Jet Propulsion Laboratory
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NASA's Space Communications and Navigation Support to Planetary Probe Missions

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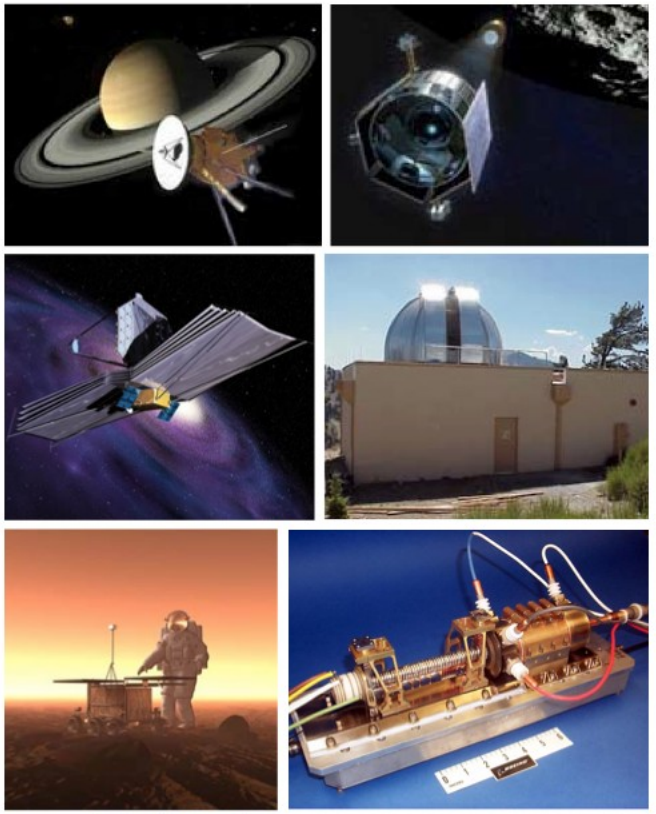

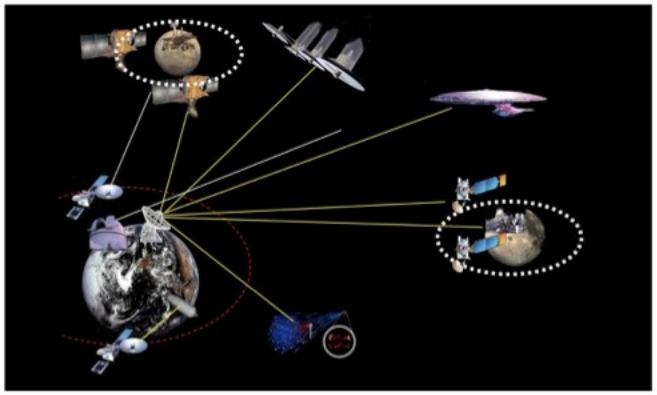

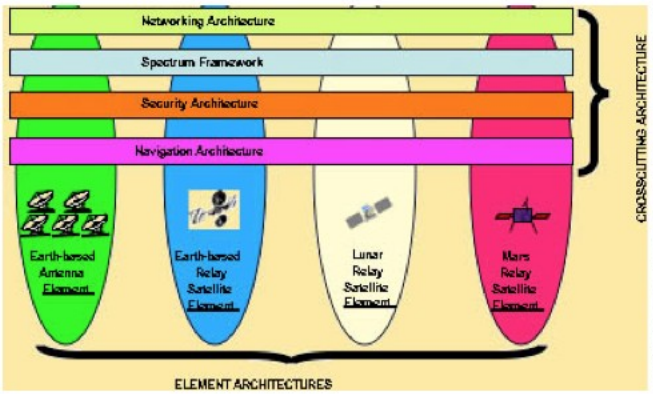

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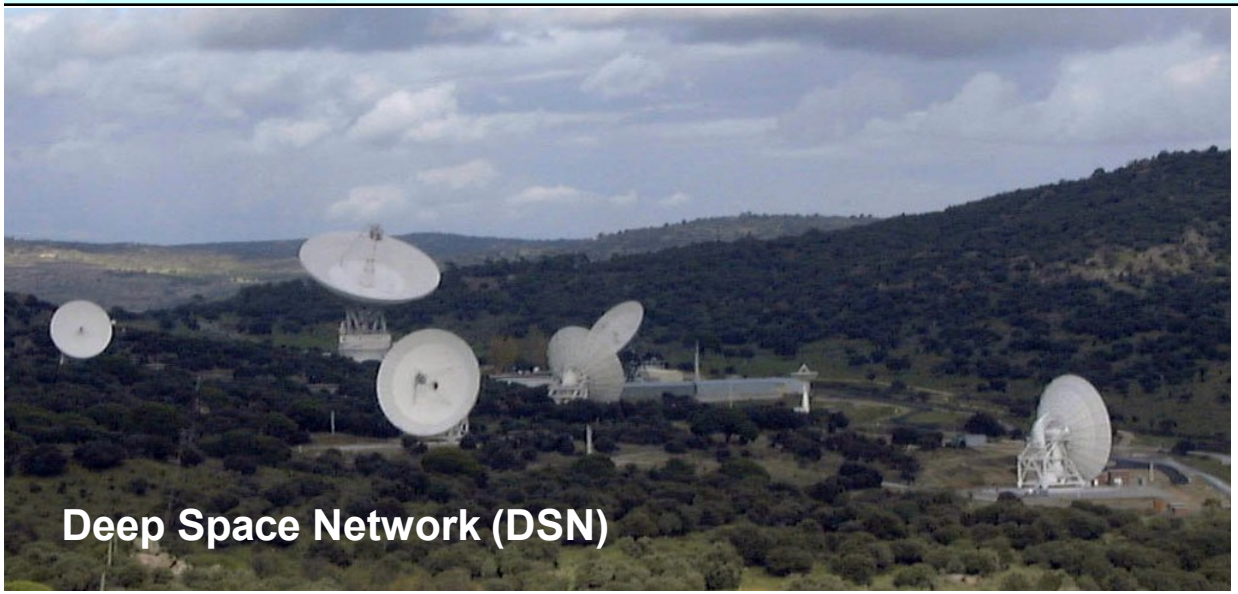
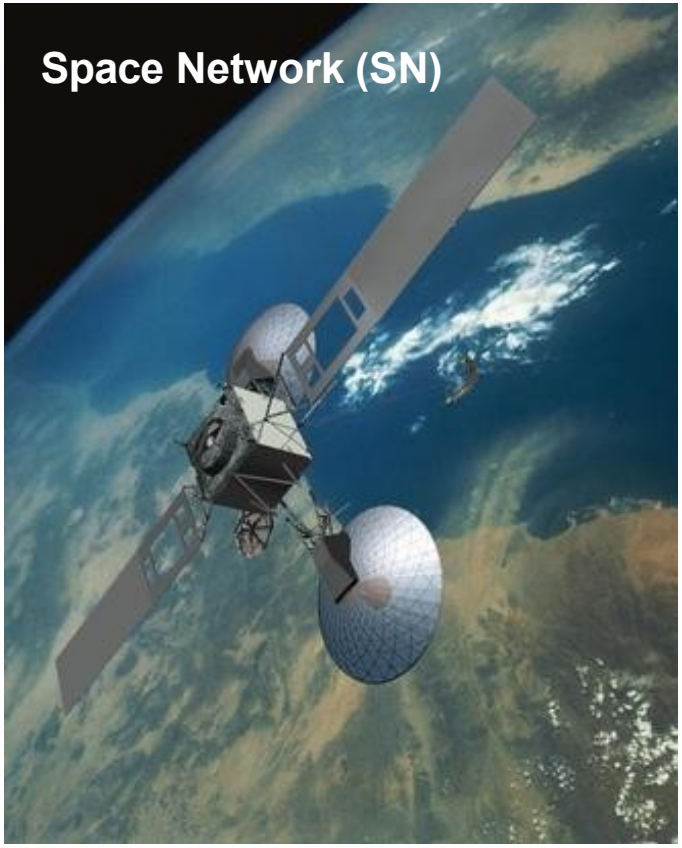
Big Antennas with a Big Job

NASA's Space Communications Networks

JPL

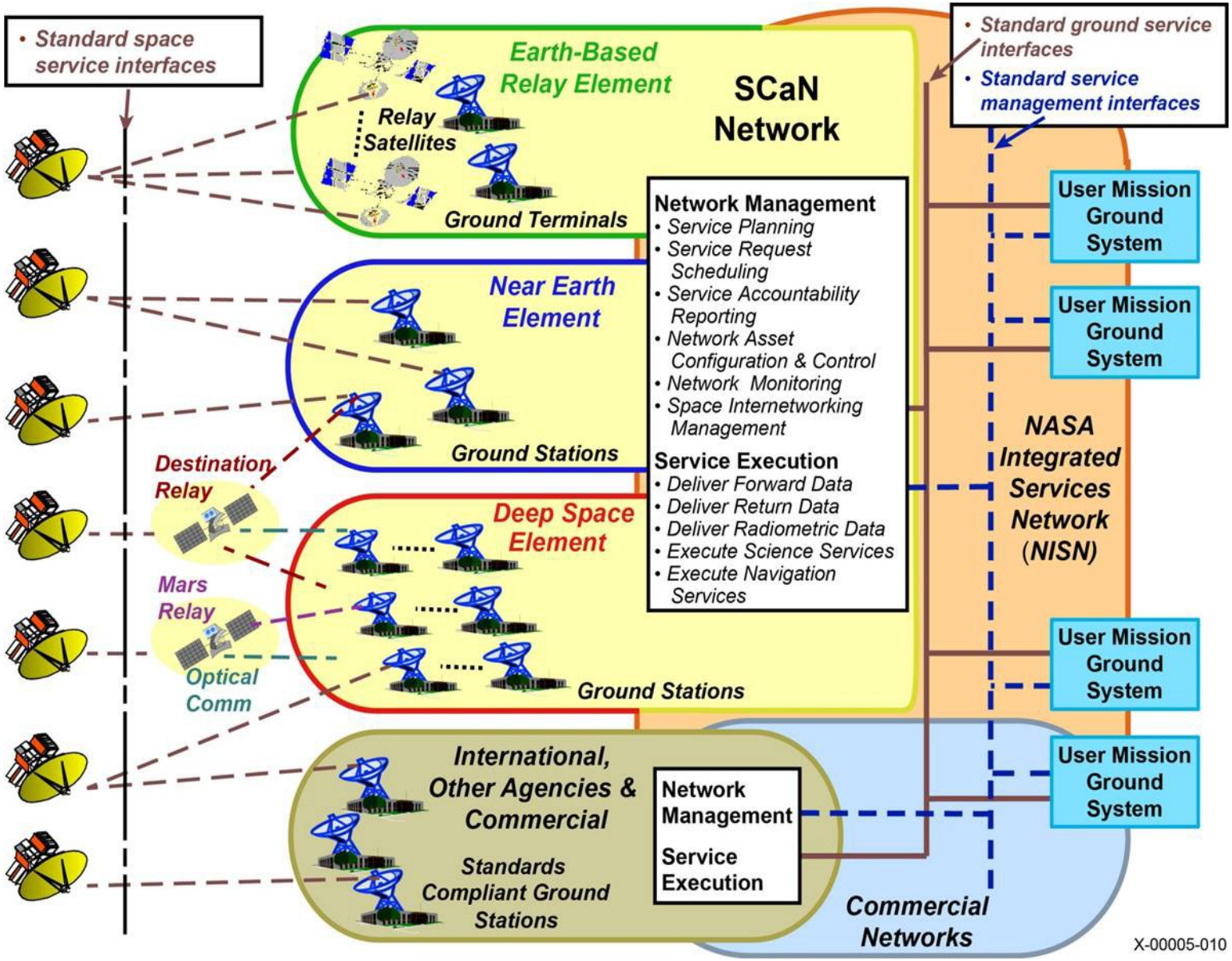




Space Communication and Navigation (SCaN)

- **Formed by NASA in 2006**
- **Manages DSN, NEN, and SN**
- **Will integrate NASA's space communications networks to achieve these goals**
  - **Reduce lifecycle costs of the SCaN communications assets**
  - **Reduce the effort required for users to obtain services from SCaN**
  - **Make it easier for NASA communications assets to infuse new technologies**
  - **Ensure the quality of SCaN services increases**

SCaN Integrated Network



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DSN Plans in Integrated Network Era

Eliminate 70m antennas as single points of failure

- Back them up with arrays of 43m BWG antennas at each DSN site

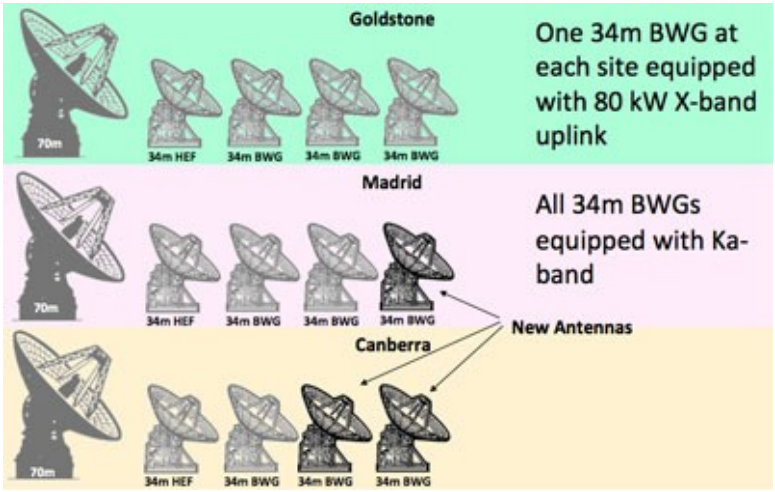
Increase use of Ka-band (32 GHz) downlink

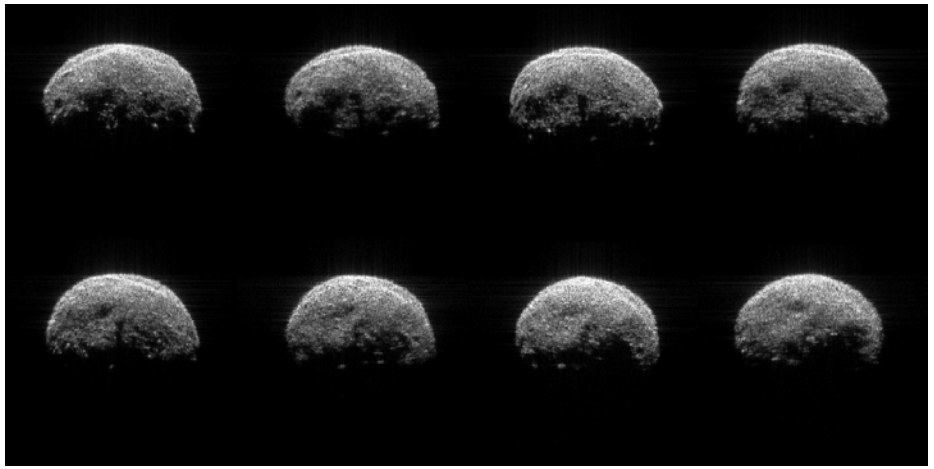
- ~4x communication performance
- 10x available bandwidth
- Use 34m BWGs for this

Continue improvements in Goldstone Radar

Improvements likely based on plans in SN and NEN

- LDPC coding
- 8PSK modulation





NASA Policies: Single 34m Antennas

- **Missions should use a single 34m antenna during routine operations**
  - **If a mission would use multiple antennas routinely, it would severely restrict the DSN's ability to service multiple simultaneous missions**
- **The 70m, or multiple 34m antennas can still be used for non-routine events, including**
  - **Trajectory change maneuvers (TCMs)**
  - **Planetary orbit insertions**
  - **Entry, Descent, and Landing (EDL)**
  - **Spacecraft emergencies**

NASA Policies: Ka-Band

- **Deep space missions should use Ka-band for downlinks over 1 Mbps**
  - **Since Ka-band is ~4 times as efficient as X-band, this results in ~1/4 the required DSN tracking time, leaving the DSN more time to track other missions**
  - **1 Mbps was chosen because, with BPSK modulation and rate ½ coding, the required bandwidth for such a signal is ~8 MHz – the maximum NASA-recommended channel size for deep space**
- **Since the policy is based on channel bandwidth, missions are free to propose links greater than 1 Mbps as long as the channel constraint is maintained**
- **For links <1 Mbps, missions can chose either X-Band or K-Band**

NASA Policies: Ka-Band Bandwidth

- **Deep space missions should restrict Ka-band downlinks to 60 MHz of bandwidth**
  - **Even though there is 500 MHz available for deep space use, we do not want this used up by a small number of missions – Ka-band will be our workhorse for many years**
  - **This is consistent with the Space Frequency Coordination Group (SFGC) recommendation**
  - **This corresponds to ~20 Msps and a spectral filter like Gaussian Minimum Shift Keying (GMSK)**
- **Note that the DSN does not have a plan to add GMSK-optimized receivers at this time**
  - **There will be a ~0.5 dB loss for missions that use GMSK**

NASA Policies: Redundant Coverage

- **Deep space missions should plan redundant DSN coverage for critical events**
  - **Though not as strictly enforced, this is sound engineering practice and should be followed if at all possible**
  - **Loss of link during a critical event can result in a mission emergency or even loss of mission**
  - **There will also be no insight into why the mission was loss**
- **The DSN plan to provide backup to the 70m antennas helps make redundant coverage possible – even when the critical event cannot be placed in an overlap view between two DSN sites**

Planetary Probe Support: Routine Ops

- **Use of a single 34m antenna should not be a problem**
  - **Cruise phase usually has low data rate requirements**
  - **Critical events can be handled with more DSN assets**

	Distance (AU)	Data Rate (Mbps)	
DSN Configuration		34m X-band	34m Ka-band
Spacecraft Configuration		3m antenna 100 W transmitter 1/6 Turbo code	3m antenna 100 W transmitter 1/6 Turbo code
Venus (Closest)	0.3	80.0	320
Venus (Farthest)	2.4	1.3	5
Mars (Closest)	0.6	20	80
Mars (Farthest)	2.6	1.1	4.26
Jupiter	5.4	0.247	0.99
Saturn	10.1	0.071	0.28
Uranus	19	0.020	0.08
Neptune	30.3	0.008	0.03

Possible routine downlink rates from various distances

Planetary Probe Support: Critical Events

- **For critical events, multiple antennas, including 70m, may be used**

	Distance (AU)	Today (Mbps)			2020 (Mbps)	
DSN Configuration		34m X-band	3 x 34m X-band	34m Ka-band	3 x 34m Ka-band	3 x 34m Ka-band
Spacecraft Configuration		3m antenna 100 W transmitter 1/6 Turbo code	3m antenna 100 W transmitter 1/6 Turbo code	3m antenna 100 W transmitter 1/6 Turbo code	3m antenna 100 W transmitter 1/2 LDPC code	3m antenna 180 W transmitter 1/2 LDPC code
Venus (Closest)	0.3	80.0	240	320	960	1728
Venus (Farthest)	2.4	1.3	3.8	5	15	27
Mars (Closest)	0.6	20	60	80	240	432
Mars (Farthest)	2.6	1.1	3.2	4.26	13	23.01
Jupiter	5.4	0.247	0.741	0.99	2.96	5.33
Saturn	10.1	0.071	0.212	0.28	0.85	1.52
Uranus	19	0.020	0.060	0.08	0.24	0.43
Neptune	30.3	0.008	0.024	0.03	0.09	0.17

Possible critical event downlink rates from various distances

Planetary Probe Support: Through a Relay

- **The previous tables indicates expected performance between a planetary relay and Earth**
  - **In most cases, the actual performance will be limited by the probe-to-relay link**
- **If the relay mission is short-lived, it can be viewed as "non-routine"**

Planetary Probe Support: Direct-to-Earth

- **Without a relay, the communications performance will be limited by the probe's systems**
  - **Typically, probe antennas will have no (or little) gain so the performance will be essentially frequency-independent**
  - **In some cases, S-band may be desired – please work with DSN in advance if this is the case**

Ground Antennas	DSN 34m	DSN 70m	DSN 70m + 4 34m's
Venus (0.3 AU)	2.75 kbps	11 kbps	22 kbps
Venus (2.4 AU)	45 bps	180 bps	360 bps
Mars (0.6 AU)	725 bps	2.9 kbps	5.8 kbps
Mars (2.6 AU)	37.5 bps	150 bps	300 bps
Jupiter	8.75 bps	35 bps	70 bps
Saturn	2.5 bps	10 bps	20 bps
Uranus	0.75 bps	3 bps	6 bps
Neptune	0.25 bps	1 bps	2 bps

Possible direct-to-Earth downlink rates from various distances
(Assumes 25W X-band transmitter and 4 DBi Antenna)

Planetary Probe Support: Navigation & Science

- **All the same navigation data types used today will be available in the Integrated Network Era**
  - **Doppler, ranging, ΔDOR**
  - **ΔDOR will require at least a second antenna, but this would not likely be routine operations (or could use a non-DSN second antenna)**
- **Many probe missions make extensive use of radio science to study atmospheres, winds, gravity fields …**
  - **These usually are non-routine**
  - **Observations usually require DSN Radio Science Receivers (RSRs), which can also be moved to non-DSN facilities if planned far enough in advance**
  - **S-band may be desired – if so, please work with DSN in advance**

Conclusions

NASA has begun integrating its space comm networks

- **Will not impact the DSN quality of service**
- **Mission-associated DSN effort and cost might even be reduced**

SCaN will continue to reach out to user communities

- **For non-NASA users, please work through international fora including IOAG, SFG, and CCSDS**

The DSN stands ready to support all probe missions

NASA policies will ensure we will be able to support many simultaneous missions of many kinds

We encourage anyone contemplating probe missions to work with the SCaN Customer Interface Office

- **It is NEVER too early to start this process**

We expect the Integrated Network and new Policies to enable easier transition to new comm and navigation capabilities and technologies