Deep Space Network (DSN) Mission Services and Operations Interface for Small Deep Space Missions

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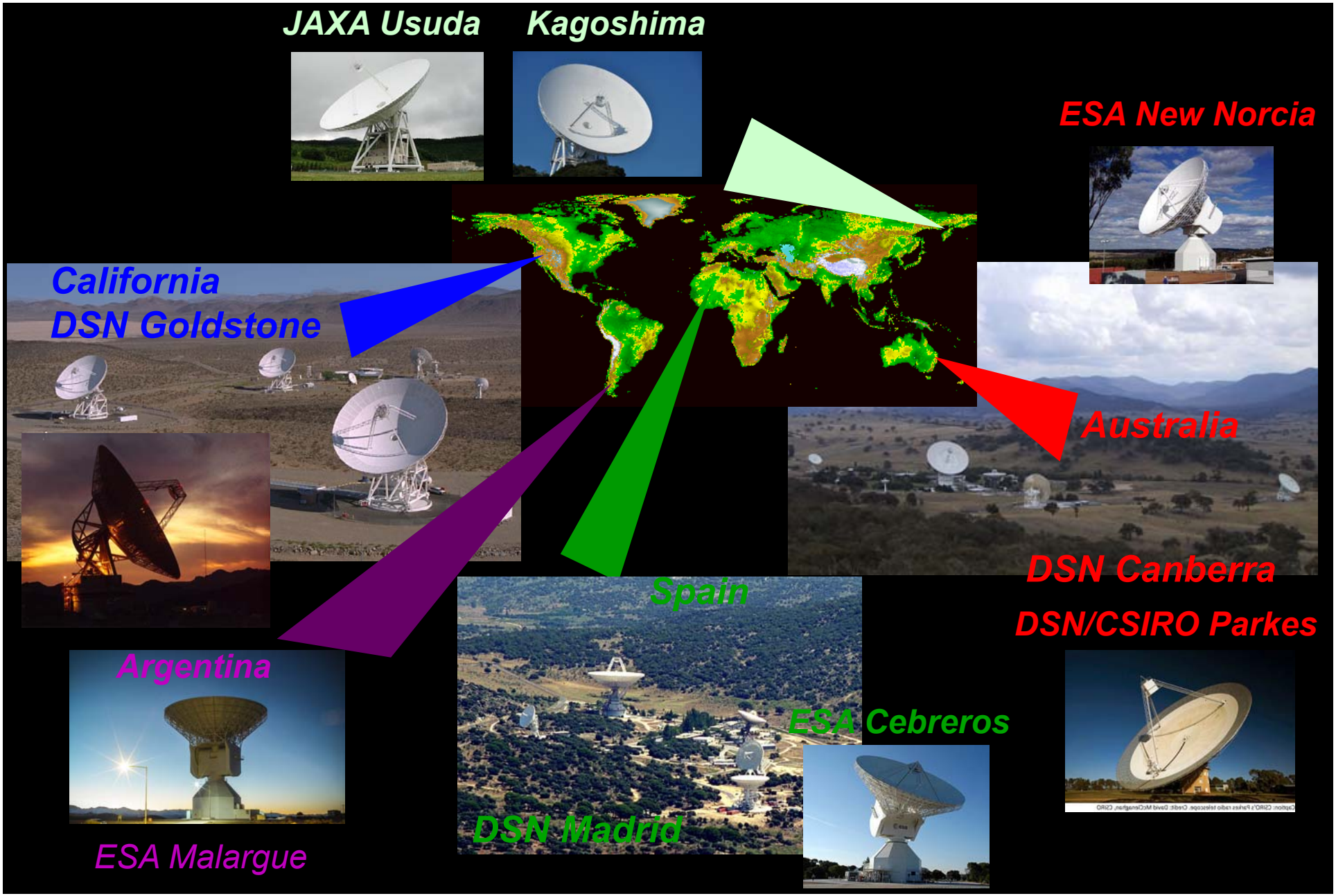
Government sponsorship acknowledged.

Agenda

- Overview of the DSN
- DSN Missions
- Commitments Process for DSN Services
- DSN Service Interfaces and TTC Data Flow
- GLOSSARY

DSN NETWORK OVERVIEW

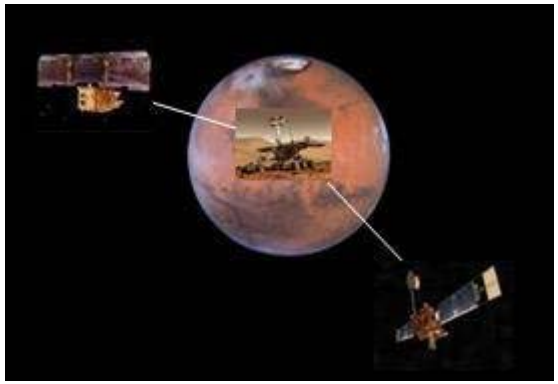
Deep Space Network (DSN): Comprises DSN and Partner 34-70m tracking sites around the globe to provide continuous communication and navigation support



Deep Space Network (DSN)

The Big Picture

DSN Antenna



Spacecraft Operations

DSCC Signal Processing Center (SPC)

WAN

JPL Deep Space Operations Center (DSOC)

Mission Support Area (MSA)

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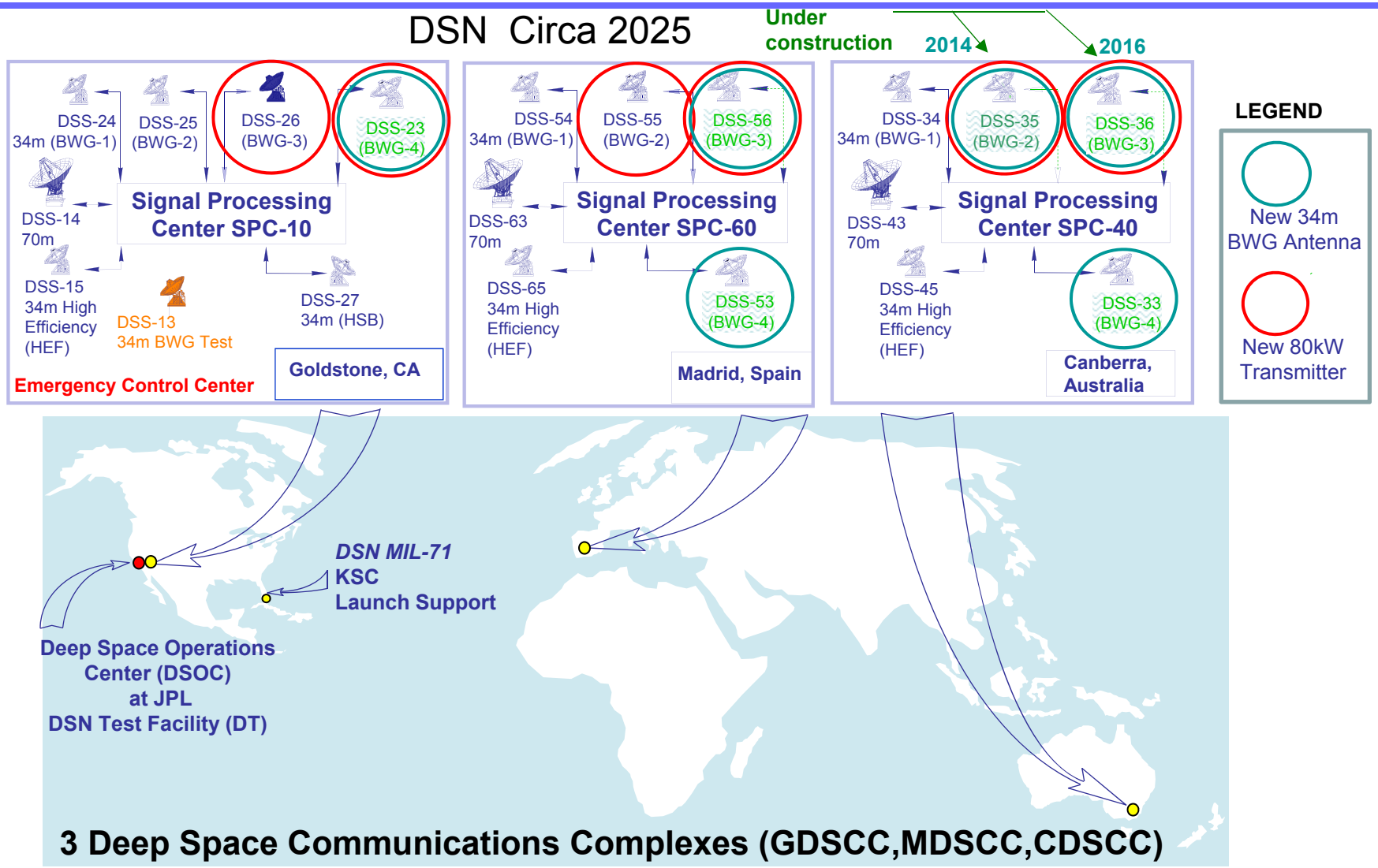
Deep Space Network (DSN)

(Future) DSN Network Overview

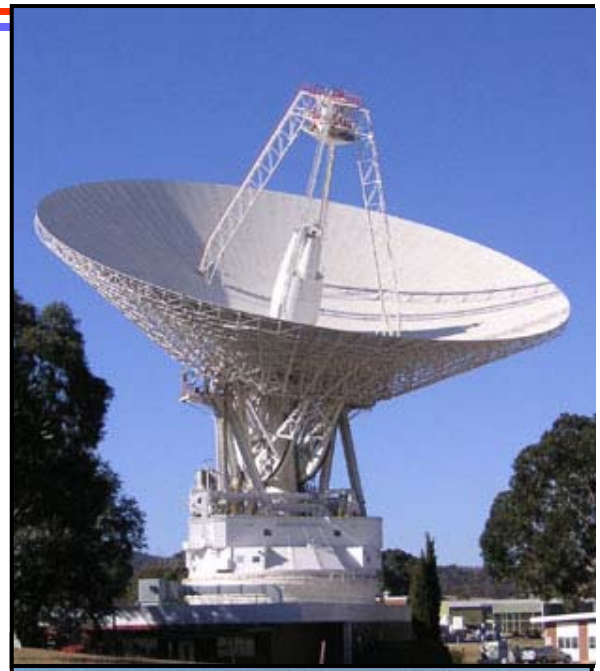


3 Deep Space Communications Complexes (GDSCC,MDSCC,CDSCC)

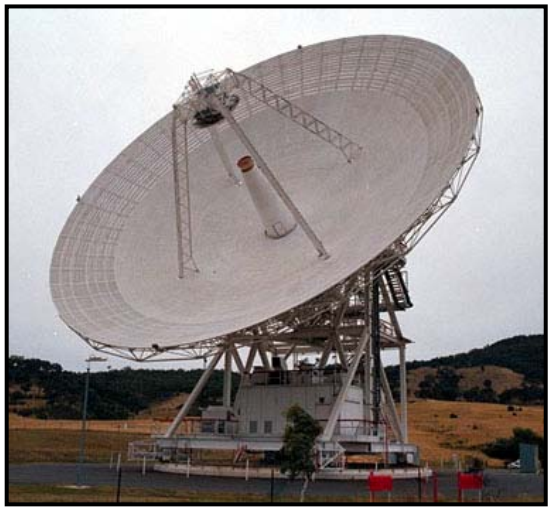
Each Complex has a monitor and control room area within the Signal Processing Center (G:SPC-10, C:SPC-40, M:SPC-60)

DSN Antennas

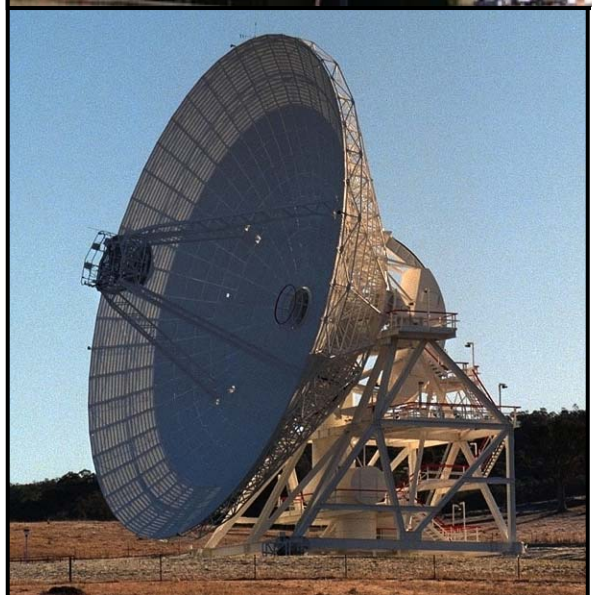
- 70-meter
  - Built in the mid-1960s as 64-meter antennas
  - Expanded to 70-meters in 1980s



- 34-meter High Efficiency (HEF)
  - Built in mid 1980s

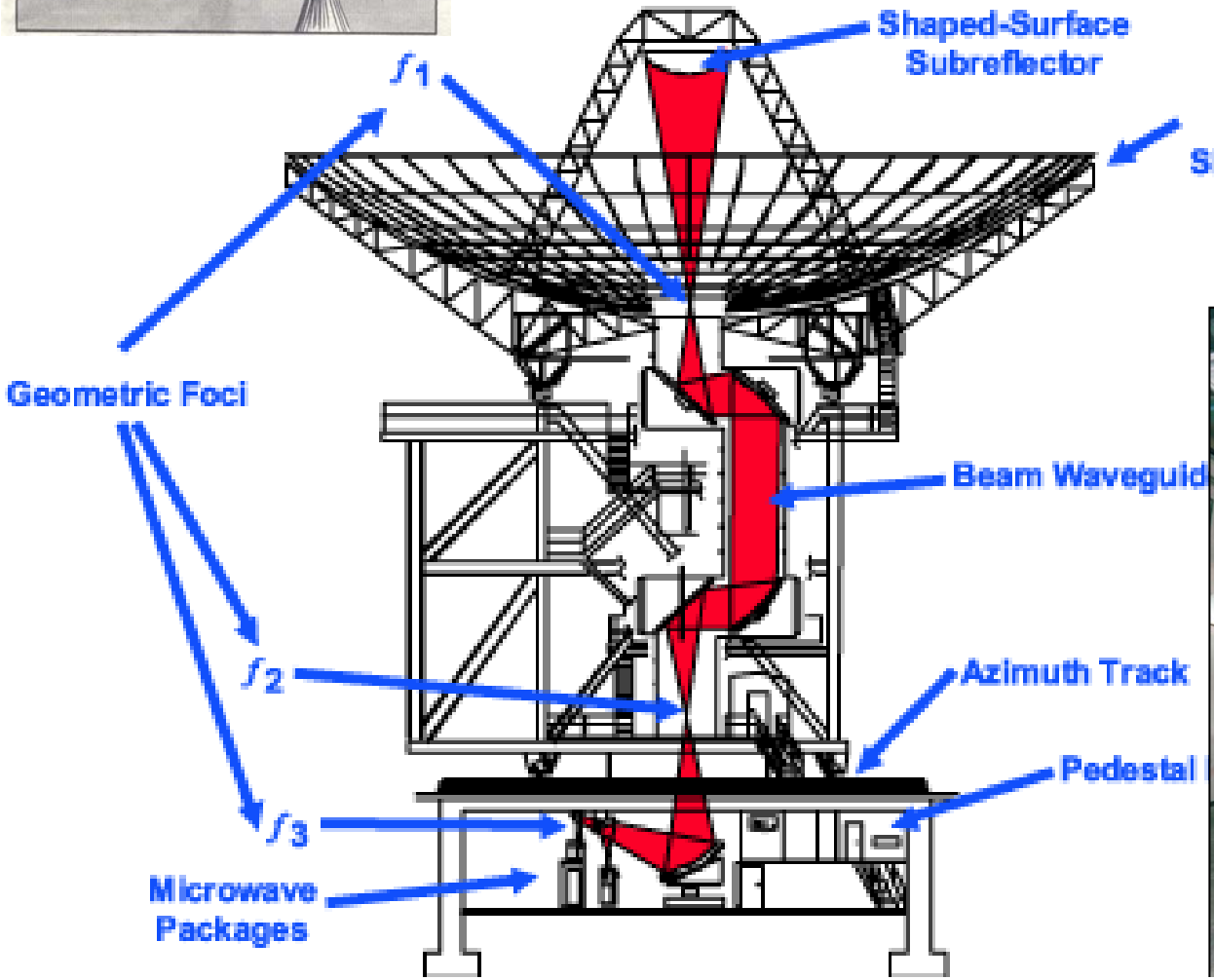


- 34-meter Beam Waveguide (BWG)
  - Built in the mid 1990s
  - Utilizes beam waveguide to remove sensitive electronics from the tipping structure to a below-ground pedestal equipment room



Deep Space Network (DSN)

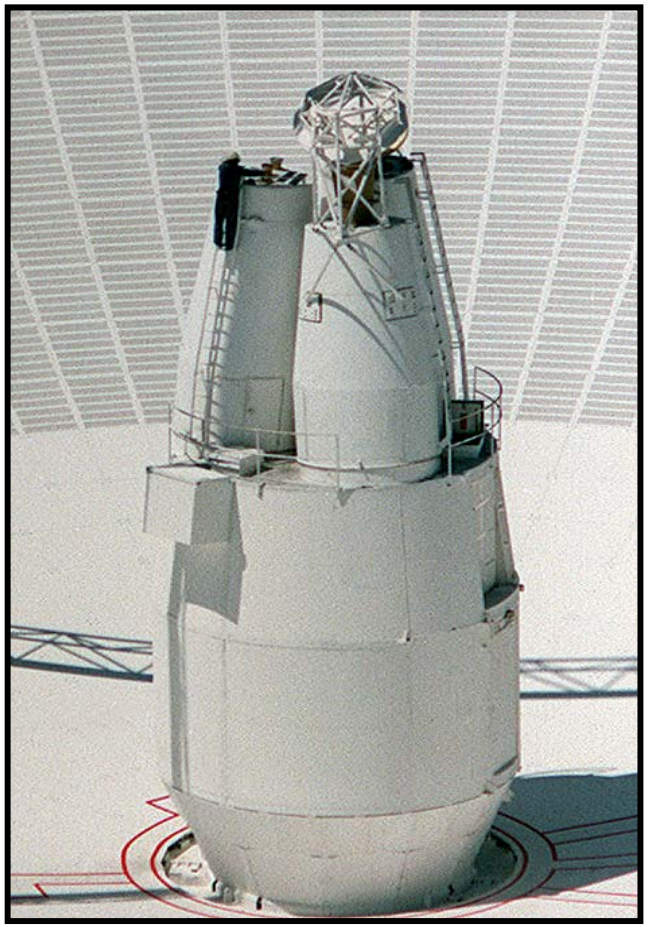
Beam WaveGuide (BWG) Antenna



DSCC Equipment Overview

Antenna Front End Electronics

- Equipment hard-wired to a particular antenna
  - Microwave systems
    - Specially designed feed horns and wave guides support multiple frequencies
      - S-band (~2GHz)
      - X-Band (~8GHz)
      - Ka-band (~32GHz)
      - Ka2 (~26 GHz)
  - Low Noise Amplifiers
    - Cryogenically cooled devices operating around 6-12 K
  - Transmitters
    - High Power Transmitters for both S- and X-bands
    - Radar Transmitters for radar astronomy



Signal Processing Center (SPC) at each DSCC

- Signal transmitted from antenna to SPC for TTC data processing and delivery to JPL Deep Space Ops Center
- SPC equipment is switchable to any antenna or globally shared
  - Data processing equipment for Telemetry, Tracking, Command, and Radio Science
  - Central monitor and control for the DSCC

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DSN Station Capabilities

DSS No.	Antenna Type	Location	Agency / Ops Org	S-Band Uplink Frequency (MHz)	S-Band Downlink Frequency (MHz)	X-Band Uplink Frequency (MHz)	X-Band Downlink Frequency (MHz)	X-Band Receiver Type	Ka-Band Downlink Frequency (MHz)	Ka-Band Receiver Type
14	70m	Goldstone, California	NASA/DSN	2110 - 2118	2270 - 2300	7145 - 7190	8400 - 8500	HMT	-	-
15	34HEF	Goldstone, California	NASA/DSN	2025-2120 (2014)	2200 - 2300	7145 - 7190	8400 - 8500	TWM,HMT	-	-
24	34B1	Goldstone, California	NASA/DSN	2025-2120	2200 - 2300	7145 - 7190, 7190 - 7235	8400 - 8500	TWM	25500 - 27000	HMT
25	34B2	Goldstone, California	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	TWM,HMT	31800 - 32300	HMT
26	34B3	Goldstone, California	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	31800 - 32300	HMT
27	34HSB	Goldstone, California	NASA/DSN	2025-2110	2200 - 2300	-	-	-	-	-
33 (2018)	34B4	Canberra, Australia	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	31800 - 32300	HMT
34	34B1	Canberra, Australia	NASA/DSN	2025-2120	2200 - 2300	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	25500 - 27000, 31800 - 32300	HMT
35 (10/2014)	34B2	Canberra, Australia	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	31800 - 32300	HMT
36 (10/2016)	34B3	Canberra, Australia	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	31800 - 32300	HMT
43	70M	Canberra, Australia	NASA/DSN	2110 - 2118	2270 - 2300	7145 - 7190	8400 - 8500	HMT	-	-
45	34HEF	Canberra, Australia	NASA/DSN	2025-2110	2200 - 2300	7145 - 7190	8400 - 8500	TWM,HMT	-	-
54	34B1	Madrid, Spain	NASA/DSN	2025 - 2110 2110 - 2120*	2200 - 2300	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	25500 - 27000, 31800 - 32300	HMT
55	34B2	Madrid, Spain	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	31800 - 32300	HMT
56 (2020)	34B3	Madrid, Spain	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	HMT	31800 - 32300	HMT
63	70m	Madrid, Spain	NASA/DSN	2110-2118*	2270 - 2300	7145 - 7190	8400 - 8500	HMT	-	-
65	34HEF	Madrid, Spain	NASA/DSN	2025 - 2110	2200 - 2300	7145 - 7190	8400 - 8500	TWM,HMT	-	-
Near Earth Spectrum	-	-	-	2025 - 2110	2200 - 2290	7190 - 7235	8000 - 8400	-	-	-

DSN Test Stations

- DSN Test Stations provide facilities for spacecraft RF compatibility testing and DSN-Mission end-to-end ground data flow test support
  - DSN Test Facility (JPL) (DTF-21)
  - DSN Compatibility Test Trailer (CTT-22)
  - DSN KSC Launch Support Facility (MIL-71)

DSN MISSION SERVICES

DSN Mission Set, 2013

HEO, LEO, Lunar, L1,L2

- CHANDRA
- JWST
- GEOTAIL
- WIND
- SOHO
- ACE
- CLUSTER-1,2,3,4
- MMS-1,2,3,4
- ARTEMIS B & C
- TDRS
- LRO
- GRAIL A & B
- LADEE

Human Space Flight

- EM-1
- EM-2

KEY

- Astrophysics
- Heliophysics
- Planetary Science

DEEP SPACE

- CASSINI
- DAWN
- EPOXI (DI)
- ExoMars 2016, 2018
- InSight
- JUNO
- MARS EXPRESS
- MARS ODYSSEY 01
- MER OPPORTUNITY
- MARS ORBITER MISSION
- MARS RECONN ORBITER
- MAVEN
- MSL CURIOSITY
- OSIRIS-Rex
- ROSETTA
- MESSENGER
- NEW HORIZONS
- PLANET-C
- VENUS EXPRESS
- SPITZER SPACE TELESCOPE
- KEPLER
- VOYAGERS 1 & 2
- STEREO A & B
- Solar Probe Plus

DSN Science:

- EGS
- GAVRT
- GBRA
- GSSR
- HCRA
- SGP

Ground Observations:

- ATOT
- REF FRAME CAL

DSN Cross-Support Services: Partnership with non-NASA Deep Space Networks

Non-NASA deep space partner networks include ESA's ESTRACK, Indian DSN (iDSN), Japanese Deep Space Center (JAXA), South African (SANSA),

DSN Supported Partner Missions

- CLUSTER (ESA)
- ExoMars (ESA)
- INTEGRAL (ESA)
- MARS EXPRESS (ESA)
- ROSETTA (ESA)
- VENUS EXPRESS (ESA)
- XMM-Newton Emergency Recovery Support (ESA)
- GEOTAIL (JAXA)
- Hayabusa (JAXA)
- PLANET-C (JAXA)
- SELENE (JAXA)
- Chandrayaan-1 (ISRO)
- Mars Orbiter Mission (ISRO)
- Phobos-Grunt Emergency Recovery Support (RUS)

Partner Supported NASA Deep Space Missions

- ACE
- DAWN
- InSight
- JUNO
- JWST
- Kepler
- MARS RECONNAISSANCE ORBITER
- MAVEN
- MER: SPIRIT & OPPORTUNITY
- MSL Curiosity
- Phoenix
- SOHO
- STEREO
- Ulysses

DSN Cross-Support Network Services

- DSN X-Support Partner Tracking Networks for NASA Deep Space Missions
  - Japanese JAXA, European ESA, SANSA HBK, Indian ISRO, USN

DSS No.	Antenna Type	Location	Agency / Ops Org	S-Band Uplink Frequency (MHz)	S-Band Downlink Frequency (MHz)	X-Band Uplink Frequency (MHz)	X-Band Downlink Frequency (MHz)	Ka-Band Downlink Frequency (MHz)
38	34m	Kagoshima, Japan	JAXA	2025 - 2120	2200 - 2300	7145 - 7235	8400 - 8500	
48	64m	Usuda, Japan	JAXA	2025 - 2120	2200 - 2300	7145 - 7235	8400 - 8500	
32	35m	New Norcia, Australia	ESA	2025 - 2120	2200 - 2300	7145 - 7190	8400 - 8500	31800 - 32300
84	35m	Malargue, Argentina	ESA	-	-	7145 - 7235	8400 - 8500	31800 - 32300
62	35m	Cebreros, Spain	ESA	-	-	7145 - 7235	8400 - 8500	31800 - 32300
75	15m	Kourou, French Guyana	ESA	2025 - 2120	2200 - 2300	7145 - 7235	8025 - 8500	
74	12m	Santiago, Chile	ESA	2025 - 2120	2200 - 2300			
51	10m	Malindi, Kenya	ESA	2025 - 2120	2200 - 2300		8025 - 8500	
50	12m 7.3m	Hartebeesthoek, South Africa	SANSA	2025 - 2110	2200 - 2300	6800 - 7200	8025 - 8500	
97	11m	Mauritius, Madagascar	ISRO	2025 - 2110	2200 - 2300	-	8025 - 8500	
94	18m	Byalalu, India	ISRO	2025 - 2120	2200 - 2300		8025 - 8500	
95	32m	Byalalu, India	ISRO	2025 - 2120	2200 - 2300	7145 - 7235	8400 - 8500	
91	13m RX 7.3m TX	South Point, HAW	USN	2025 - 2120	2200 - 2300	7145 - 7235	8400 - 8500	31800 - 32300
39	13m RX 7.3m TX	Dongara, AUS	USN	2025 - 2120	2200 - 2300	7145 - 7235	8400 - 8500	31800 - 32300

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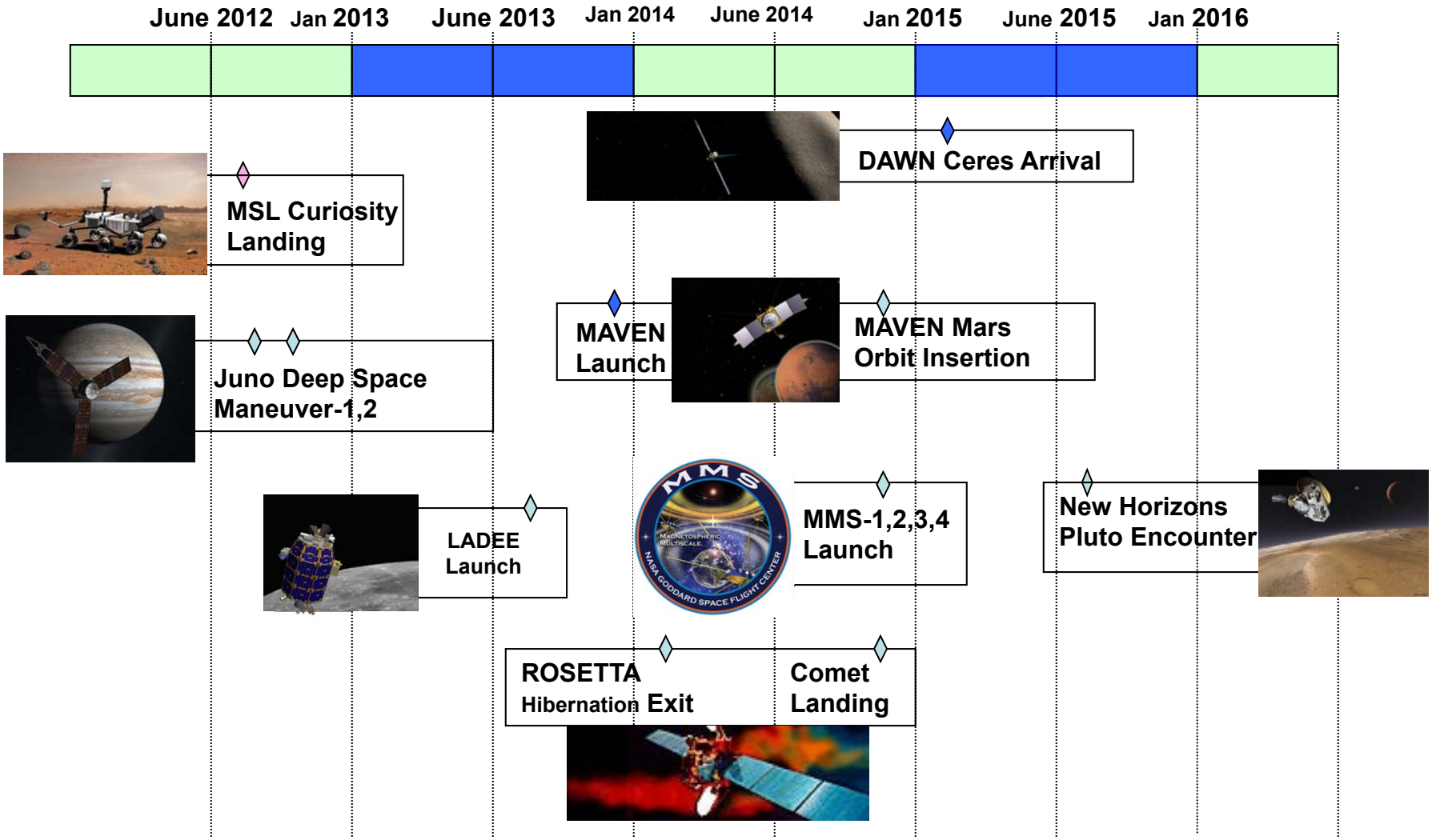
Deep Space Network (DSN)

Mission Events Timeline, Aug 2012 – 2015 (or why I like my job)



Diverse Operations Paradigms

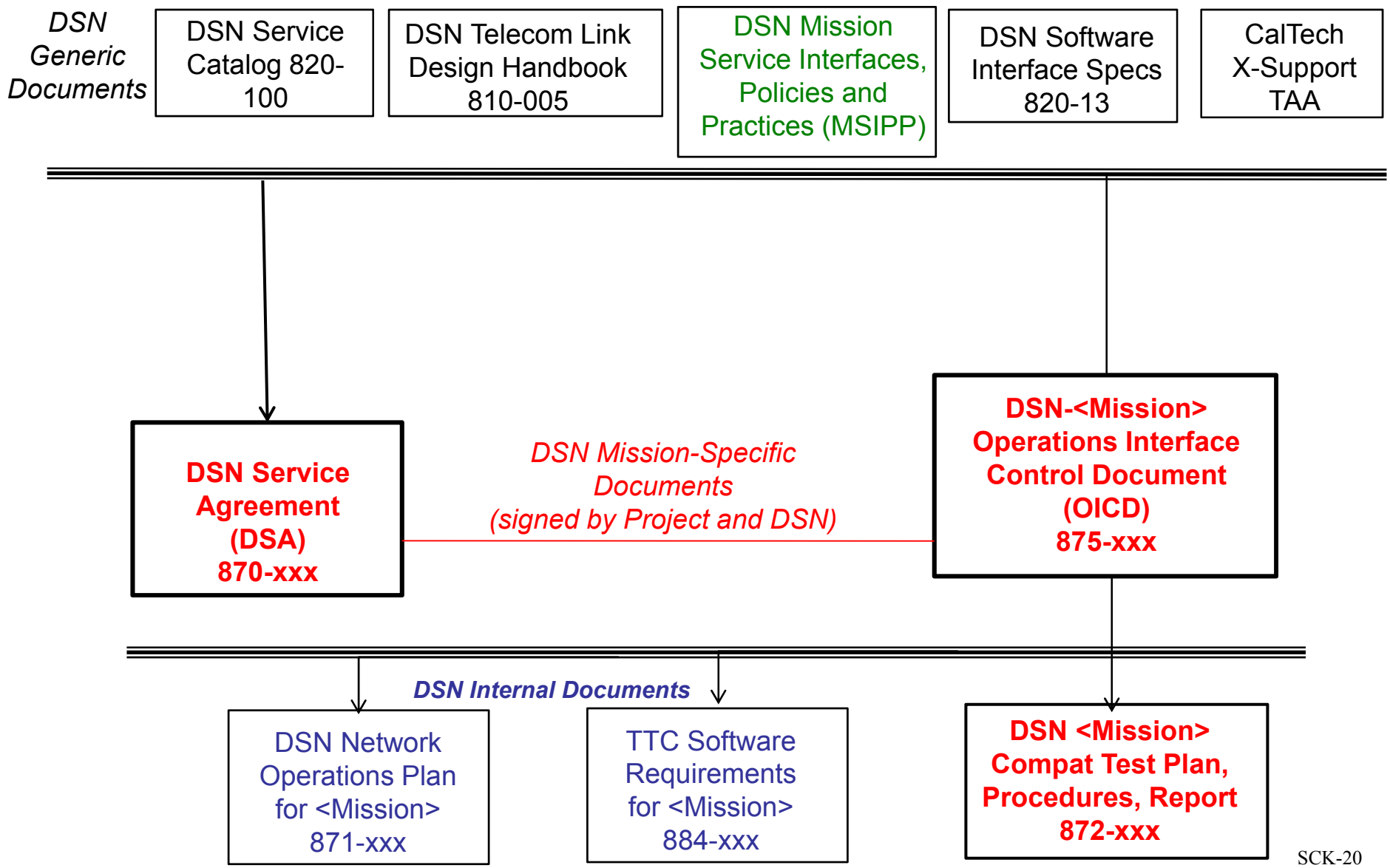
- Missions with lifetime of months vs. decades
- Missions which plan sequences months in advance vs. real-time ops
- Missions staffed 24x7 vs. unattended operations
- Missions with One-Way-Light-Time (OWLT) of seconds vs. hours
- Missions with passes of minutes vs. hours
- Missions in development vs. extended phases covering decades
- Missions with onboard automation vs. ground-intensive ops
- Missions with cruise period of years vs. days
- Missions with cross support across several networks vs. DSN-only
- Data rates at bits-per-second (bps) vs. megabits-per-second (Mbps)

DSN MISSION SERVICE COMMITMENTS PROCESS

DSN Mission Interface

- DMSP&M – DSN Mission Services Planning & Management Office 902
  - DSN Mission Support Definition and Commitments Office (Office 9021) functions as the service provider gateway for all projects.
  - DSN Mission Interface Manager (MIM) is responsible for interfacing with the customers from pre-project planning through design, development, testing, flight operations, and closeout
    - Develop, negotiate, and document the DSN Service Agreement
    - Identify any requirements for new capabilities, non-standard interfaces, and custom engineering support
    - Develop the detailed interfaces from the projects to the DSN
    - Plan and ensure the required RF compatibility and interface testing
    - Plan critical events and ensure the provision of operations support for the mission
    - Represent the project to DSN to assure a continued understanding of the project's needs, concerns, system performance
  - DSN MIM is document owner for Mission DSN Service Agreement and Operations Interface Control Document (OICD)

DSN Mission Interface Document Tree



Generic DSN Mission Services Documents

- **DSN Service Catalog** (DSN 820-100) - provides a comprehensive overview of the capabilities and standard services available from the DSN to support flight projects and experiment investigations.

- **DSN Mission Service Interfaces, Policies and Practices** (MSIPP, 875-001) - establishes basic policies and practices that are applicable to mission customers of the DSN and describes key DSN-Mission Operations interfaces.

- **DSN Telecommunications Link Design Handbook** (DSN 810-005)
  http://deepspace.jpl.nasa.gov/dsndocs/810-005/ – provides a source of technical information useful in the design of spacecraft telecommunications equipment for mission customers. The information is intended to provide reasonable assurance to mission customers that their spacecraft telecommunications subsystem design will be compatible with the established or planned DSN configurations.

- **DSN External Software Interface Specifications** (DSN 820-13 Series) – includes a set of documents that provide detailed definitions of external interfaces between the DSN and mission users. Included within the scope of interface definitions are data delivery protocols, communications definitions/assignments, data formats, data rate characteristics, and physical and electrical characteristics.

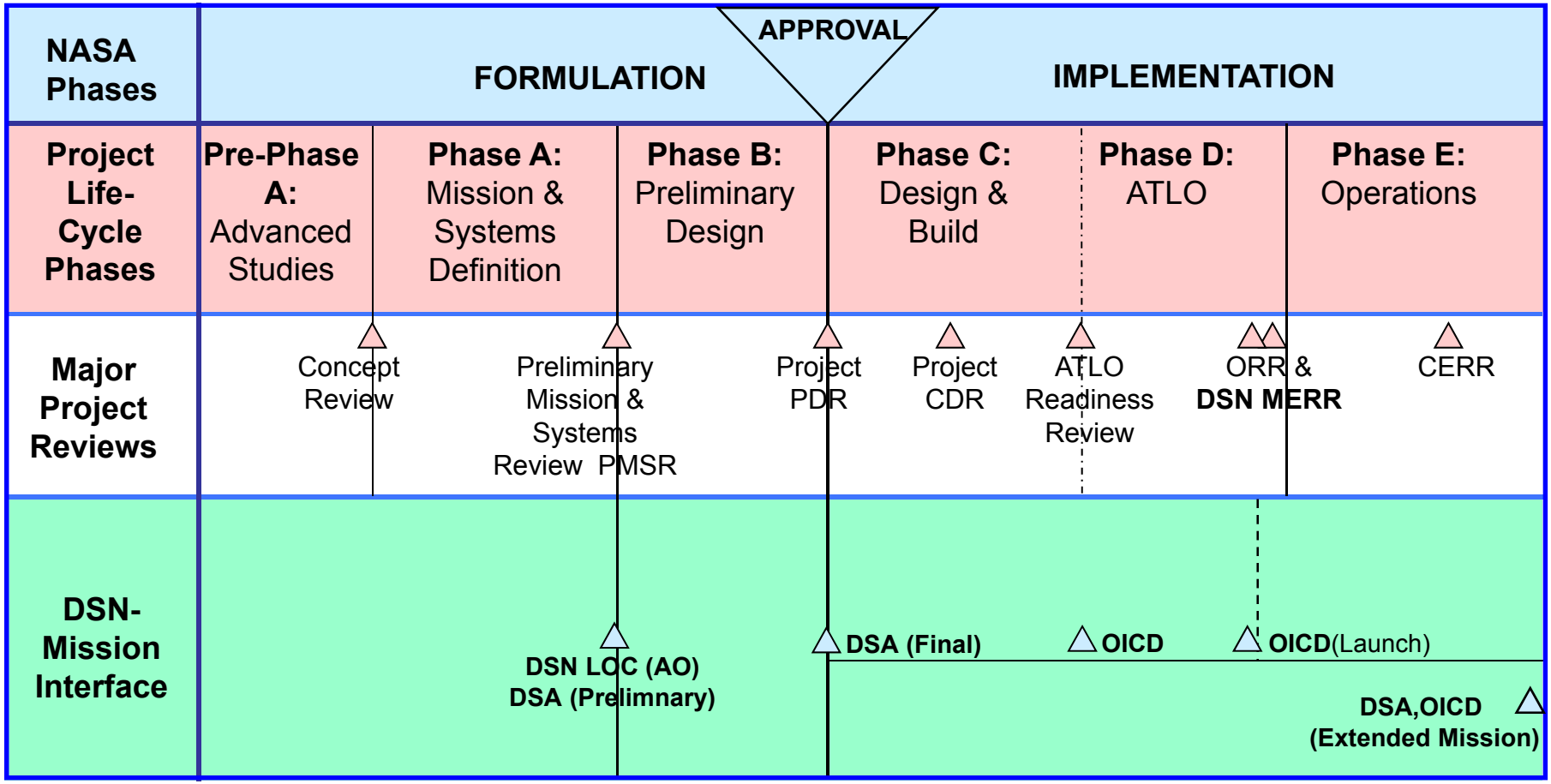
DSN Mission Interface Documents

- **DSN Service Agreement (DSA) for <Mission>**, DSN 870-xxx Series) – documents the commitment for a specific mission to receive standard and custom data services and engineering support from the DSN, including any request for cross-support services using non-DSN stations. This document is in effect until defined end of mission.

- **DSN-<Mission> Operations Interface Control Document (OICD)**, (DSN 875-xxx Series) - defines and controls the software and operational interfaces related to the provision of agreed services and the exchange of mission data between a mission and the DSN. The scope of an OICD includes: RF telecom parameters, operational interfaces, data and product delivery interfaces, service management interfaces, engineering support interactions, service validation, and support plans for critical mission events. This is a living document that is updated as required over the lifetime of the mission.
- *DSN OICD references mission system requirements documents applicable to the DSN and provides an appendix to trace requirements to DSN documents*

- **DSN-<Mission> Compatibility Test Plan, Procedures, and Report** (DSN 872-xxx Series) – documents the DSN RF compatibility test plan, procedures, and results

DSN Interface during Project Lifecycle

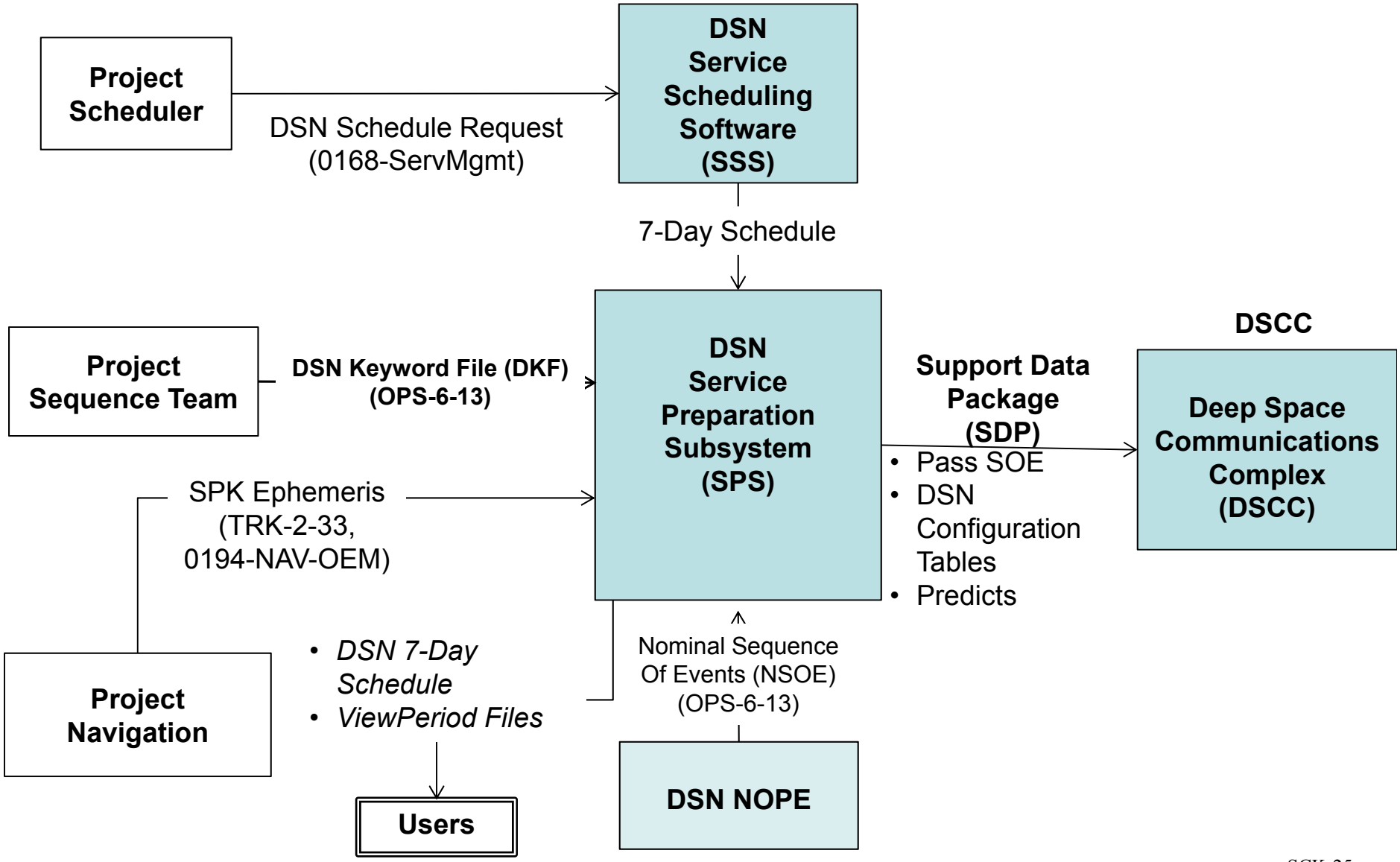


Legend:

LOC:	Letter of Commitment (AO Proposals)
DSA:	DSN Service Agreement
MERR:	DSN Mission Event Readiness Review (MERR)
OICD:	Mission Operations Interface Control Document
ORR:	Operations Readiness Review

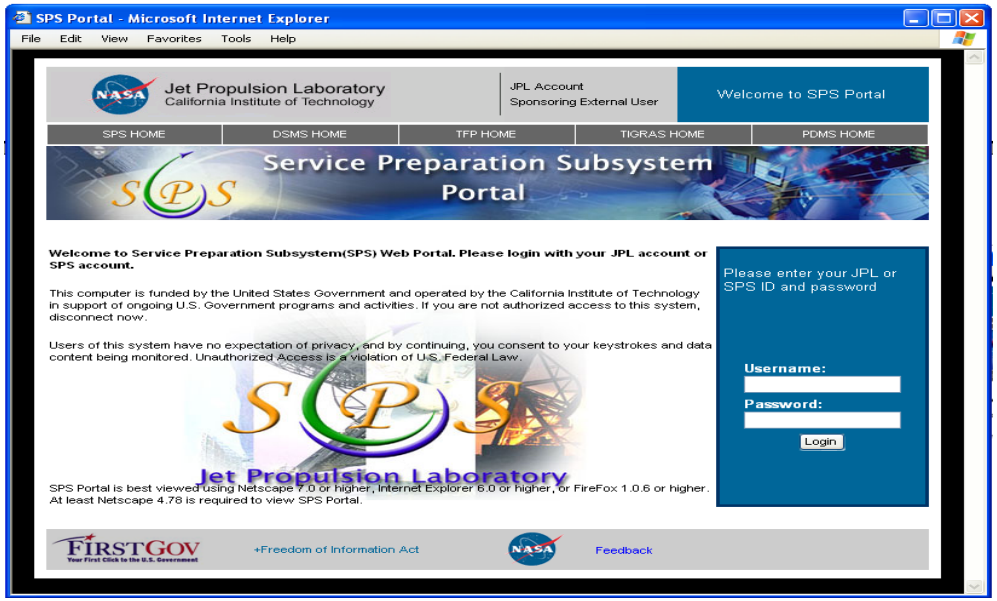
DSN DATA FLOW AND SERVICE INTERFACES

DSN Service Preparation Interfaces



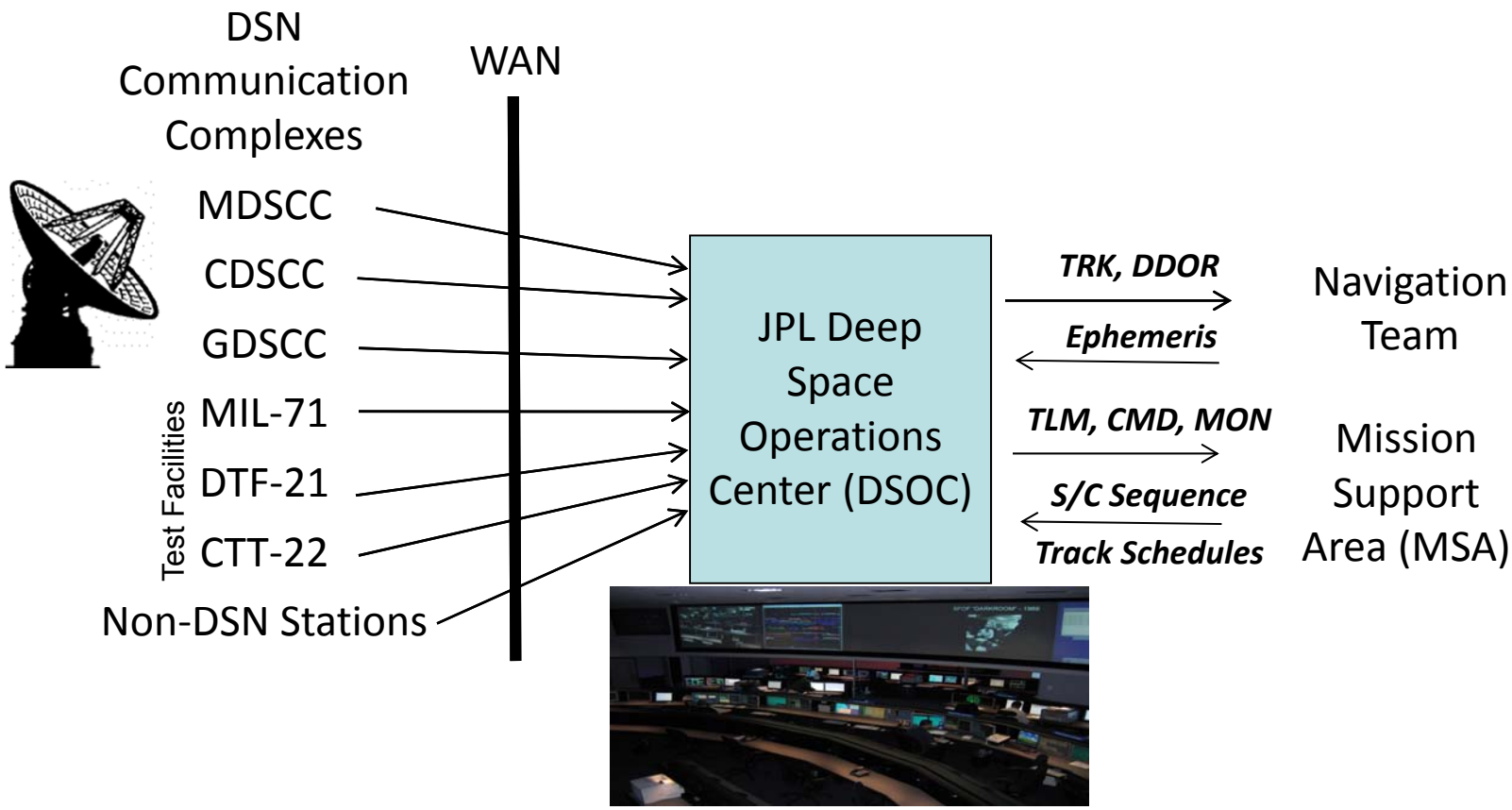
SPS Web Portal

- Located at: https://spsweb.fltops.jpl.nasa.gov
- Includes repository and tools for:
  - Spacecraft Trajectory Files (SPK, EOM)
  - Solar System Body Trajectory Files (Planetary, Satellite, other)
  - Viewperiod Files
  - DSN Sequence of Event (SOE) Files
  - Station Support Data Package (Predicts)
  - Station Configuration Files
  - Radio Source Catalog Files
  - Earth Orientation Parameters (EOP)
- DSN Schedules, including user interface for scheduling change requests
- Developer Resources:
  - SOAP API (file uploading)
  - Documents
  - XML schemas



Deep Space Network (DSN)

DSN Mission Ops Data Interfaces: Big Picture



DSN TTC Equipment

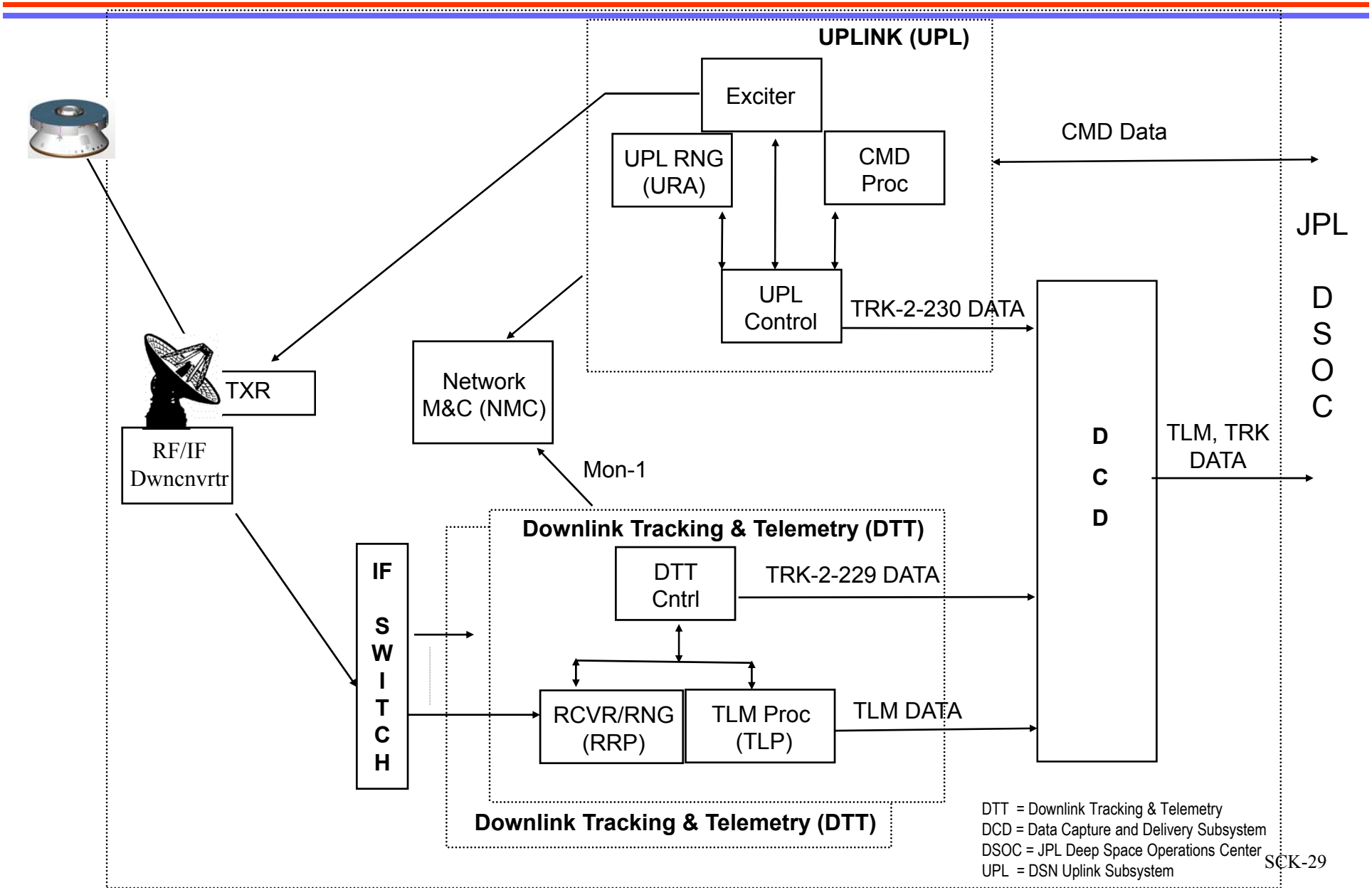
DSCC SPC Equipment

- DSN Uplink (UPL) Command Subsystem
  - Generate command modulation
  - Provide uplink carrier (Exciter and Transmitters)
- DSN Downlink Tracking and Telemetry (DTT)
  - Demodulate the received downlink signal
  - Decode and process the telemetry data
  - Generate the downlink tracking data
- DSN Radio Science Receiver (RSR)
  - Open loop recording of full spectrum
- DSN Full Spectrum Array Processing (FSPA)
- DSN Data Capture and Delivery (DCD)
  - Capture, store, and deliver downlink data from DSCC to JPL DCD

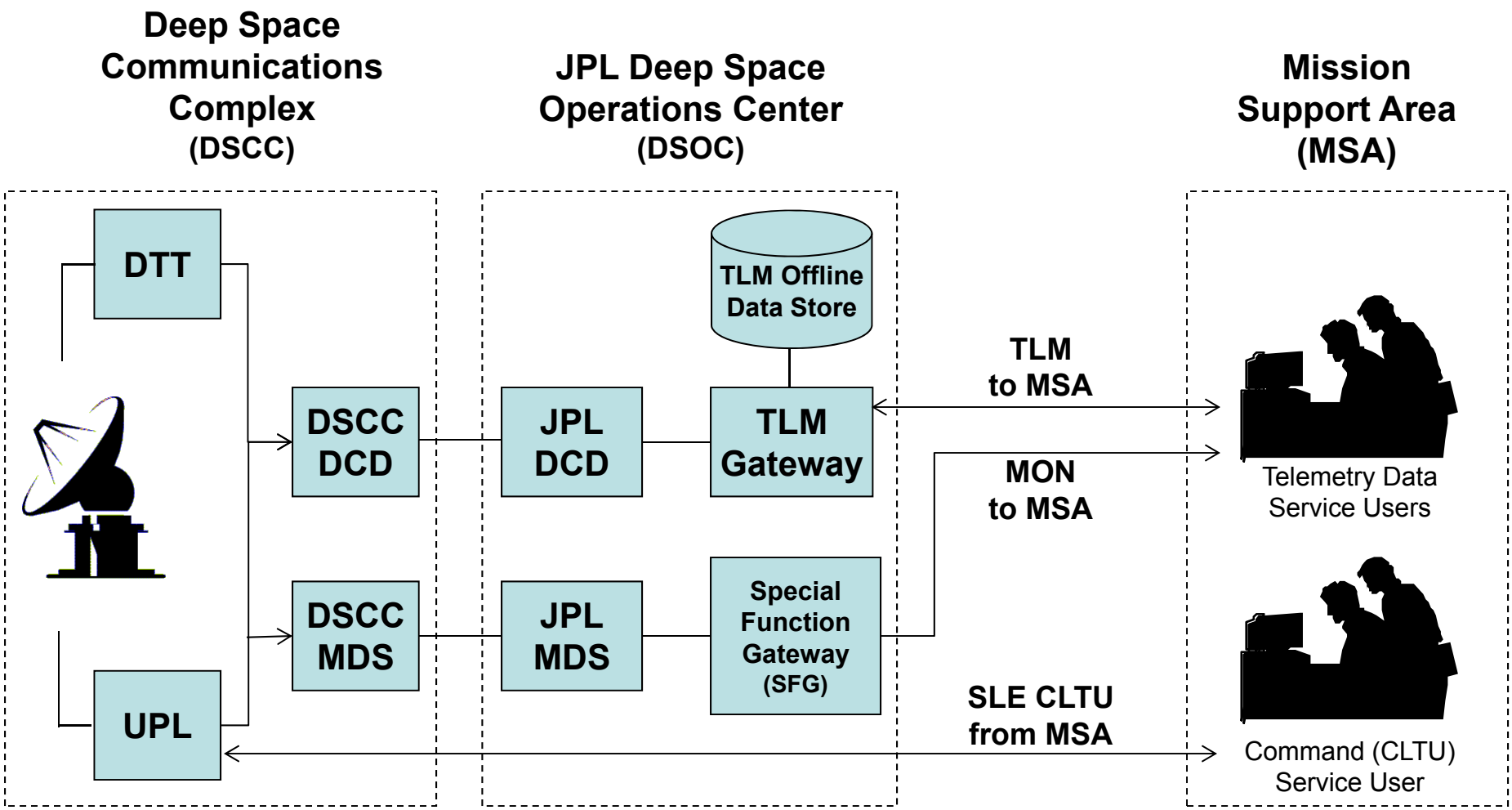
JPL DSOC Software

- Tracking Data Delivery Software (TDDS)
  - Capture uplink/downlink tracking data from station and generate tracking data products (TRK-2-18, TDM, and TRK-2-34)
  - Radiometric Data Conditioning and File Delivery Service (RMDC)
- Telemetry Delivery Software (TDS)
  - Capture and deliver telemetry and monitor data to mission user
- Monitor Input Assembly
  - Capture station monitor data and generate 0158-MON data

Station Uplink/Downlink Data Flow



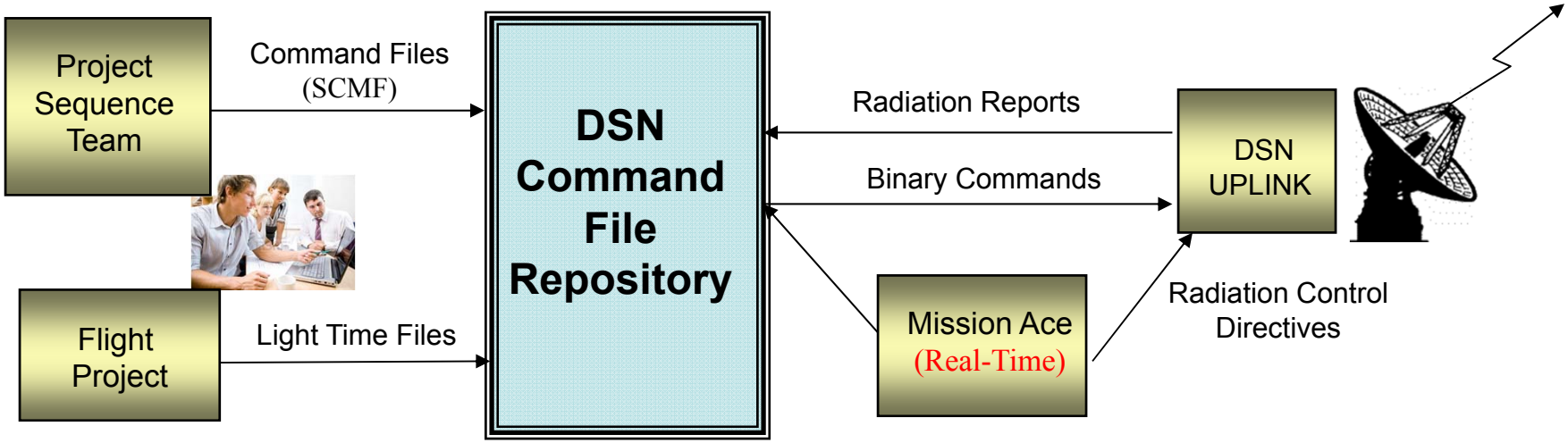
DSN Telemetry, Command, and Monitor Data Flow



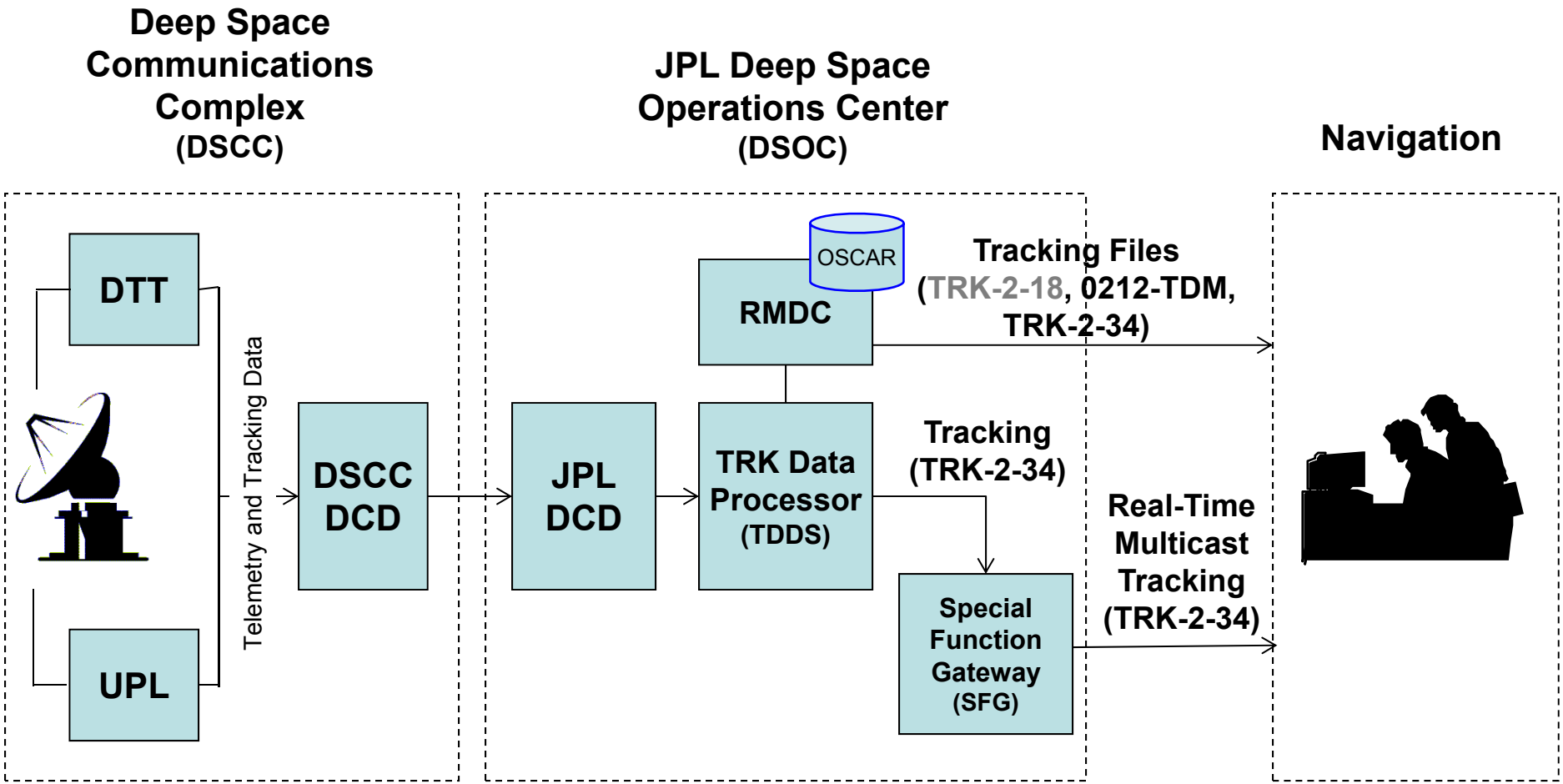
DTT = Downlink Tracking & Telemetry
DCD = Data Capture and Delivery Subsystem
MDS = Monitor Data Server
MON = Monitor data

SLE = Space Link Extension Protocol
TLM = Telemetry data
UPL = DSN Uplink Subsystem

Command Overview



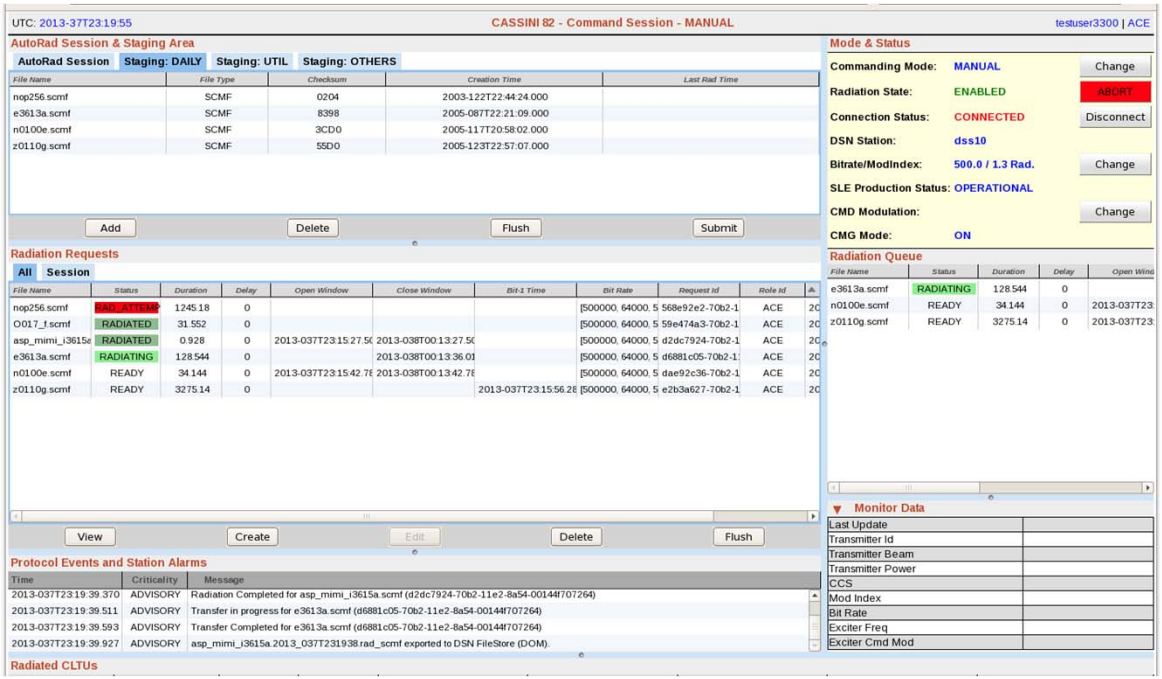
DSN Tracking Data Flow



DTT = Downlink Tracking & Telemetry
DCD = Data Capture and Delivery Subsystem
RMDC = Radiometric Data Conditioning
UPL = DSN Uplink Subsystem

Command Web Interface*

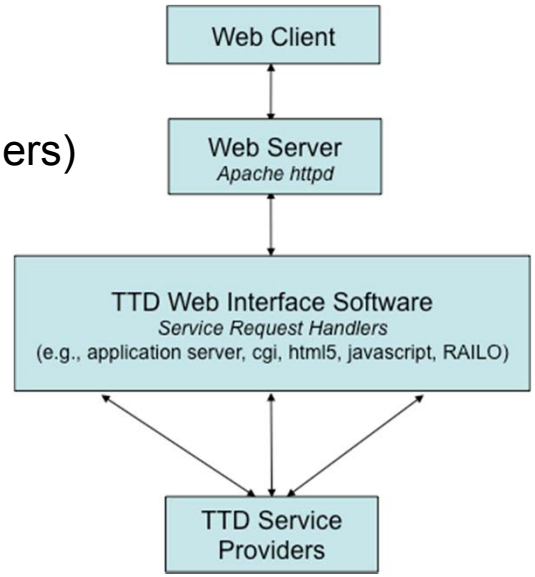
- The DSN provides a platform independent web interface which allows missions to stage command files on a DSN repository for subsequent radiation.
  - Command session controlled can be pre-scheduled or controlled in real-time
  - File interface is through the Spacecraft Command Message File (SCMF) 0198-Telecomm-SCMF
  - Command User Interface capabilities include, authentication, control of radiation requests, viewing monitor data pertaining to command session
  - Transfers files to station for radiation
  - Optionally creates a Rad_SCMF for each radiation request



- Scheduled to be available
- in December 2013

Telemetry Web Services Capabilities*

- The DSN telemetry system will add a new web service interface allowing users to access telemetry services through a secure protocol.
  - Missions users be able to access their telemetry through REST APIs, and web application GUI for:
    - Frame and Packets
    - Metadata, such as pass based data (eg. Lock status vs SNR)
    - Tables, such as data types and quantity delivered
- Query for file of telemetry (packets, frames)
  - Returning binary SFDUs
  - Returning raw packets and frames (stripped of SFDU headers)
  - Returning ascii-formatted telemetry (browser)
  - Returning ascii data set summary (sfducheck)
  - Returning ascii-formatted telemetry parameters (sfdulist)
- Query for stream of SFDUs (packets, frames, channels)
- Create/edit/delete subscriptions
  - Based on passes
  - Based on periodic time intervals



*Available in 2014 - 2015

Glossary

- **DSCC** – Deep Space Communications Complex. Any of three NASA facilities designed to provide telecommunications for flight projects and science data for ground-based observers. Each DSCC comprises a signal processing center (SPC), several deep space stations (antennas and associated equipment), supporting infrastructure. The DSCCs are located in Goldstone, CA; Canberra, Australia; and Madrid, Spain.
- **DSOC** – Deep Space Operations Center. JPL Central Pasadena site which contains DSN operational equipment and from where the Comm Chief, Ops Chief, TSS, DSOT and RSR teams operate.
- **DSIT** - Data System Integration Team. JPL engineers responsible for engineering, integration, test and configuration of the DSOT TTC servers and software processing.
- **DSOT** - "*Data Control*" - Data System Operations Team responsible for TTC E2E data services, including capturing telemetry, tracking, and monitor data from the DSN and processing and delivering data products to the user
- **DSS** – Deep Space Station. An antenna and its associated receive and transmit equipment.

Glossary (Cont.)

- **MIM – DSN Mission Interface Manager**
- **NOPE – DSN Network Operations Planning Engineer**
- **PDSE – DSN TTC Project Data System Engineer**
- **RMDCT** – DSN Radio Metric Data Conditioning Team processes and corrects radio metric data and delivers file products to flight project navigation teams
- **ROC** – DSN Remote Operations Center where DSN operations can be monitored. The ROC is used when conducting DSN training activities and when providing advisory support during mission critical operations for flight projects.