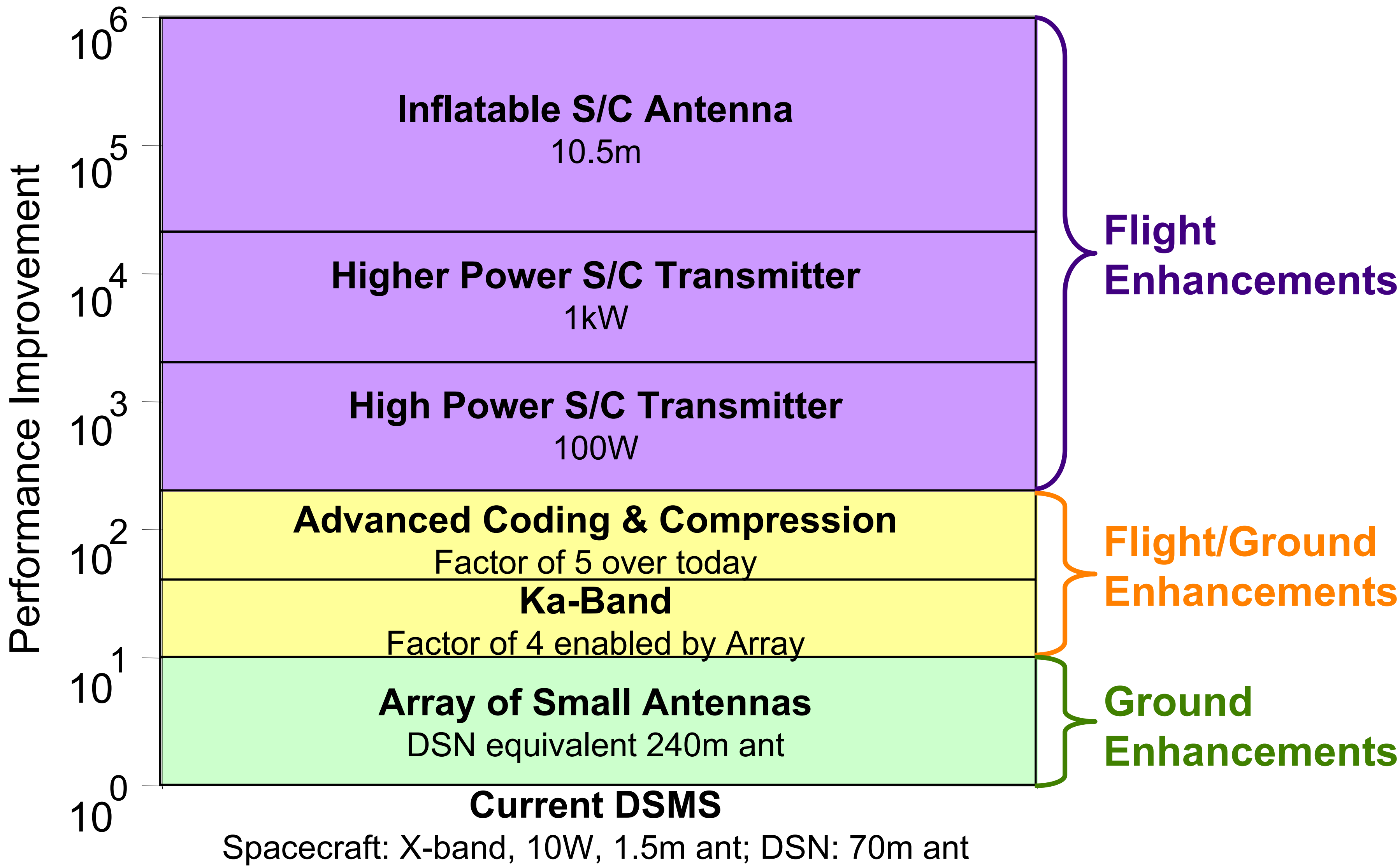
Optimal diameter is around 34 m



Maximizing RF Performance: Arrays and Other New RF Technology

- Arrays of 400 12m antennas could provide the equivalent of a 240m antenna at each of three longitudes. This alone could provide a factor of 10 increase in bit-rate over a 70m antenna (or a factor of 40 over a 34m antenna)
- Improvements in other RF technology are already underway:
  - Ka-band will lead to a factor of 4 increase in bit-rate over X-band
  - Improved data compression, coding, and modulation could lead to a factor of > 5 increase
  - A 100W transmitter would lead to a factor of 10 increase over today's ~10W transmitters
  - A 1 kW transmitter would lead to an additional factor of 10 increase
  - A 10.5m inflatable antenna would lead to 50x increase over today's 1.5m antennas
- A new deep space transponder will be required to take advantage of the increased performance, (ROM development cost ~$20M)

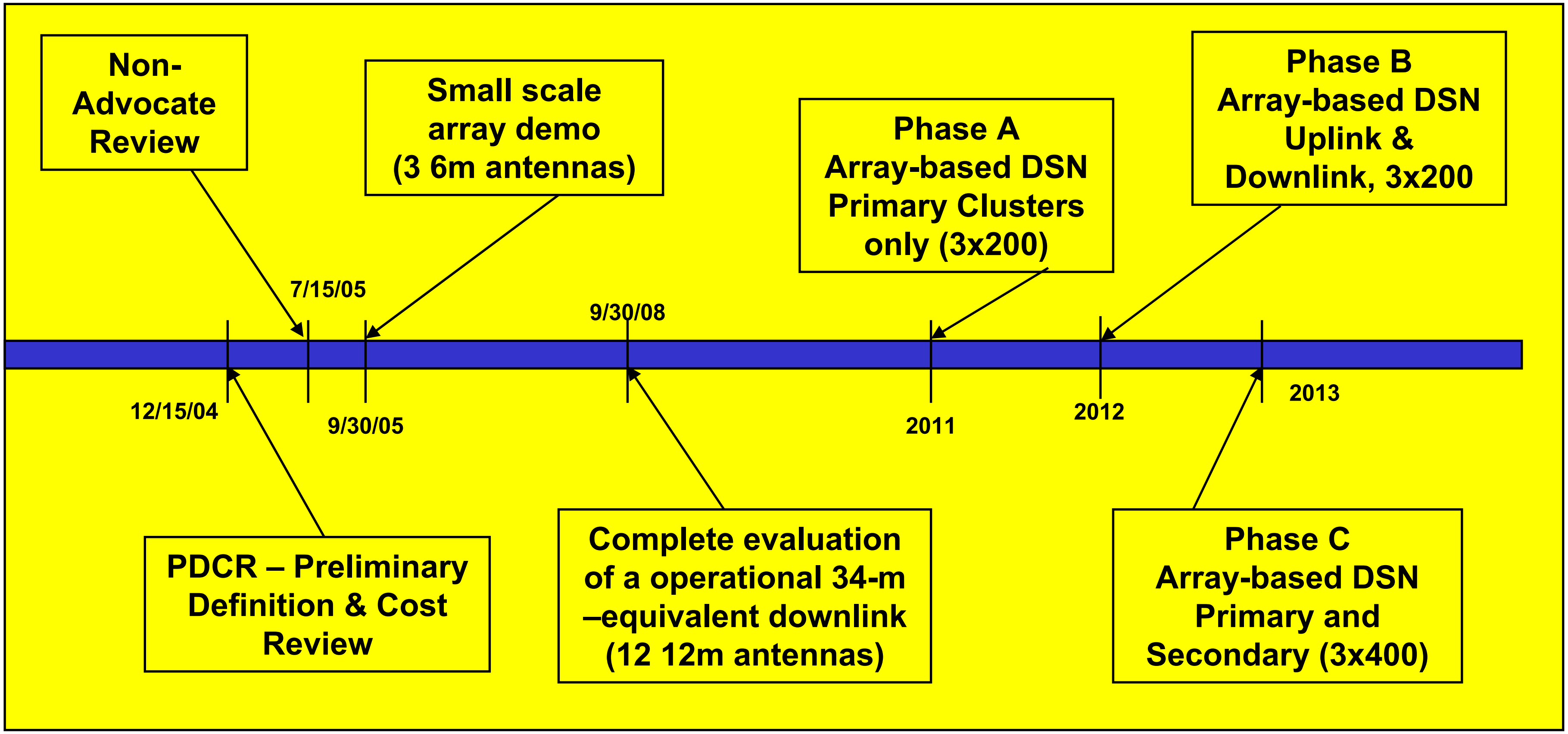
Projected RF Communication Performance Increases – Getting 10^6



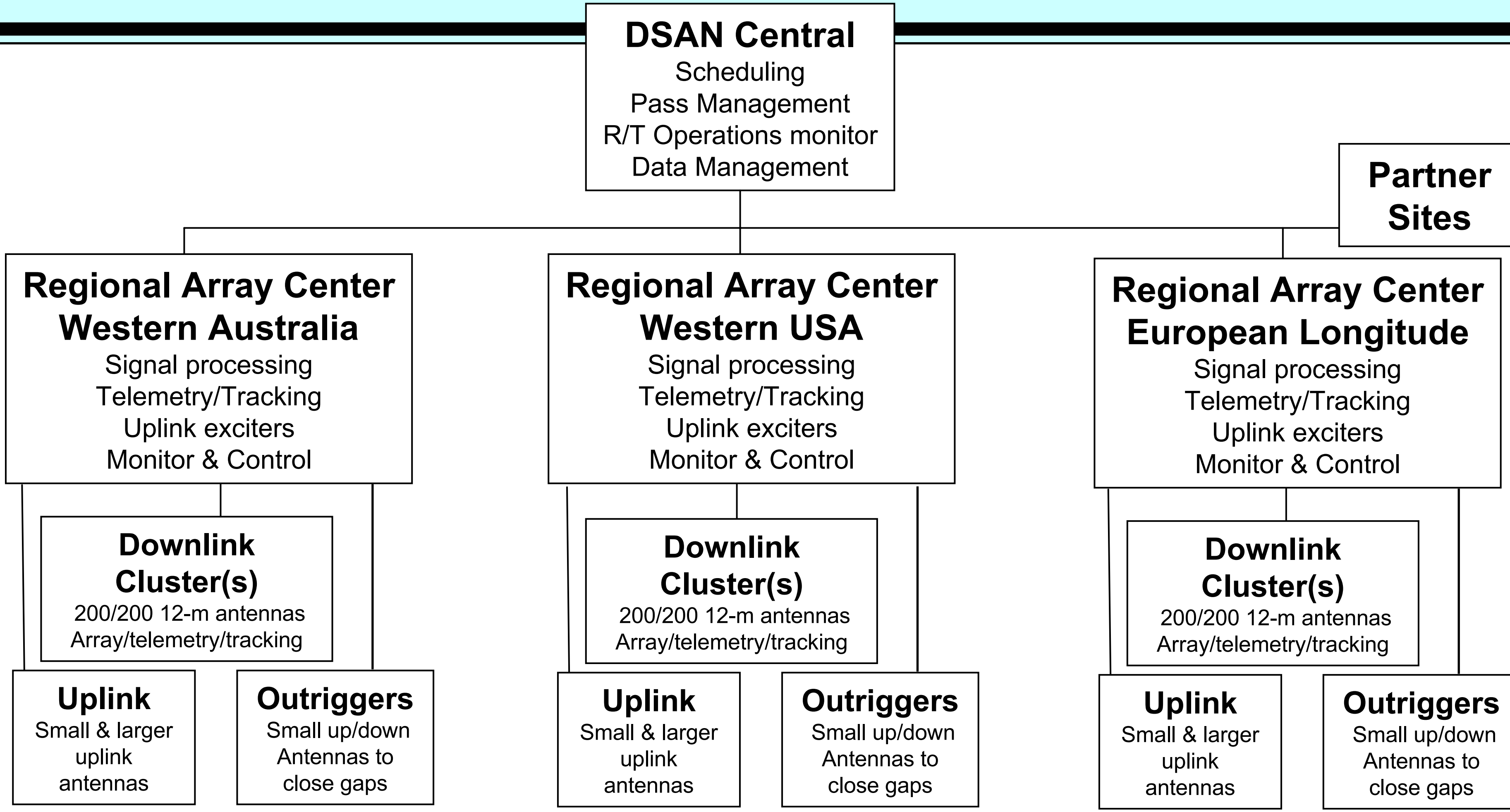
Benefits of a Next Generation RF DSN to NASA Missions

- Flexibility to trade new performance increases with parameters other than data rate
  – Lower mission costs, reduced power, antenna mass, pointing requirements, …
  – Reduced dependence on gravity assists, due to lower mass
  – Smaller communications orbiters
- Improve data-rate from low-gain antennas during descent and landing or spacecraft emergencies
- Provide precision plane-of-sky spacecraft position measurements for navigation
  – Precision of DDOR will increase by 10x over current capability – crucial for outer planet spacecraft navigation
  – Real-time milli-arcsecond accuracy
  – Improves targeting and orbit determination and reduces mission risk
- Provide operational benefits
  – Graceful failure – eliminates single points of failure
  – Weather diversity
  – Expandability
  – Reduced operational costs
- Improve radio link science data return: Increased Signal/Noise of radio occultation measurements by more than 20 dB
  – Investigate planetary atmospheres at both higher and lower altitudes

High Level Array Implementation Roadmap



Proposed Architecture of the Array-based DSN



* DSAN will have two clusters near each longitude, each with approximately 200 12-m antennas, to protect against adverse weather. The primary cluster will reside next to the Regional Array Center (RAC) and the uplink antennas. The secondary cluster will be downlink only

Reducing the O&M Cost

- Key contributors are:
  - Single 24x7 facility for real-time operations
    - The DSN has four such facilities
  - Centralized IT function (software loading, computer setup)
    - The DSN has staffs at all sites to conduct the functions
  - Validation of mission inputs, at submission
    - For the DSN the mission inputs are validated, often, at the pass setup
  - Schedule/Script-based real-time operations, rare human intervention
    - The DSN requires frequent steps of human intervention
  - Single hand-off between development and sites
    - The DSN has dual hand-off
  - Less-sensitive to failure of antenna/LNA (G/T degradation)
    - For the DSN, failure results in loss-of-link,
- See the Concept of Operations (900-001, Rev C) for more details

Staffing (Preliminary)

- **DSAN Central**
  5 24x7 Operators
  40 8x5 positions
  Engineering support
  - **Regional Array Center**
    2 24x7 Rovers
    (12 FTE, optional)
    - **Cluster(s)**
      8x5 positions
      (50 FTE)
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Total O&M & customer interface staff to support x10 70m capability
5-11 24x7 positions
190 8x5 positions

The Road to a Plan

What

√ Level 1 req
√ System Req
√ Architecture
√ Operations Method'y
√ Decomposition

How

Δ Organization
Δ Schedule
√ WBS
Risk
Δ Sites
Δ NEPA
EH&S
Training
etc

Validate Feasibility/ Risk

Δ Antenna
Δ 2/3-element demo
√ Ball study – Maintenance
Δ Uplink

Cost
8/1/2004

Development
O&M
HW Replacement

PDCR
12/15/2004

900-001, Rev C
Concept of Operations

Project Implementation Plan

√ Completed
Δ Underway

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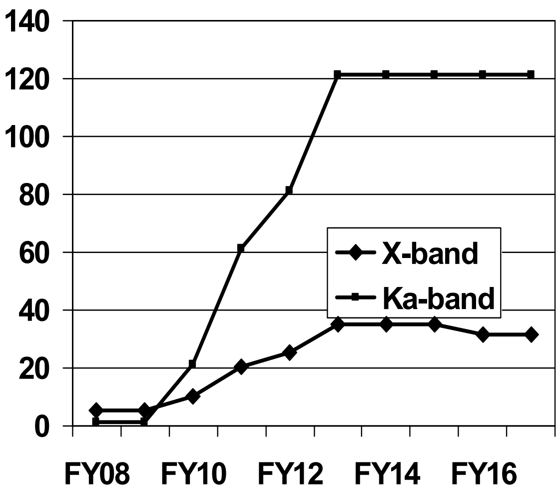

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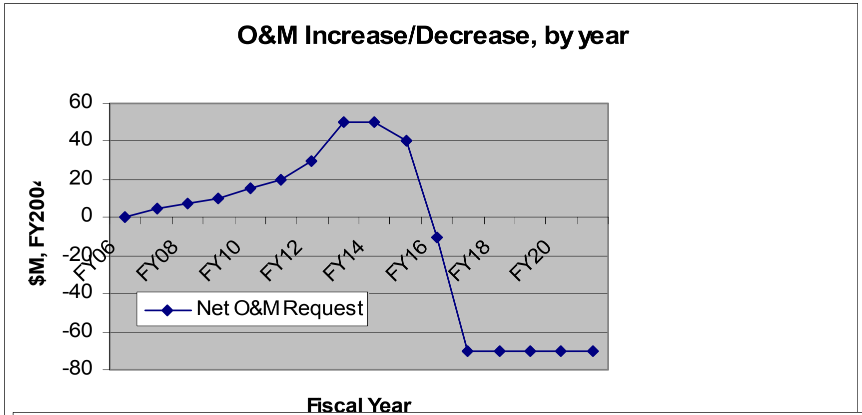
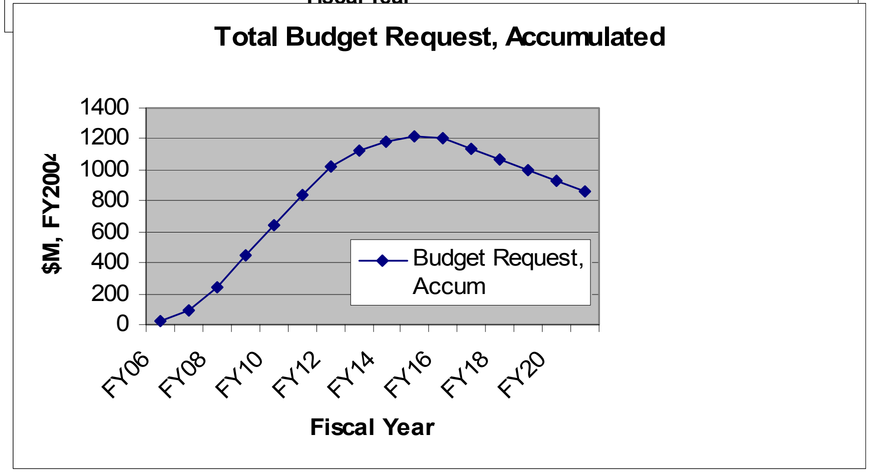
More Efficient!





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For Additional Information

- On-line:
  - Go to IND
  - Click on 960
  - Peruse documents & presentations