NASA Deep Space Network
The Deep Space Network has sites in three locations around the world that hand off to each other allowing continuous contact with a distant spacecraft as Earth rotates.
The Deep Space Network is a unique, worldwide network of spacecraft tracking facilities operated for NASA by JPL.

- Operated since 1959; JPL was originally part of the Army.
- Sites are located at Madrid, Spain; Canberra, Australia and Goldstone.
- Locations were originally chosen to assure radio quiet (i.e., surrounded by hills/mountains and away from populated areas) and to provide continuous spacecraft coverage (i.e., approximately 120 degrees apart).
Deep Space Network

• **Spacecraft Telemetry (downlink)**
  • Collecting the data transmitted by spacecraft
    - Images
    - Data from science instruments
    - Spacecraft health information

• **Spacecraft Commanding (uplink)**
  • Transmitting sequences of instructions from mission controllers to the spacecraft
    - Science observations
    - Trajectory maneuvers
    - Orbit insertions
    - Descents and landings

• **Spacecraft Tracking**
  • Calculating predictions as to the position and velocity of a spacecraft based on doppler, range, and interferometry measurements.

• **Navigation**
  • Determining where the spacecraft needs to be and planning necessary trajectory correction maneuvers or orbit trim maneuvers.
The DSN is solely responsible for navigation, command and data acquisition for NASA high earth orbiters and deep space missions

- Also tracks low earth spacecraft in emergencies and (sometimes) DoD spacecraft
  - Approximately 15 emergency events per year which use high power transmitters and have a two hour call-up window
- Mission set includes approximately 50-60 spacecraft tracked on a regular & emergency basis and includes spacecraft more than 12 billion kilometers from earth -- round trip signal time is more than 23 hours!
- Number of spacecraft is largest in NASA history and increasing
- Similarly, number and length of critical data acquisitions is increasing

- The DSN additionally tracks non-NASA spacecraft launched by other spacefaring nations such as Japan, Germany, France and Russia
DSN Facilities

The three Deep Space Network Sites

GOLDSTONE, CALIFORNIA

MADRID, SPAIN

CANBERRA, AUSTRALIA

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.
Goldstone DSCC

Goldstone Deep Space Communications Complex is the keystone of the DSN

- Largest site with the most antennas: 70m, five operational 34m’s, 26m, R&D 34m and 11m and a 34m radio telescope used for educational outreach (including DoD dependent education)

- One 34m includes a radio science system that provides the most stable system ever built and is used for gravity wave detection experiments

  - Stability is the equivalent of one second in 30 million years!

GDSCC serves also as a center of DSN research and development due to its proximity to JPL

- Installation of new technology and prototype developments to verify system performance

- First article installations

GDSCC is considered a National Resource by act of Congress
Additionally, Goldstone performs continuous wave radar observations of near Earth asteroids, other natural objects and planets.

- Uses high power radiation of up to 500KW with extremely weak return signals
- Asteroid tracking is particularly important because of short times from discovery to tracking, extreme public interest and the need to understand the threat they pose to Earth
DSN operates at 1.6-1.7 GHz (L), 2.0-2.3 GHz (S), 7.1-8.5 GHz (X) and 31-35 GHz (Ka)

Eventually will have optical communications capability and 37-41 Ghz communications for human exploration of Mars

DSN sites currently have transmitter powers of up to 400KW at S-Band; 20KW at X-Band; and 50 watts at Ka-Band

Radar radiates at 500KW at 8.6 GHz

Deep space spacecraft typically have transmitter powers of approximately 15 watts

Distances and small spacecraft antennas result in extremely weak received signal conditions
Missions

Some missions currently being tracked by the DSN

Spitzer Telescope

Cassini

Mars Odyssey

Mars Express

Mars Global Surveyor

Mars Exploration Rovers

Ulysses

Stardust

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.
Characteristics of The DSN

Received Signal Sensitivity:
The received energy from Voyager at Neptune, if integrated for 300 million years, would be just enough to set off a small photographic flashbulb!

\[
\text{Received power} = 10^{-17} \text{ Joules/sec}
\]

Command Power:
The DSN puts out enough power in commanding Galileo that it could easily provide high quality commercial TV at Jupiter!

\[
\text{Transmitted power} = 400 \text{ kW}
\]

Dynamic Range of the DSN:
The ratio of the received signal power to the DSN transmitting power is like comparing the thickness of a sheet of tissue paper to the entire Earth!

\[
\text{Ratio} = 10^{27}
\]
Characteristics of The DSN (2)

Navigational Accuracy:
Voyager navigation at Neptune was equivalent to being able to tee-off from California and place the ball on a green in Washington, D.C.!

Angular accuracy = 50 nrad

Frequency Stability:
The DSN's ionic clocks used to achieve this navigation accuracy are so stable that only one second of error would accumulate every 30 million years!

Allan variance = $10^{-15}$ in 1000 seconds

Once-in-a-lifetime Science Opportunities:
The reliability of a spacecraft and the DSN together is equivalent to driving an automobile for 3 billion miles without a single failure!
Characteristics of The DSN (3)

Signal Levels

The signal level of a 70m antenna receiving a signal from Pioneer 10 is more than a billion times weaker than the signal received by a direct TV system.

-95 dbm vs. -255 dbm

The most distant spacecraft the DSN currently tracks is Voyager 1. The round-trip light time (RTLT) is 23:12:32. The range to the spacecraft is 12,525 million kilometers.
The destination point for data received by the antennas at any of the three complexes is the Deep Space Operations Control Center at JPL.

- Data is processed for distribution to Scientists around the world, and archived for future use.
- Commands to spacecraft are transmitted through the operation center.