A Vision for the Next Generation Deep Space Network

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The Challenge for Deep Space Communications

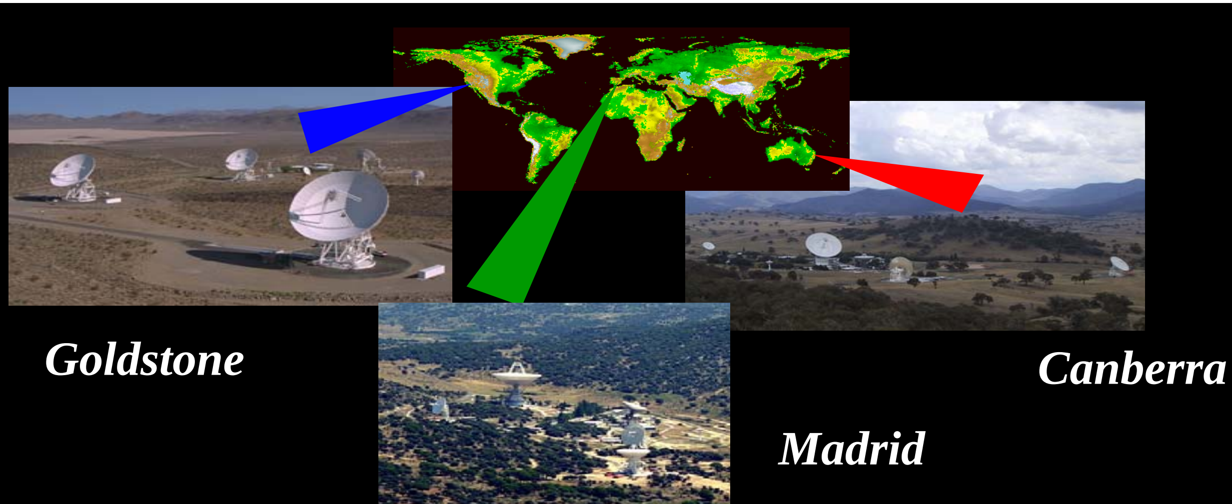
- Over the next 30 years deep space communication will have to accommodate orders-of-magnitude increase in data to and from spacecraft and at least a doubling of the number of supported spacecraft

- The present DSN architecture is not extensible to meet future needs in a reliable and cost effective manner

- NASA must develop a new strategy for deep space communications that meets the forthcoming dramatic increase in mission needs

What is the Present Deep Space Network?

- **Three major tracking sites around the globe, with 16 large antennas**, provide continuous communication and navigation support for the world's deep space missions
- **Currently services ~ 35 spacecraft** both for NASA and foreign agencies
  - Includes missions devoted to planetary, heliophysics, and astrophysical sciences as well as to technology demonstration
- **Spigot for science data** from most spacecraft instruments exploring the solar system, as well as a critical element of radio science instruments
- **A $2B infrastructure that has been critical to the support of 10's of $B of NASA spacecraft** engaged in scientific exploration over the last few decades



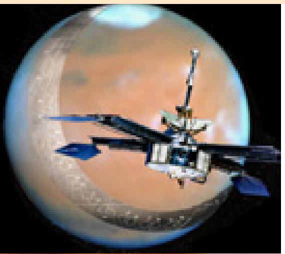
Why Does NASA Need a Next Generation DSN?

- **Many of the current DSN assets are obsolete or well beyond the end of their design lifetimes**
  - The largest antennas (70m diameter) are more than 40 years old and are not suitable for use at Ka-band where wider bandwidths allow for the higher data rates required for future missions
  - Current DSN is not sufficiently resilient or redundant to handle future mission demands
- **Future US deep space missions will require much more performance than the current system can provide**
  - Require ~ factor of 10 or more bits returned from spacecraft each decade
  - Require ~ factor of 10 or more bits sent to spacecraft each decade
  - Require more precise spacecraft navigation for entry/descent/landing and outer planet encounters
  - Require improvements needed to support human missions
- **NASA has neglected investment in the DSN, and other communications infrastructure for more than a decade**
  - Compared to 15 years ago, the number of DSN-tracked spacecraft has grown by 450%, but the number of antennas has grown only by 30%
- **There is a need to reduce operations and maintenance costs beyond the levels of the current system**

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

NASA's Science Missions are Changing

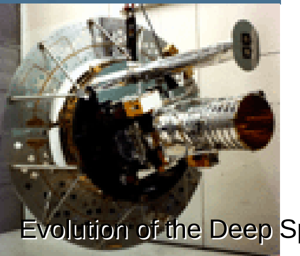
- **MGS, Mars Odyssey, & MRO will obtain high resolution images of only about 1% of Mars surface**
  - **Data rate is a constraint on the ability to understand the planet**
- **Science and human exploration missions need remote sensing as now done for the Earth**



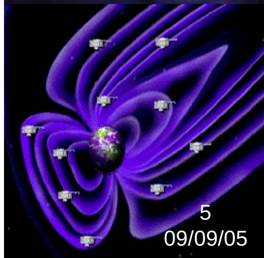
Preliminary solar system reconn. via brief flybys. → **Detailed Orbital Remote Sensing.**

***In situ* exploration via short-lived probes.** → ***In situ* exp. via long-lived mobile human & robotic elements.**

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

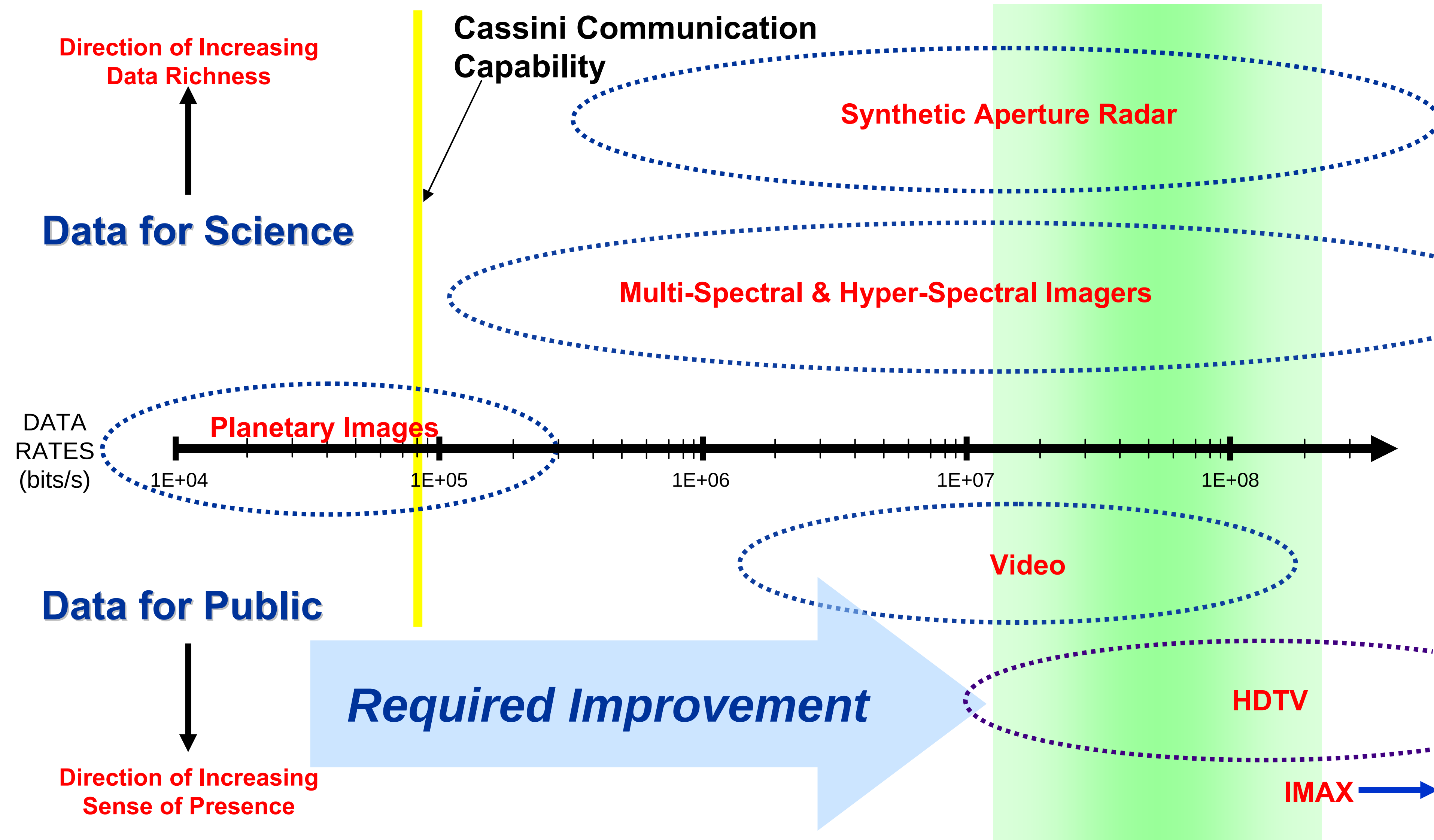


Single, large spacecraft for solar & astrophysics obs. → **Constellations of small, low-cost spacecraft. (e.g., MMS, MagCon)**



Next Generation DSN

Doing Similar Remote Sensing at Other Planets as We do Today at Earth



The DSN and Outer Planets Missions

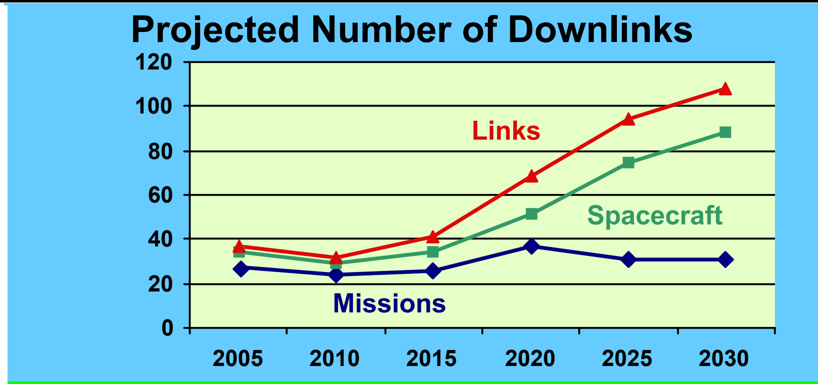
A capable DSN is especially critical to outer planet missions since communication is much more difficult compared to the inner solar system

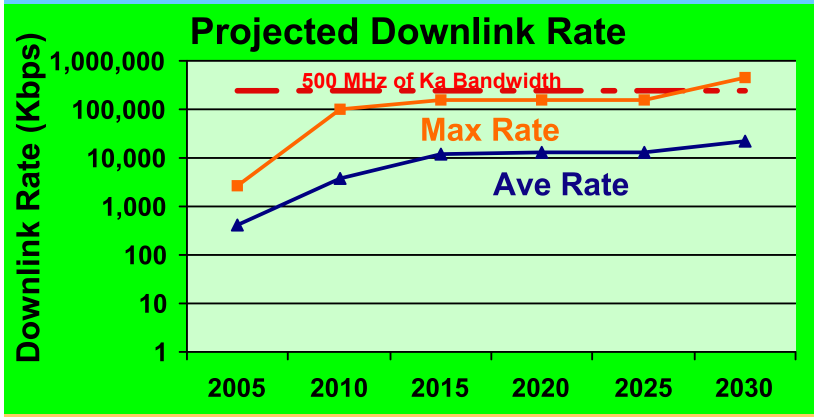
Relative Difficulty

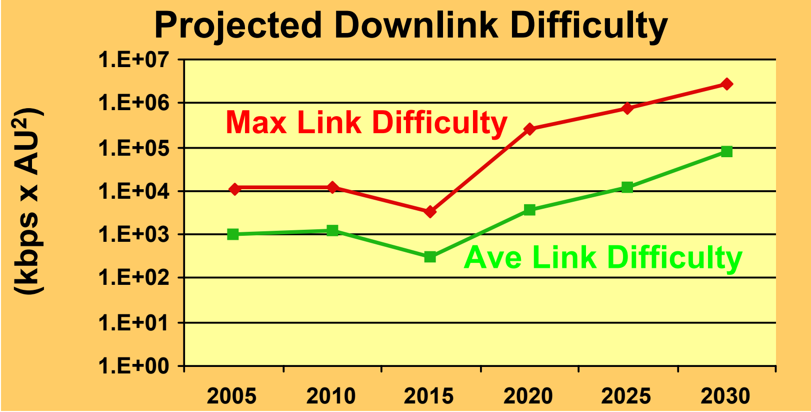
Place	Distance	Difficulty
Geo	4×10^4 km	Baseline
Moon	4×10^5 km	100
Mars	3×10^8 km	5.6×10^7
Jupiter	8×10^8 km	4.0×10^8
Pluto	5×10^9 km	1.6×10^{10}

DSN's Future Mission Drivers

- **Probable future DSN mission sets are frequently analyzed**
  - All NASA missions beyond geosynchronous Earth orbit
  - Science and exploration missions
- **Analysis shows that by 2030 DSN must be ready to support:**
  - 1000X downlink performance increase (likely more for certain missions)
  - 2X number of spacecraft increase

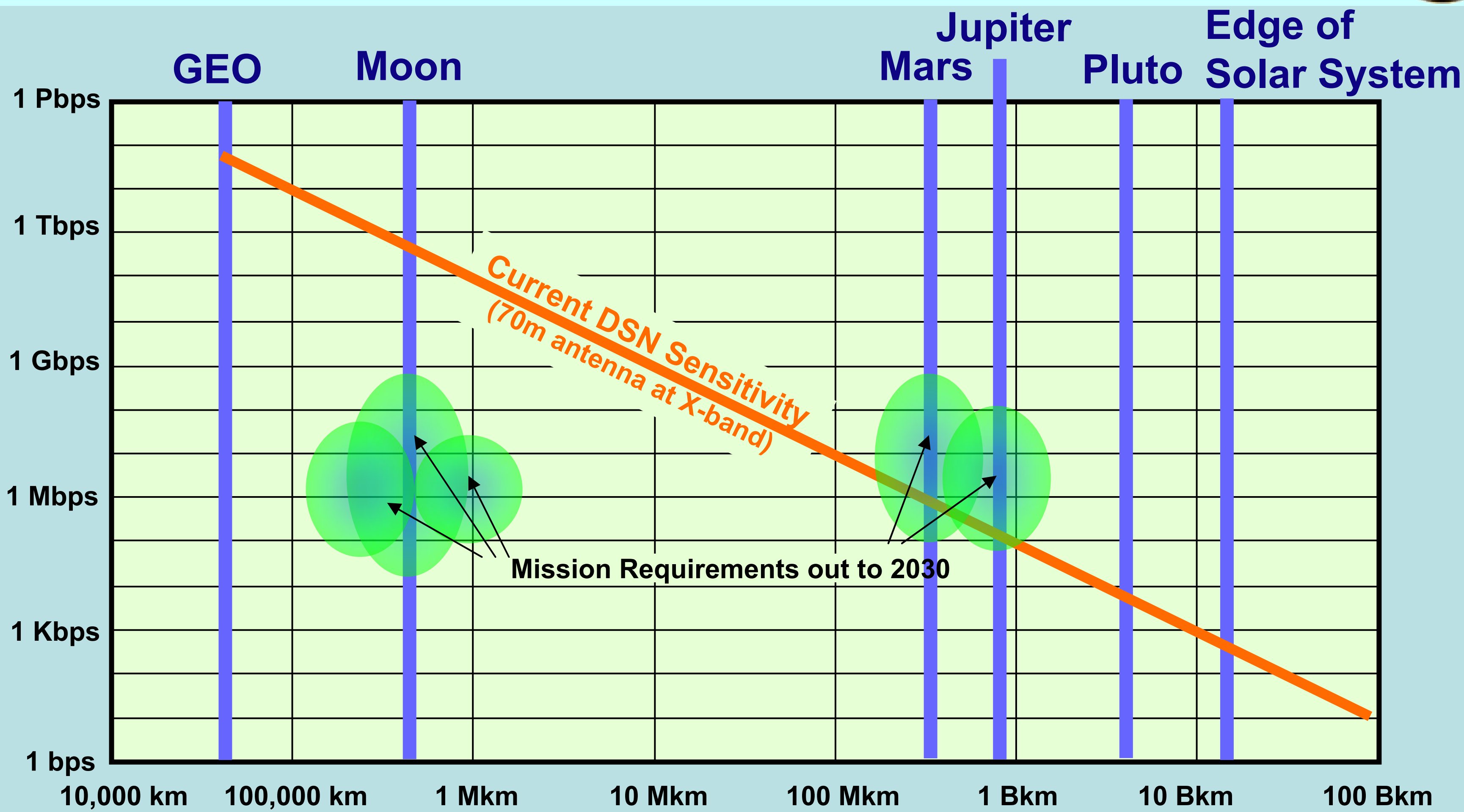






Next Generation DSN

DSN Performance Gap



- 1,000-fold increase is needed to support planetary missions
- Adequate sensitivity already exists for all lunar and Earth libration point missions

Planning for the DSN Future

Planning process:

- NASA and JPL have generated a roadmap for the DSN based on requirements derived from analysis of probable future mission sets
- This DSN roadmap is being integrated into an overall NASA Space Communications Program Plan by the NASA Space Communications Architecture Working Group (SCAWG)
- The SCAWG made recommendations about the future of space communications to the NASA Administrator (Griffin) and the NASA Strategic Management Council
- The NASA Administrator declared that NASA has neglected the DSN and communications infrastructure investment and asked that a plan be ready to deliver to Congress in February 2007

A Plan for the DSN Future

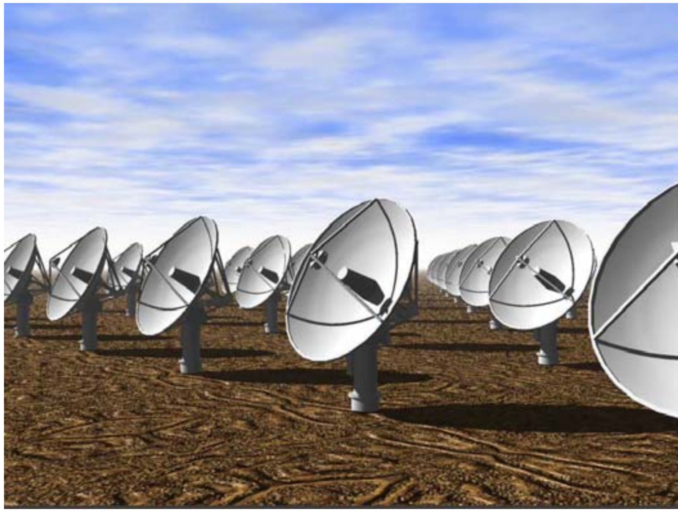
Recommended key elements of future DSN:

- **Radio communication** with large arrays of small antennas will be the backbone of deep space communications (#2 recommendation of SCAWG, after next generation TDRSS)
  - Would serve all missions, large and small, new and old
  - Technology is mature and low-risk
  - Costs will be recovered over time through reduction of DSN operations and maintenance costs
- **Orbital data relays** at the Moon, Mars, and perhaps other planets will allow the highest possible communication volumes from spacecraft at those bodies
- **Optical communication** would allow the transfer of extremely high data rates on "trunk lines" from Mars or the Moon to Earth, or for special missions (but would require implementation of an extensive reception infrastructure)

The Next Generation DSN: Arrays of Small Antennas

Arrays of small radio antennas will provide:

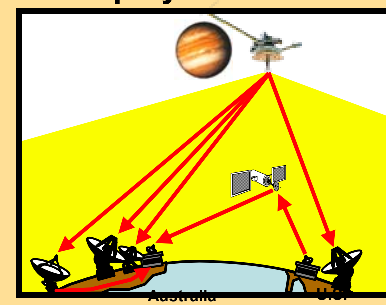
- **More resilience and redundancy:**
  - Graceful degradation in performance in case of antenna or receiver failures – fewer single points of failure
- **Much greater data flow to and from spacecraft:**
  - Meets the data rate requirements of most future NASA missions and instruments
- **Easily scalable architecture when growth is required**
- **Significant growth in the number of spacecraft that can be simultaneously tracked**
  - Each with just the required aperture
- **Higher precision spacecraft navigation**
  - Required for precision entry/descent/landing and for outer planet exploration
- **Improved cost-effectiveness**
  - Substantially reduces operations and maintenance costs: Plug-and-play components with longer lifetimes



Arrays: What Has Already Been Accomplished

- **Radio astronomers have used arrays since the 1970s**
- **DSN supported Voyager's Uranus and Neptune encounters with arrays of antennas (including international radio telescopes)**
- **DSN helped save Galileo through routine use of antenna arrays (including Parkes)**
- **Mid 80s plan to expand DSN with 34m antennas rather than 70m assumed arrays**
  - DSN currently offers 34m arraying as a standard service (used often by Cassini)
- **Array breadboard task is underway as a technology demonstration**
  - Developing 3 antennas (6- and 12-m diameter) and components that can be mass-produced for low cost
  - Demonstrating signal combining algorithms

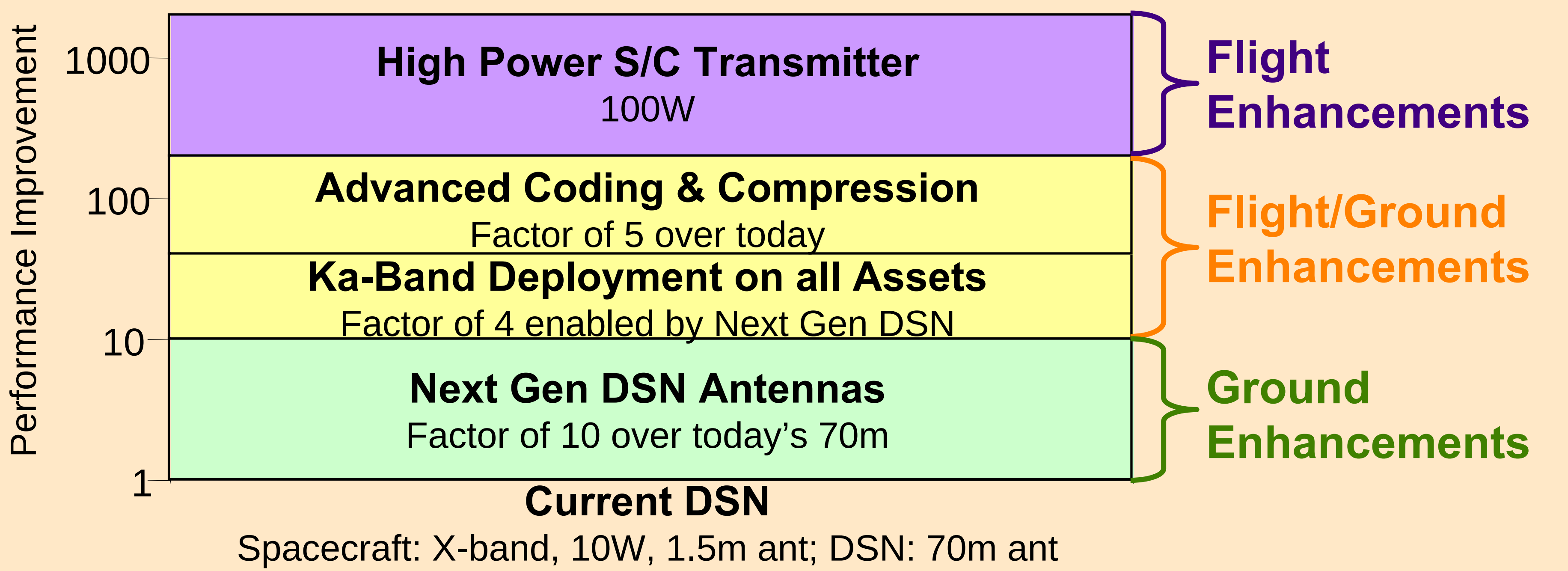
DSN arrays enabled Galileo to succeed after its HGA failed to deploy



6-m DSN Array breadboard antenna

End-to-End RF Communication Performance

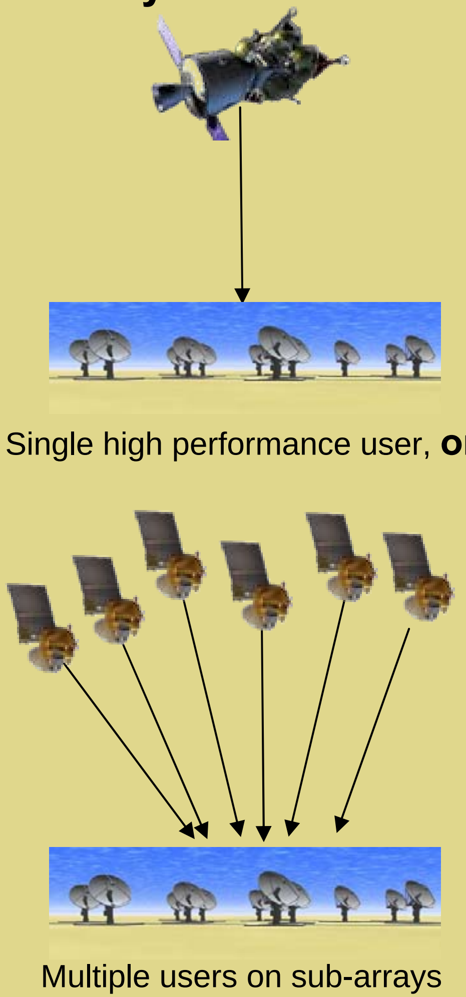
- **Future end-to-end communication performance will rely on more than just improvements to ground facilities**
    - Additional enhancements are under development



- **X 1,000 performance increase possible for most deep space missions**
- **Some missions might achieve more – up to 1,000,000**
    - Via higher power transmitters, larger spacecraft antennas, or optical communication

Example Benefits of Future DSN to NASA Missions

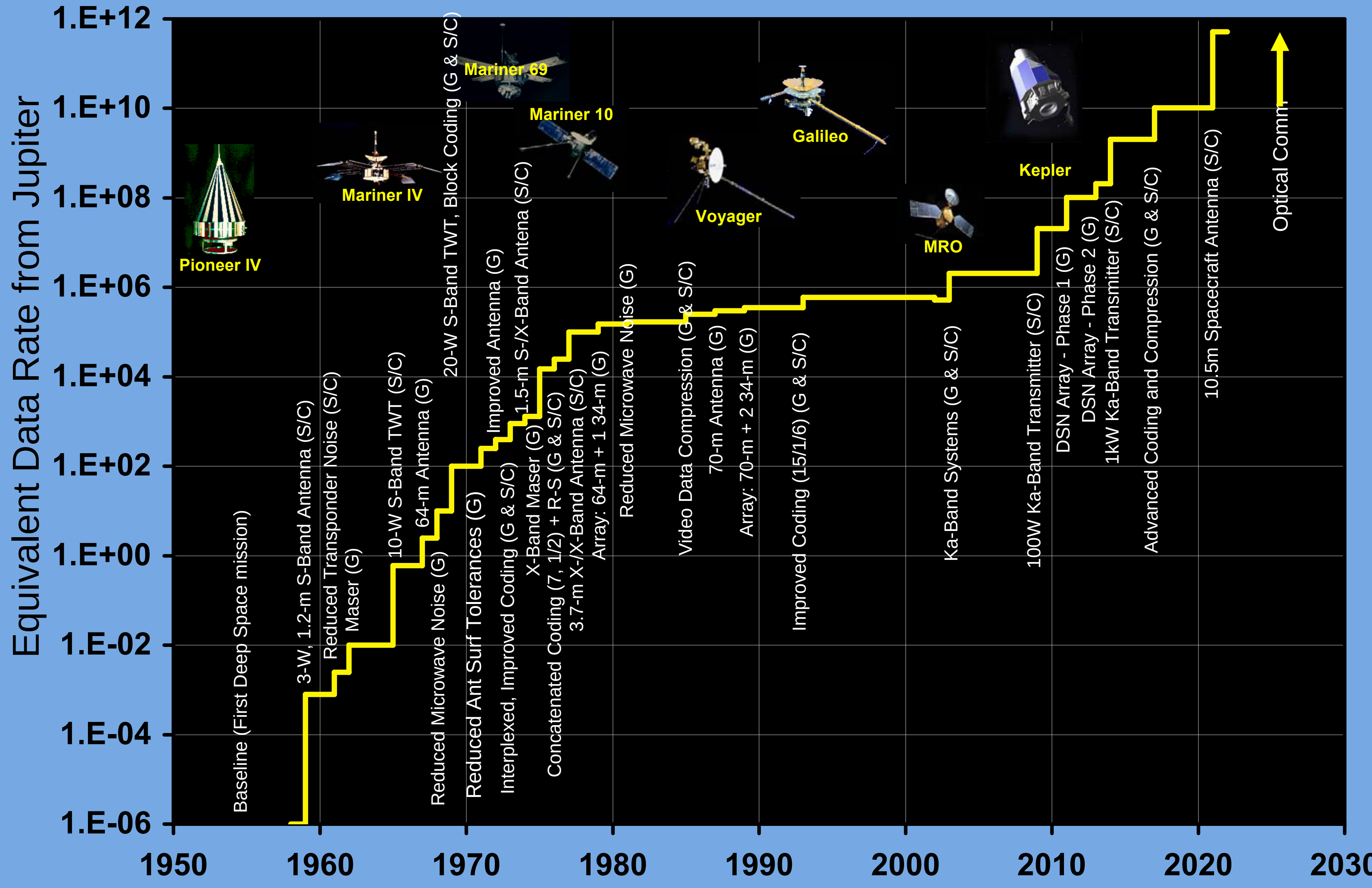
Flexibility of the Array Architecture



- **Orders of magnitude increase in downlink data rates**
  - Video instead of single images
  - Improved multi-spectral imaging
    - Increased temporal and/or spatial resolution
    - Increased wavelength and/or geographical coverage
  - Room to grow to support the human exploration era
    - Including intense robotic exploration of Mars
- **Orders of magnitude increase in up uplink data rates**
  - Enables expected growth of software uploads and human communication needs
- **Same instrument performance much farther from Earth**
- **Direct-to-Earth transmission can enable new mission concepts for probes, rovers, and balloons**
  - Hemispherical planet coverage (e.g., for multiple probes, longer communication periods)
  - Improved position/velocity measurements (e.g., for winds)
- **Improved mission parameters/cost**
  - Higher link sensitivity could be used to lower spacecraft power, mass, pointing accuracy requirements, …
- **Improved data-rate from low-gain antennas during descent and landing or spacecraft emergencies**

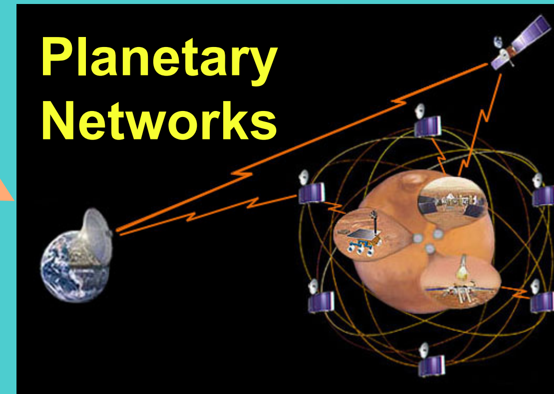
Next Generation DSN

DSN: Looking Forward



Global coverage of Deep Space

Current state of the art



High performance exploration

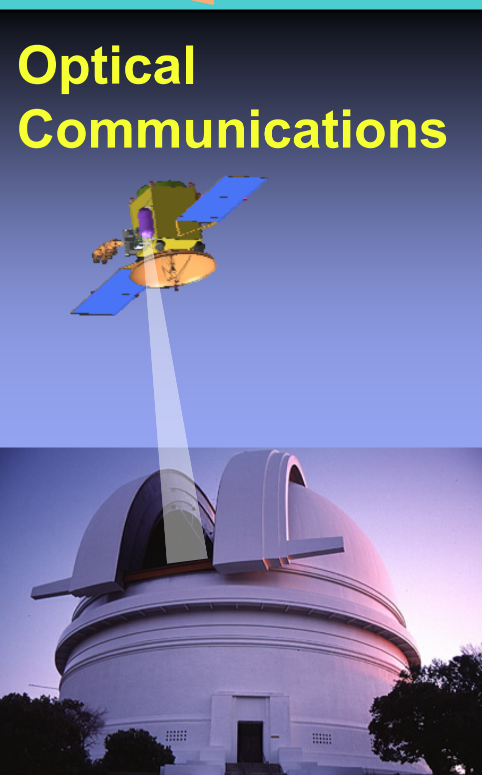
Increased accessibility

Improved nav and position locations

Modular and expandable

Low cost manufacturing and operations

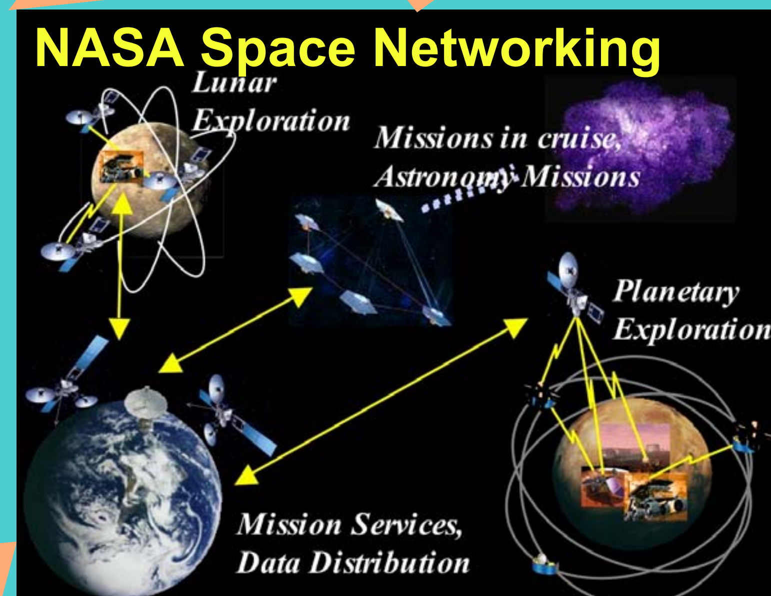
x40 performance



High bandwidth communications

Low mass spacecraft components

Beginning of technology growth curve



High reliability

High Performance: ≥ x1000 by 2015

Cost effective

Planetary networks, seamless connectivity

Summary

- **NASA mission models indicate that orders-of-magnitude growth in network capacity are required over the coming decades**
- **To meet these future requirements a new end-to-end DSN architecture is envisioned that includes antenna arrays, local networks at the Moon and Mars, and eventually optical communications on some links**
- **All subsequent NASA deep space missions would be orders-of-magnitude more science-capable**
- **The schedule for implementation of the next generation DSN will depend on NASA budgetary and programmatic decisions, in addition to the pressure of future mission requirements**
  - The science community is free to express their opinion to NASA
- **Until the new DSN is in place NASA is committed to ensuring that the current DSN can meet mission commitments**