Deep Space Network

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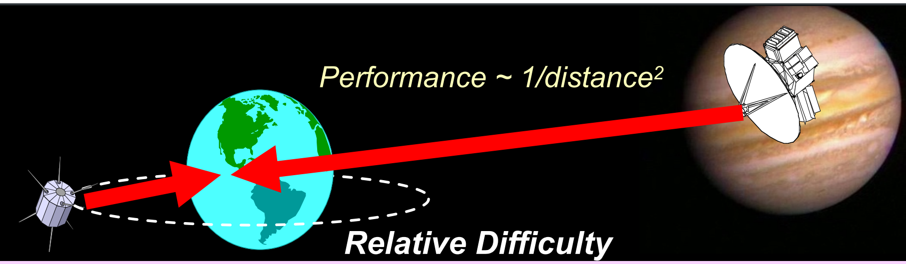
The Deep Space Network
NASA's Connection to the Moon, Planets, & Beyond

- Large antennas at three global sites: California, Madrid, Canberra
- Captures all information from our spacecraft
  - Most sensitive receivers
- Sends all instructions to them
  - Most powerful transmitters
- Provides most of the navigation
  - Most stable clocks and best algorithms
- Enabling more than 30 spacecraft in flight today

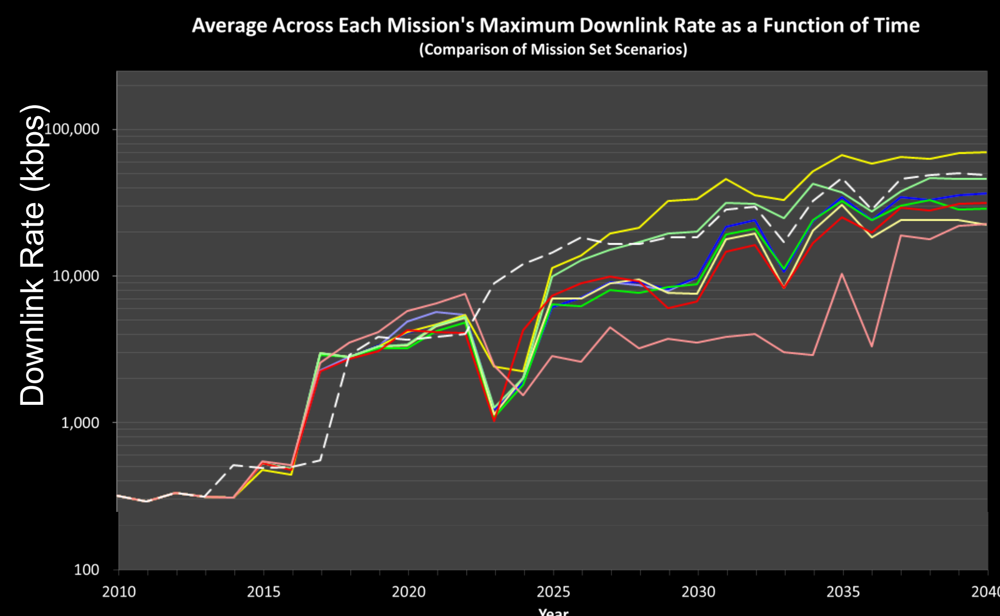
Date Volume Challenges

- Space loss over huge distances
  - Performance ~Shannon limit
  - Selective data return
- Temporal links
- Increasing demand from space missions
  - Need to keep up with 10x/decade trend
- Data flow is not automated
  - Contacts are scheduled
  - Limited data management autonomy



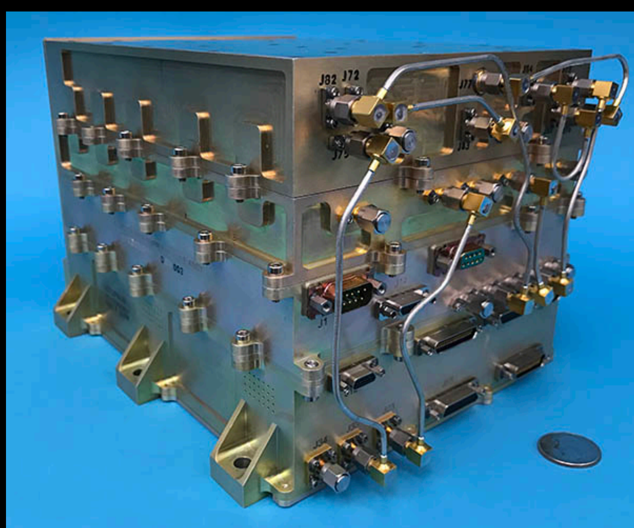
Relative Difficulty

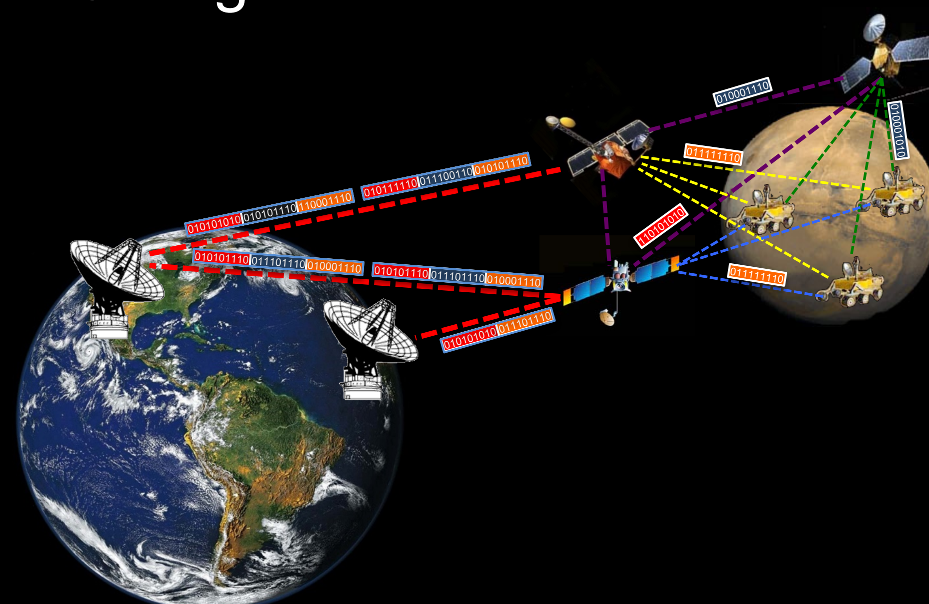
Place	Distance	Difficulty
GEO	4×10^4 km	Baseline
Moon	4×10^5 km	100
Mars	3×10^8 km	5.6×10^7
Jupiter	8×10^8 km	4.0×10^8
Pluto	5×10^9 km	1.6×10^{10}



Key Emerging Technologies for the DSN

- Ka-band communications
- Optical communications
- Advanced error-correcting coding and modulation
- Software Defined Radios (flight and ground)
- Disruption/Delay Tolerant Networking

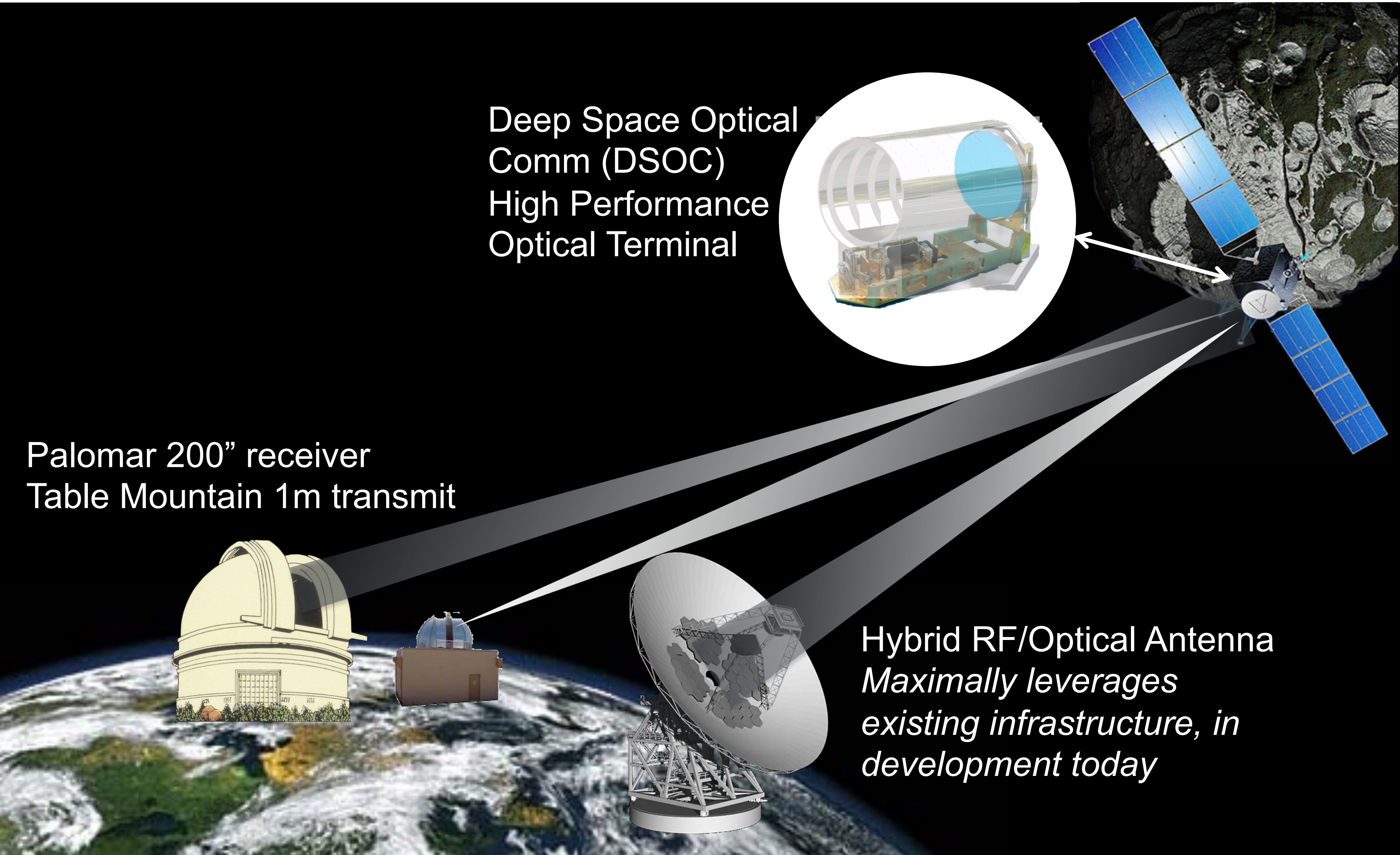




Inserting New Technology (or anything else!)

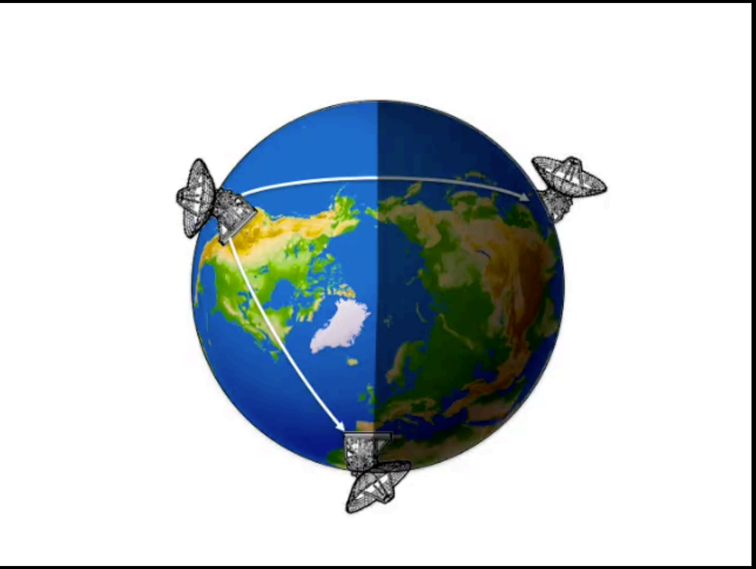
- DSN cannot stop operations - ever
- Maintenance is scheduled just like a spacecraft user
  - Short down times
- Single antennas are taken down at infrequent intervals
  - Up to 6 months
  - Opportunity for new capabilities
- System wide upgrades are infrequent
  - Can use one complex to cover for another in these cases
  - Involves close cooperation of users

Coordinating Flight & Ground: Optical Comm



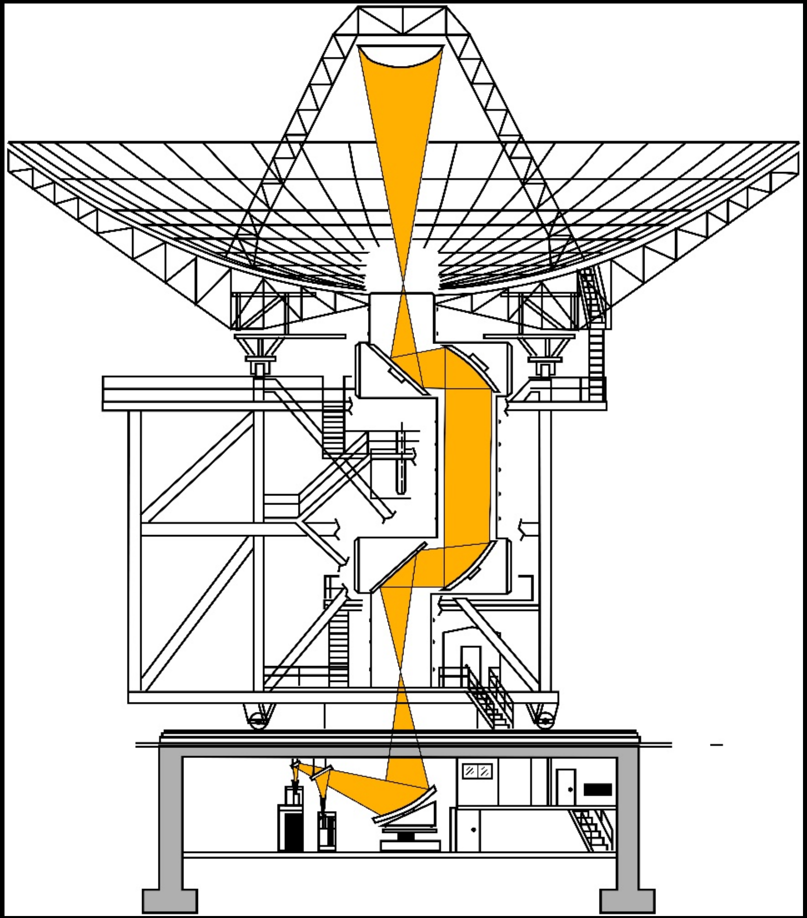
Dealing With Node Losses, Intrusions

- Antennas have failures, as do all subsystems in the DSN
  - Reschedule users to other antennas as possible
  - Reschedule to later passes if needed
  - Lack of spacecraft automation is a problem
- All antennas are operated remotely from site in prime shift
  - Very robust COOP
- Spectrum is protected by ITU and UN
  - Very few incursions
- Cyber is a threat being worked
  - In "old days" we were safe because bad actors needed 34m antenna
  - Today, some actors have these – and biggest threat is internal to our information systems



Special Maintenance Challenges and Solutions

- Some systems are very old
  - 70m antennas date to 1966 – sort of
  - Some 34m antennas date to 1991
  - >20-year-old support equipment
- Many systems custom to the DSN
  - Low noise amplifiers, transmitters, …
- Ample spares kept in stock
- Beam Waveguide 34m antennas
- Reliability-Centered Maintenance
- Parametric trends used to plan replacements and upgrades
  - Careful attention to long-lead items
  - Often design new systems because old ones are no longer available



Guiding Principals: Limited Bandwidth & Connectivity

- Building resilient distributed systems
  - Reschedule users to other antennas as possible
  - Reschedule to later passes if needed
  - Lack of spacecraft automation is a problem
- All antennas are operated from the complex in prime shift
  - Very robust COOP
- Spectrum is protected by ITU and UN
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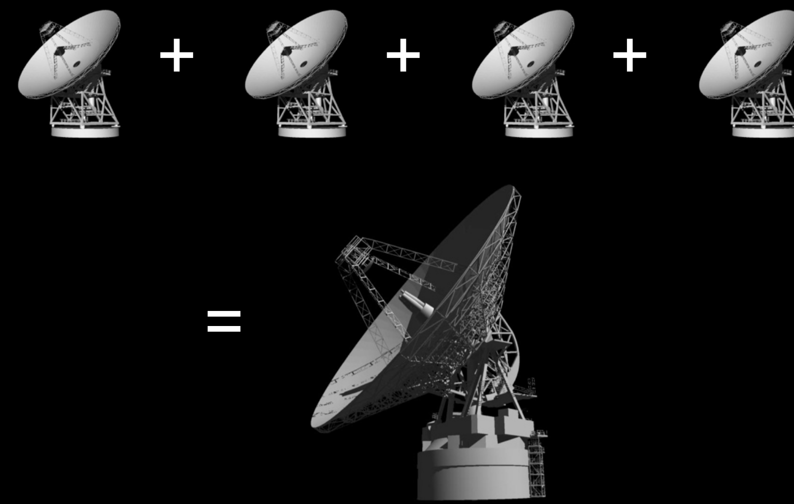
Flexibility and Scalability

- The DSN is inherently flexible
  - All sites use same architecture and processes
  - All antennas can provide all services – mostly
  - Using CCSDS standards for communications



Using 34m Antenna Array to Back Up 70m

- DSN is inherently scalable
  - Can easily add or subtract antennas
  - Array antennas for more downlink performance
    - Have demonstrated uplink too – but not yet operational
- We work with our customer community to determine the needed scale and flexibility
  - We perform market research for 25 years in the future
  - We have user groups and publish our plans

Conclusion

- **The DSN is a distributed data system with significant challenges**
  - **Performance at the very edge of theory**
  - **Legacy equipment**
  - **Temporal links**
- **Need to continually increase performance**
  - **Infuse or lead new technology**