



# Mission Operations

**Sami Asmar**

*Sardinia Seminar*



**Jet Propulsion Laboratory**  
California Institute of Technology

# You are now a: Mission Operations Manager

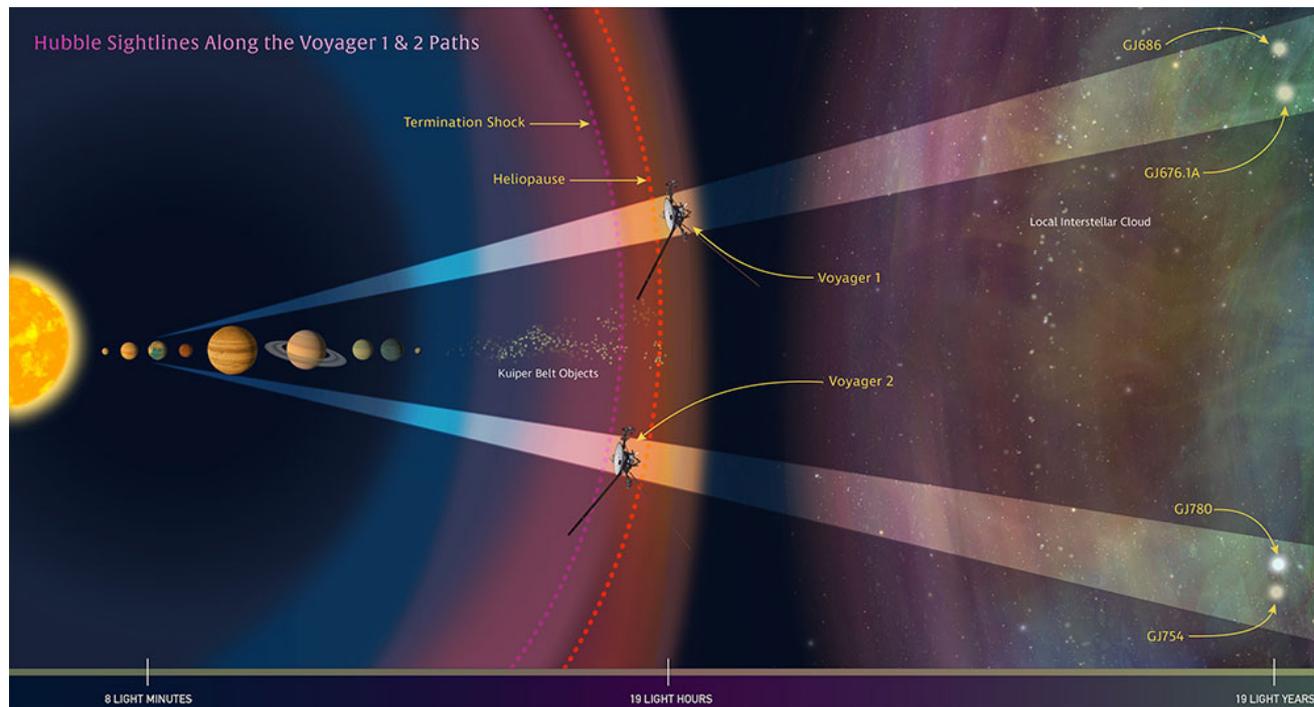
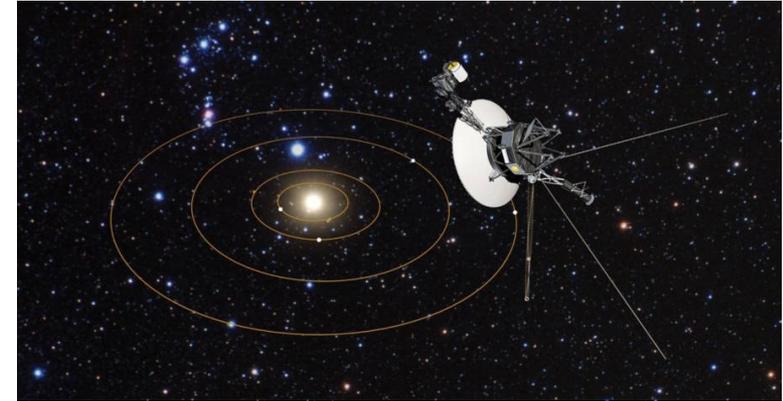
- How do you think
- What are the basic principles of your job
- Mission Phases
- The Round Trip Light Time
- Office Hours on Mars (Sol)
- Live by Sequence numbers
- The Radio Signals
- Navigation products
- Etc.





# Deep Mission Operations At the Speed of Light

- Cannot joystick operations
- Round trip light time (RTLTL) to Voyager 1 is ~40 hours
- Mars RTLTL varies

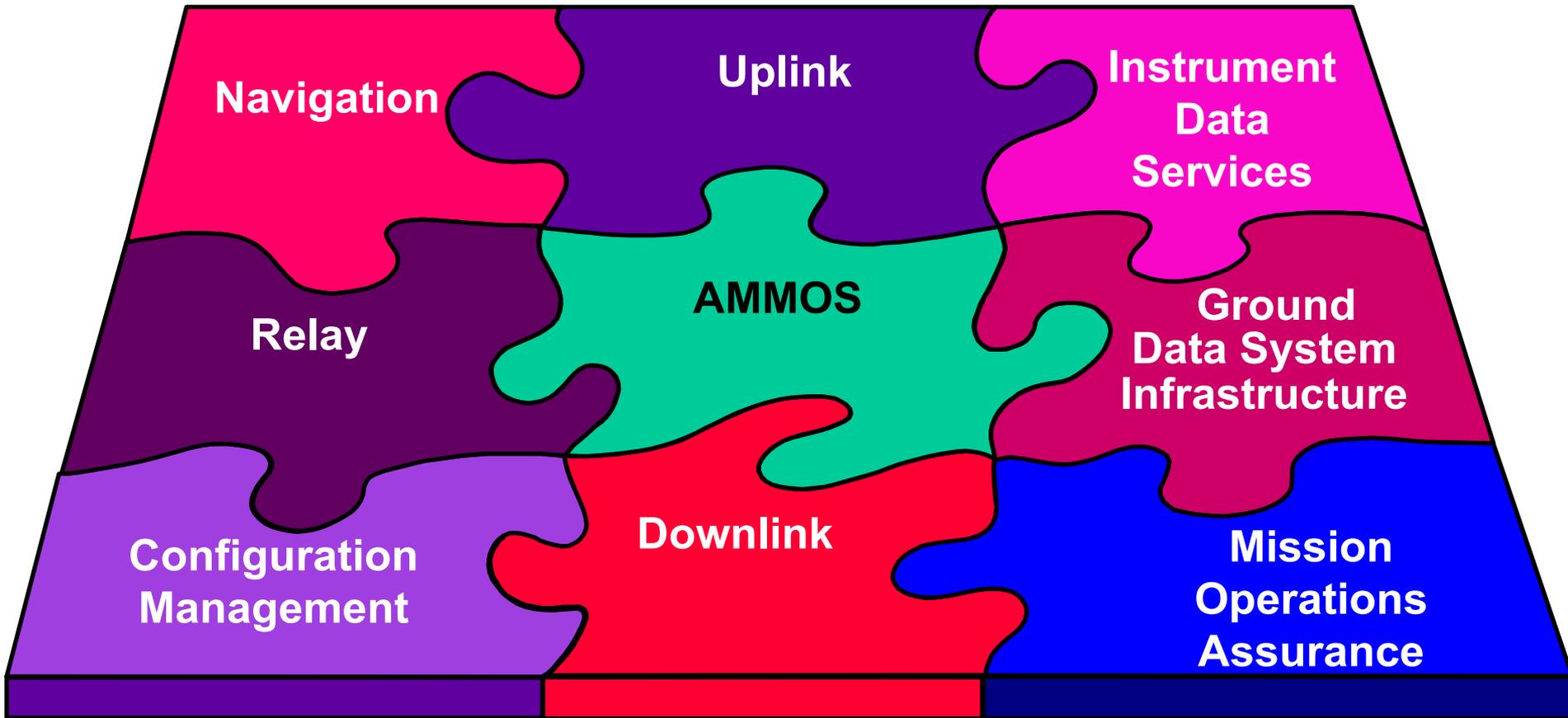


# Failure is Rare

- DSN has provided network support for every successful Mars mission
- To date, NASA, ESA, and ISRO have had successful Mars missions
- JPL NAV has supported every successful Mars mission

<u>Spacecraft</u>	<u>Launch date</u>	<u>Mission</u>	<u>Outcome</u>
<a href="#"><u>Mariner 4</u></a>	28-Nov-64	NASA Flyby	Successful
<a href="#"><u>Mariner 6</u></a>	25-Feb-69	NASA Flyby	Successful
<a href="#"><u>Mariner 7</u></a>	27-Mar-69	NASA Flyby	Successful
<a href="#"><u>Mariner 9</u></a>	30-May-71	NASA Orbiter	Successful
<a href="#"><u>Viking 1 lander / orbiter</u></a>	20-Aug-75	NASA Lander / Orbiter	Successful
<a href="#"><u>Viking 2 lander / orbiter</u></a>	9-Sep-75	NASA Lander / Orbiter	Successful
<a href="#"><u>Mars Observer</u></a>	25-Sep-92	NASA Orbiter	Spacecraft failure
<a href="#"><u>Mars Global Surveyor</u></a>	7-Nov-96	NASA Orbiter	Successful
<a href="#"><u>Mars Pathfinder</u></a>	4-Dec-96	NASA Rover	Successful
<a href="#"><u>Mars Climate Orbiter</u></a>	11-Dec-98	NASA Orbiter	Spacecraft failure
<a href="#"><u>Mars Polar Lander</u></a>	3-Jan-99	NASA Lander	Spacecraft failure
<a href="#"><u>Mars Odyssey</u></a>	7-Apr-01	NASA Orbiter	Operational
<a href="#"><u>Mars Express</u></a>	2-Jun-03	ESA Orbiter	Operational
<a href="#"><u>Spirit (MER-A)</u></a>	10-Jun-03	NASA Rover	Successful
<a href="#"><u>Opportunity (MER-B)</u></a>	8-Jul-03	NASA Rover	Operational
<a href="#"><u>MRO</u></a>	12-Aug-05	NASA Orbiter	Operational
<a href="#"><u>Phoenix</u></a>	4-Aug-07	NASA Lander	Successful
<a href="#"><u>Curiosity (Mars Science Laboratory)</u></a>	26-Nov-11	NASA Rover	Operational
<a href="#"><u>Mars Orbiter Mission</u></a>	5-Nov-13	ISRO Orbiter	Operational
<a href="#"><u>MAVEN</u></a>	18-Nov-13	NASA Orbiter	Operational

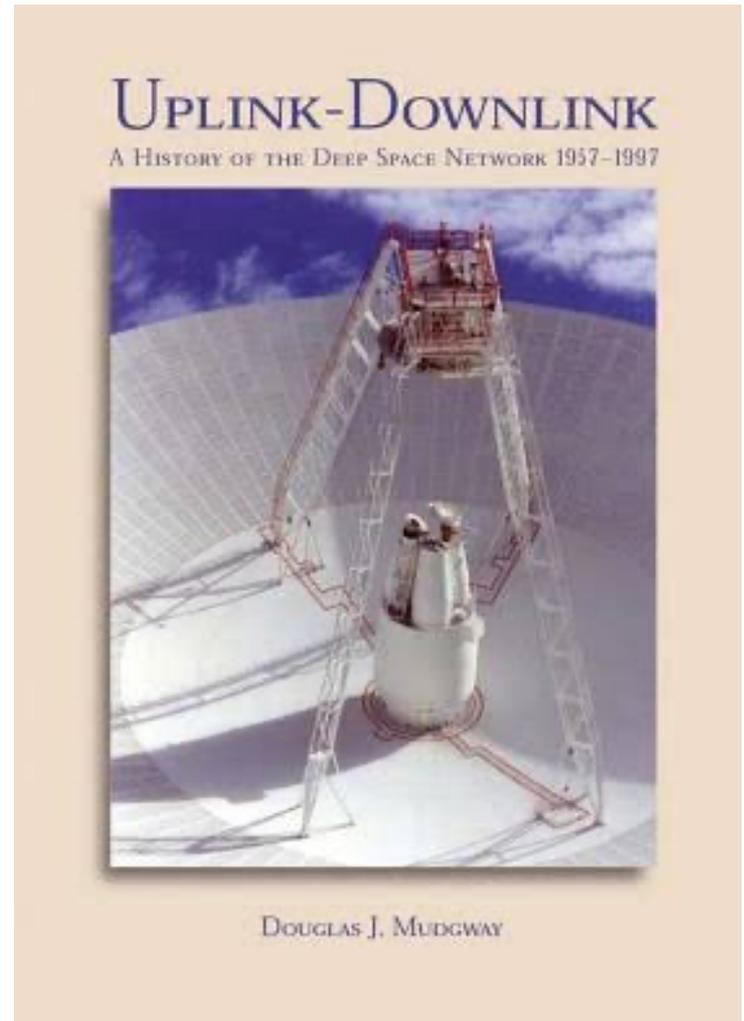
# Mission Operations



*From Advanced Multi-Mission Operations System*

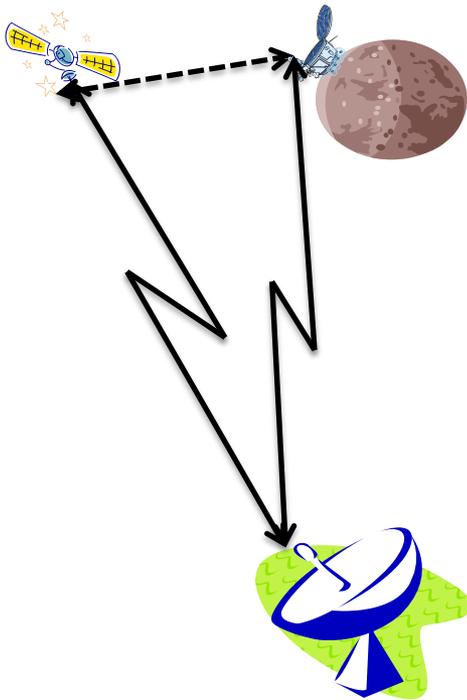
# How Are Missions Operated

- **Elements:**
  - **Uplink-Downlink**
  - **Relay**
  - **Navigation**
  - **Sequencing**
  - **Flight System**
  - **Payload**
  - **Ground System**
  - **Critical Events**
- **Other:**
  - **Mission Assurance**
  - **Configuration Management**
  - **Etc.**



# Uplink & Downlink: Functions of the DSN

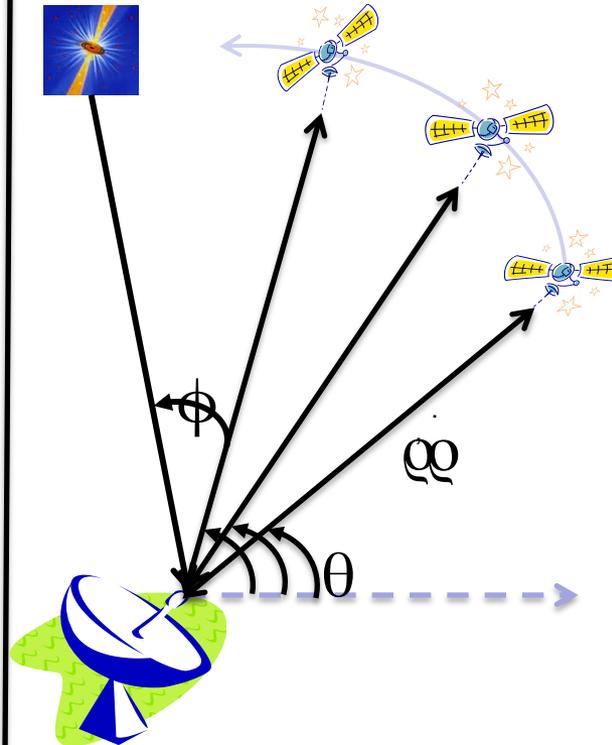
## Telecommunication



**Uplink (Command):** 20KW Transmitters; S-band (2 GHz) and X-band (8 GHz); Data Rates from 10 bps to 10 Kbps

**Downlink (Telemetry):** S-band (2 GHz), X-band (8 GHz), Ka-band (26 or 32 GHz); Data Rates from 10 bps to 125 Mbps

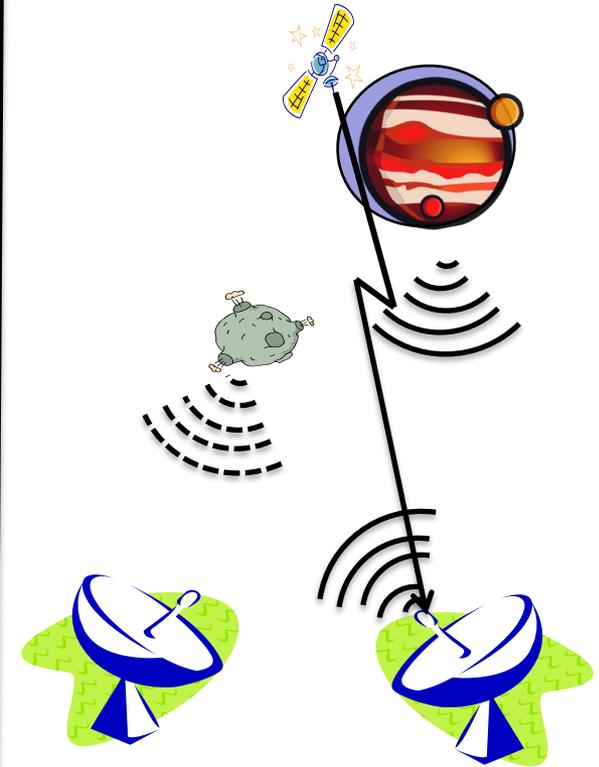
## Tracking



Collect multiple data types used for orbit determination:

- Range
- Doppler
- Angles
- Delta-DOR
- Very Long Baseline Interferometry (VLBI)

## Science



**Radar:** Bouncing a radio signal off a celestial body and processing the received reflected signal

**Radio Science:** Observations of changes in a spacecraft radio signal as it passes through a planetary atmosphere

**Radio Astronomy:** Observations of naturally occurring radio emissions

# NASA DSN and Partner Agencies around the globe provide continuous communication and navigation support for deep space missions

**JAXA Usuda**



**Uchinoura**

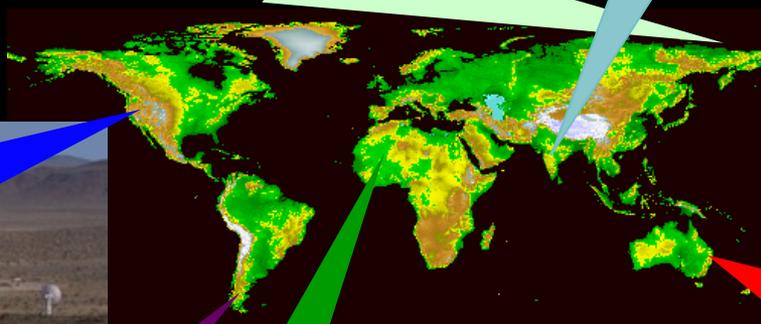


**ISRO IDSN-32**

**ESA New Norcia**



**DSN Goldstone**



**Australia**

**DSN Canberra**

**DSN/CSIRO Parkes**



**Spain**



**DSN Madrid**

**ESA Cebreros**



**Argentina**



**ESA Malargue**

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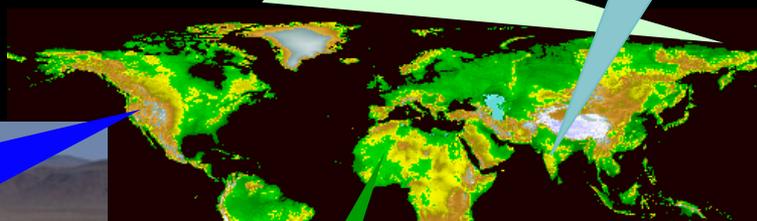


*ISRO IDSN-32*

*ESA New Norcia*



*DSN Goldstone*



**Error Message**

**Slide Is Out of Date!**

*DSN Canberra*

*DSN/CSIRO Parkes*

*Spain*



*DSN Madrid*

*ESA Cebreros*



*Argentina*



*ESA Malargue*



# NASA DSN and Partner Agencies around the globe provide continuous communication and navigation support for deep space missions

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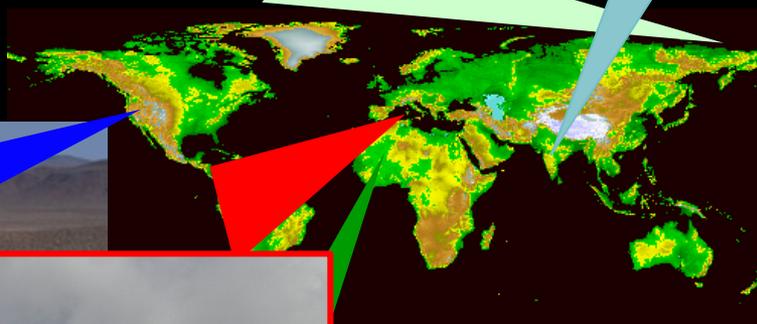


**ISRO IDSN-32**

**ESA New Norcia**



**DSN Goldstone**



**SDSA**



**Australia**



**DSN Canberra**

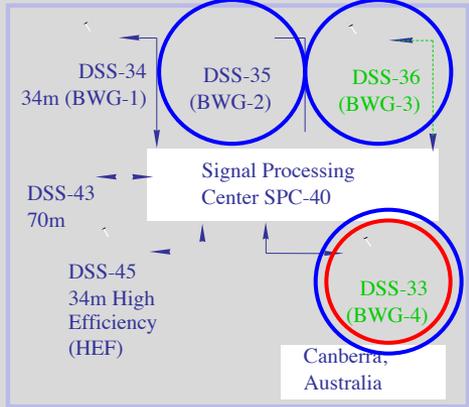
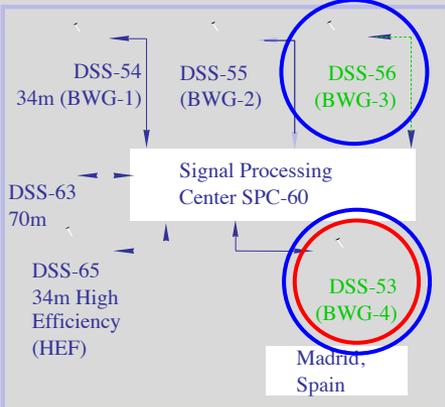
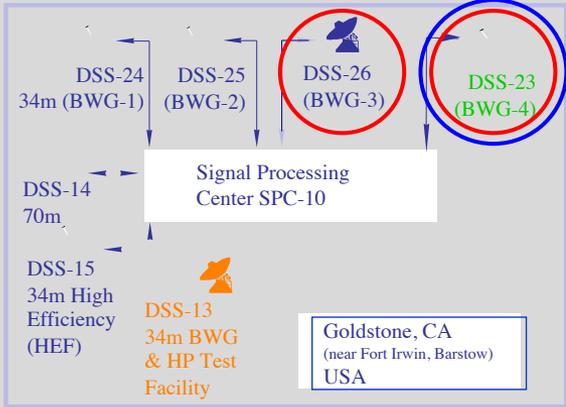
**DSN/CSIRO Parkes**



**ESA Cebreros**



# DSN Facilities by 2025



**LEGEND**



**Antennas**

**Operational Dates**

DSS-35	10/2014
DSS-36	10/2016
DSS-56	10/2019
DSS-53	10/2020
DSS-33	10/2022
DSS-23	10/2024

**80 kW XTR**

**Operational Dates**

DSS-26	9/2015
DSS-53	10/2020
DSS-33	10/2022
DSS-23	10/2024

# Which DSN Station to Request for your Mission

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)
14	70m	Goldstone, California	NASA/DSN	2110 - 2120	2270 - 2300	7145 - 7190	8400 - 8500	-
15	34HEF	Goldstone, California	NASA/DSN	2025 - 2110	2200 - 2300	7145 - 7190	8400 - 8500	-
24	34B1	Goldstone, California	NASA/DSN	2025-2120	2200 - 2300	7145 - 7190, 7190 - 7235	8400 - 8500	25500 - 27000
25	34B2	Goldstone, California	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	31800 - 32300
26	34B3	Goldstone, California	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	31800 - 32300
34	34B1	Canberra, Australia	NASA/DSN	2025-2120	2200 - 2300	7145 - 7190, 7190 - 7235	8400 - 8500	25500 - 27000, 31800 - 32300
35	34B2	Canberra, Australia	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	31800 - 32300
36	34B3	Canberra, Australia	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	31800 - 32300
43	70M	Canberra, Australia	NASA/DSN	2110 - 2120	2270 - 2300	7145 - 7190	8400 - 8500	-
45	34HEF	Canberra, Australia	NASA/DSN	2025-2110	2200 - 2300	7145 - 7190	8400 - 8500	-
54	34B1	Madrid, Spain	NASA/DSN	2025 - 2110 2110 - 2120*	2200 - 2300	7145 - 7190, 7190 - 7235	8400 - 8500	25500 - 27000, 31800 - 32300
55	34B2	Madrid, Spain	NASA/DSN	-	-	7145 - 7190, 7190 - 7235	8400 - 8500	31800 - 32300
63	70m	Madrid, Spain	NASA/DSN	2110-2120*	2270 - 2300	7145 - 7190	8400 - 8500	-
65	34HEF	Madrid, Spain	NASA/DSN	2025 - 2110	2200 - 2300	7145 - 7190	8400 - 8500	-

# Meeting The Challenges of Deep Space Missions

## Deep Space Challenges

- Very Limited Spacecraft Mass, Power, & Volume & Unique Operational Segments
- Extreme Communications Links
- Complex Long-Distance Navigation
- Trajectories Demanding Full-Sky Visibility



Large 34m and 70m antennas, in three complexes ~120 degrees apart via global partnerships, with very sensitive receivers, very powerful transmitters, and very accurate clocks.

Mission-unique operational segments drive mission-specific service planning & scheduling to start a couple of years rather than a couple of weeks prior to launch.

## Mission-Class Drivers

- Observatory-Class Missions
- Legacy Missions
- Outer Planet Missions
- Mars Exploration Missions
- Ground-Based Science
- Human Space Flight ( future )



## Capability Diversity

•Multi-band diversity: Different antennas have different combinations of Cat A S & X, Cat B S & X, Ka 26 GHz, Ka 32 GHz , & Ka 34 GHz; Ka-band operations can be weather driven

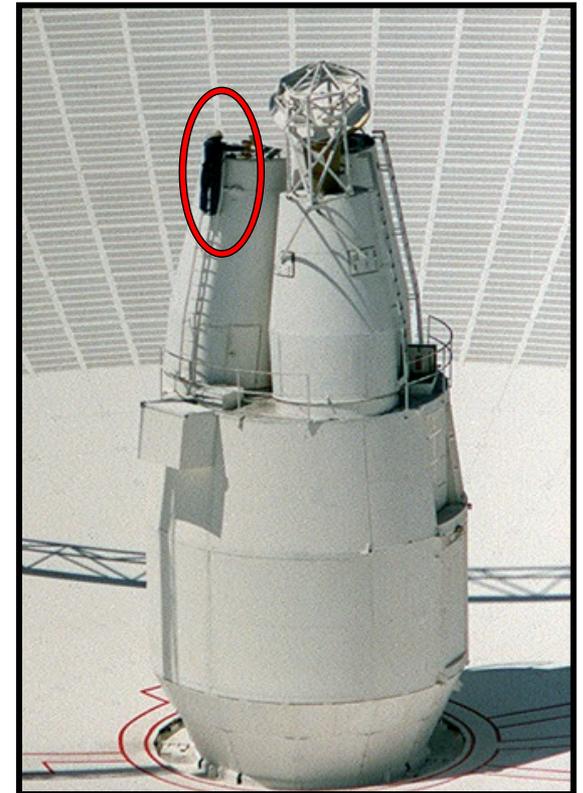
•Receiver/Transmitter diversity: High-rate Ka 26 GHz receivers vs. high sensitivity Block V receivers; transmitter power ranges from 50W to 400 kW, depending upon band & use.

•Coding & Modulation diversity: Multiple telemetry processing, decoding, and formatting schemes

•Antenna Utilization diversity: Single antenna links (1-way, 2-way, & 2-way coherent), multiple antenna VLBI schemes for navigation, multi-antenna arraying, MSPA, and radar.

# What Makes the DSN Unique?

- **Weak downlink signals require:**
  - Very low noise amplifiers (Cryogenically cooled devices operating around 6-12 K)
  - Precise frequency and timing standards
  - Ultra-stable receivers
  - Data rates from 10 bps to 125 Mbps
  - Large, moving antenna structures
- **Uplink to distant spacecraft requires:**
  - High power (20-80 KW X-Band and 20-500 KW S-Band) transmitters / large apertures (high EIRP)
  - Phase continuous ramped uplinks
  - High stability
- **Precision radiometric data requires:**
  - Ranging precision down to the nanosecond level
  - Precision media calibrations
  - Delta-Differenced One-way Range (Delta-DOR) measurements



# DSN Standard Services

- **Command Services**
  - Radiation
  - Delivery
- **Telemetry Services**
  - Frame
  - Packet
  - File
  - Beacon Tone
  - Relay Data Service
- **Tracking Services**
  - Validated Radio Metric Data
  - Delta-Differential 1-Way Ranging (Delta-DOR)
- **Calibration and Modeling Services**
  - Platform Calibration
  - Media Calibration
- **Radio Science Services**
  - Experiment Access
  - Data Acquisition
- **Radio Astronomy / Very Long Baseline Interferometry (VLBI) Services**
  - Signal Capturing
  - VLBI Data Acquisition
  - VLBI Data Correlation
- **Radar Science Services**
  - Experiment Access
  - Data Acquisition
- **Service Management**
  - Allocation and scheduling of assets
  - Configuring, monitoring, and controlling the DSN asset
  - Reporting service execution results

# DSN Operational Staffing Profile

## Deep Space Operations Center (DSOC) at JPL

DSN Operations Chief (Ops Chief)	24X7
DSN Communications Chief (Comm Chief)	24X7
Data System Operations Control (Data Control)	24X7
Tracking Support Specialist (TSS)	24X7

## Deep Space Communications Complexes (DSCCs)

Supervisor on Duty (SOD)	24X7
Link Control Operator (DSS-##)	24X7
Antenna/Hardware Maintenance	8X5 *

## DSN Engineering Staff

JPL Project Management of Non-NASA Mission, Sami Asmar	<i>Business Hours*</i>
DSN System Engineering Team	<i>Business Hours*</i>
DSN Mission Interface Manager (MIM)	<i>Business Hours*</i>
DSN Network Operations Project Engineer (NOPE)	<i>Business Hours*</i>
DSN Integration, Test & Analysis Engineer	<i>Business Hours*</i>
DSN Project Data Systems Engineer	<i>Business Hours*</i>
DSN Ground Communications Product Delivery Manager	<i>Business Hours*</i>

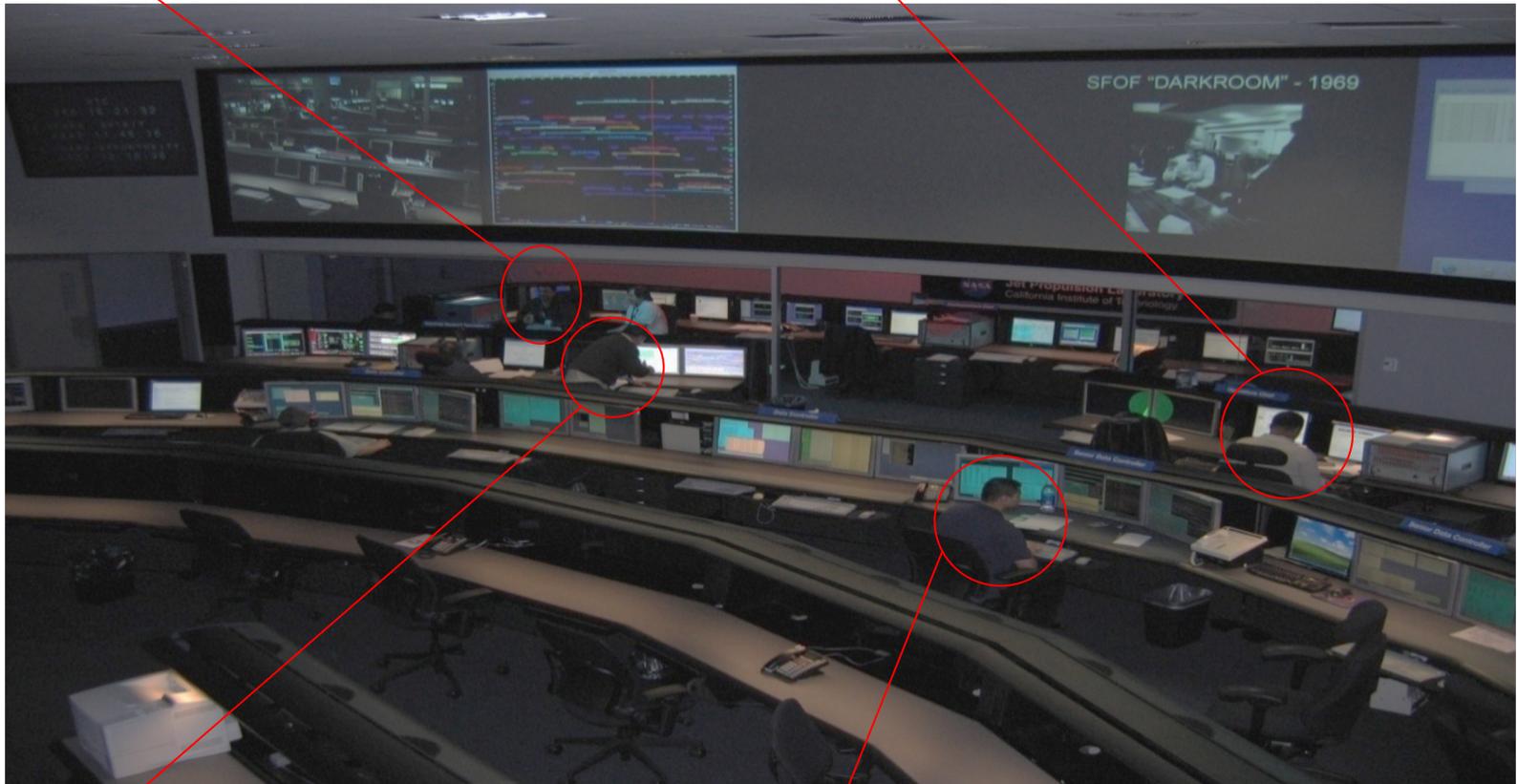
\* Also supports during critical events, as arranged

# Deep Space Operations Center

## The Dark Room at JPL

Comm Chief

Ops Chief



TSS

Data Control

# Deep Space Operations Center

## The Dark Room: Hub of Mission Ops

- Real-time monitoring of all DSN activities 24/7
- DSN Operations & Maintenance contractor
  - Operations planning and scheduling
  - Support product generation
  - Engineering support functions
  - Configuration management
- Data Processing Subsystems
  - Receivers
    - Down-conversion
    - Carrier and sub-carrier detection
  - Telemetry Processing
    - Decoding & Formatting
  - Radiometric Processing
    - Doppler & Ranging
  - Command Processing
    - Formatting & Modulation
  - Monitor and Control
    - Operator interfaces & Monitoring performance
  - Communications
    - Voice and Data



# **DSN is the Ops Manager's Best Friend!**

- **Tracking support for from launch through on-orbit operations**
- **plays a key role as a member of the Flight Project's Ground System Team**
- **DSN ensures success with:**
  - **comprehensive pre-launch compatibility testing**
  - **end-to-end ground system interface testing**
  - **operational scenario tests and nominal and faulted Launch/MOI Operations Readiness Tests**
  - **Integrated network data flow simulations ensure success with multiple backup stations for critical events**

## **DSN Mission Interface Manager (MIM)**

- **Serves as primary point of contact for DSN service commitment and management throughout the mission lifecycle (Mission Phase B to Phase E)**

## **DSN Network Operations Project Engineer (NOPE)**

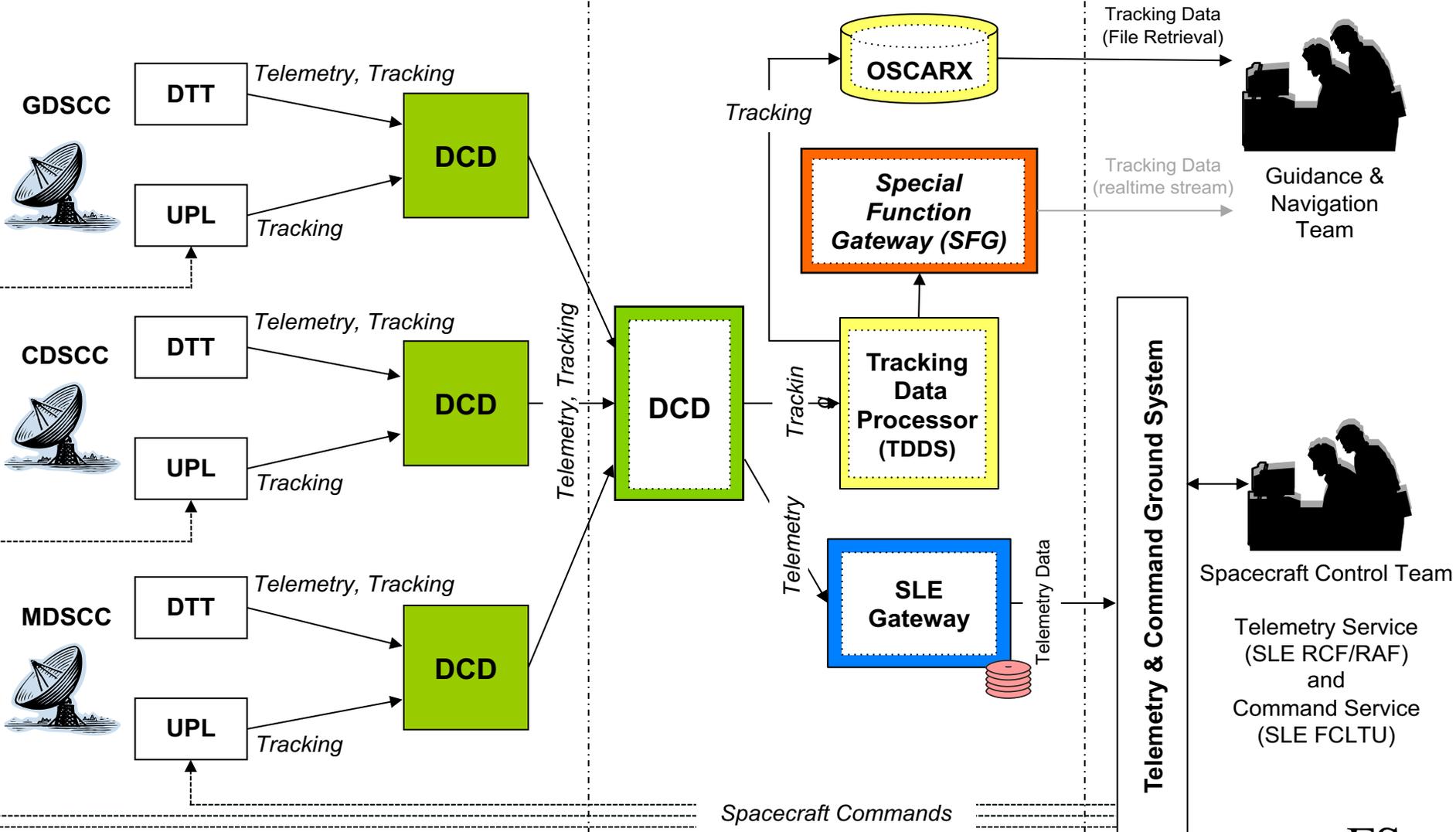
- **Serves as primary point of contact for DSN operations-related activities in preparation of and during Mission Phase E**

# Telemetry, Tracking, and Command DSN High-Level Dataflow

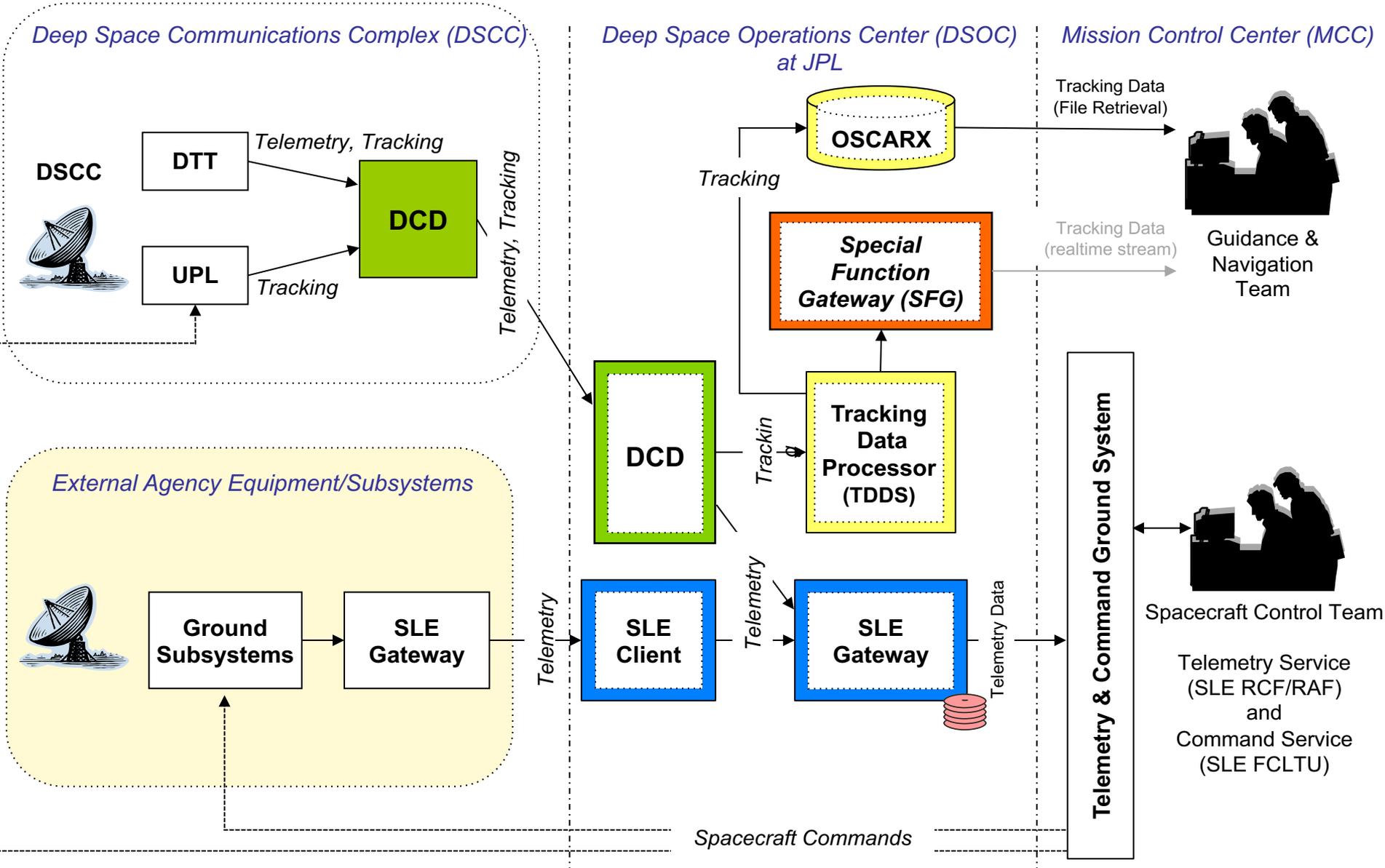
*Deep Space Communications Complex (DSCC)*

*Deep Space Operations Center (DSOC) at JPL*

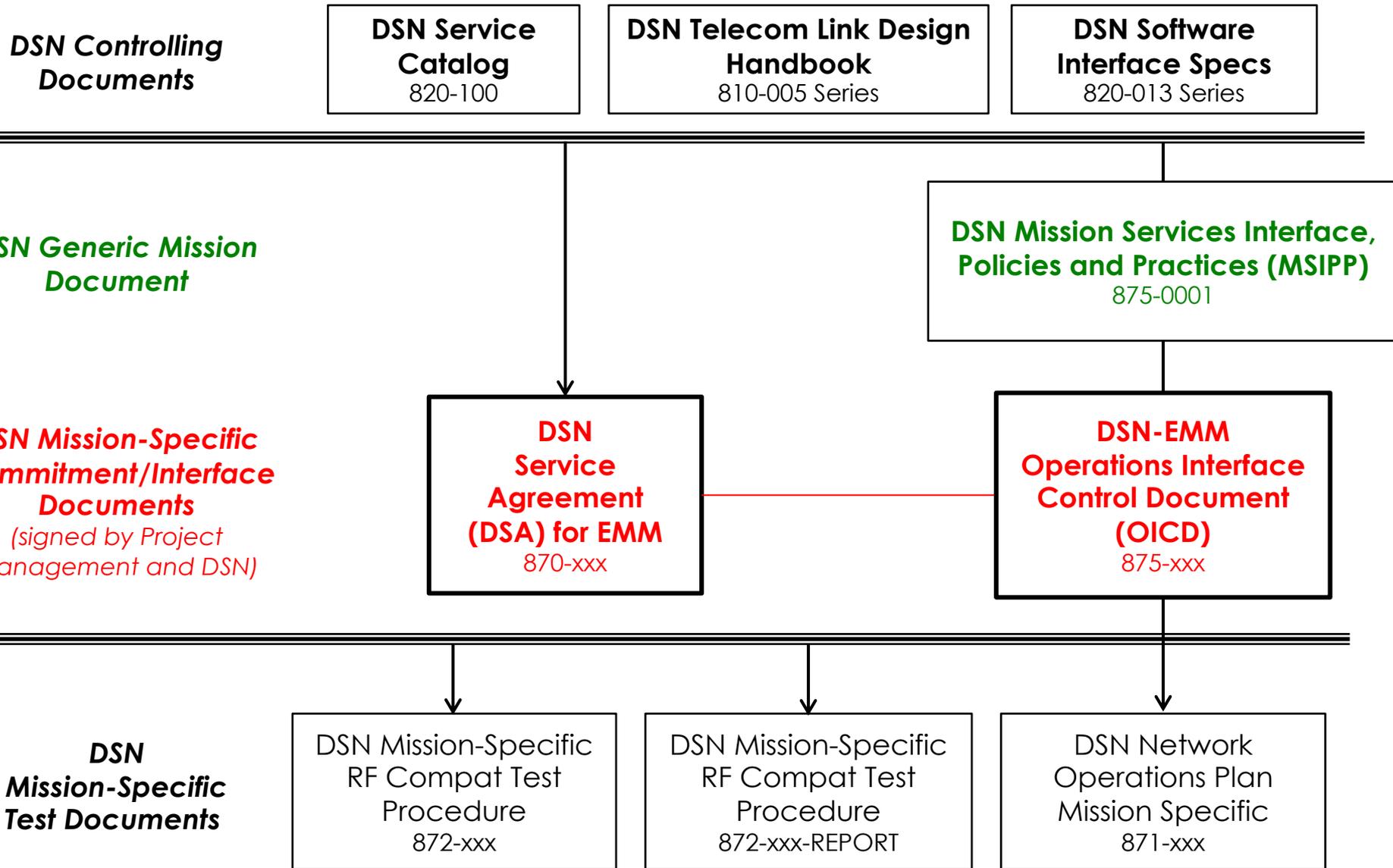
*Mission Control Center (MCC)*



# Cross Support for External Agency S/C



# DSN Mission Interface Document Tree



# DSN Support Levels

- **DSN Level-1 (L1) Support**

- Highest sustainable degree of responsiveness by adding on-site DSN personnel support
  - DSN deploys up to 100 additional staff
    - ~20 per complex and ~40 SFOF and ROC/Harris
- Highest sustainable degree of reliability by scheduling of dual/backup DSN assets
- Examples: launch, planetary encounter, unique scientific event

- **DSN Level-2 (L2) Support**

- High sustainable degree of responsiveness by adding on-site and/or on-call DSN personnel support
- High sustainable degree of reliability by scheduling of dual/backup DSN assets
- Examples: critical command pass or maneuver prior to planetary encounter

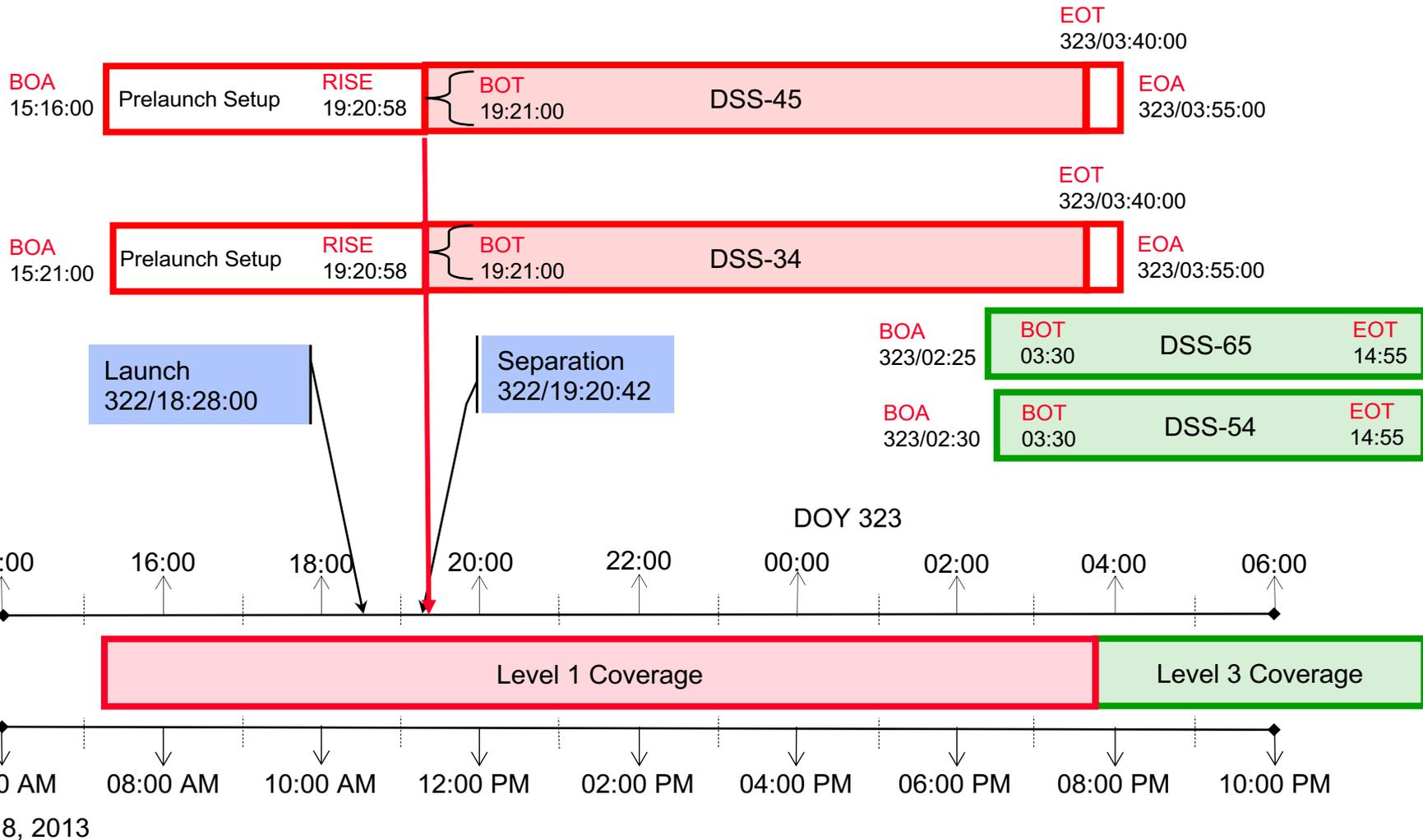
- **DSN Level-3 (L3) Support**

- Ground system availability that is commensurate with important events
- DSN deploys one to three additional staff (nominally)
- Example: spacecraft propulsive maneuver

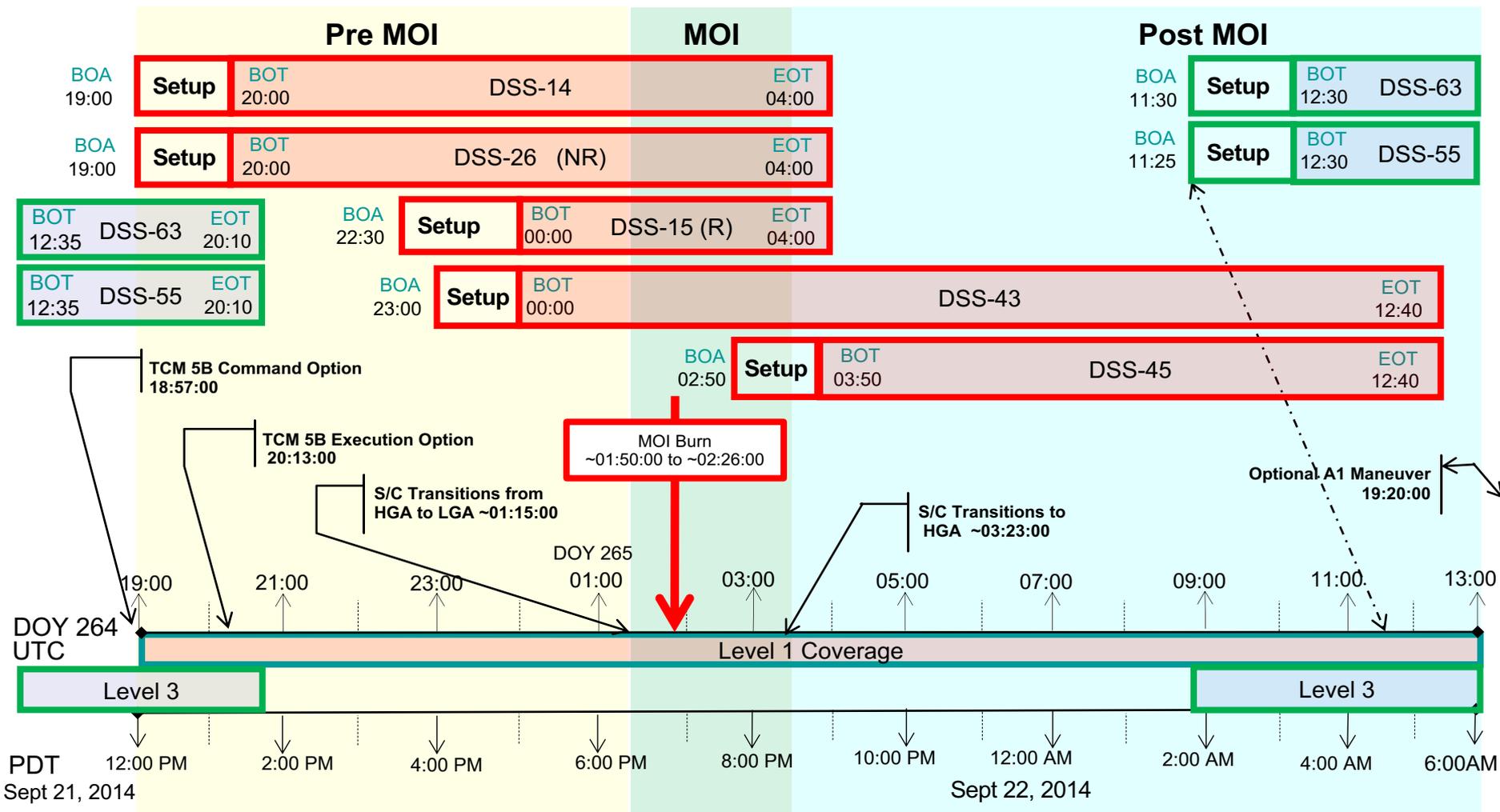
- **DSN Level-4 (L4) Support**

- Routine mission operations
- Nominal staffing provides the required expertise to conduct routine operations and effect rapid recovery or workaround in case of problems

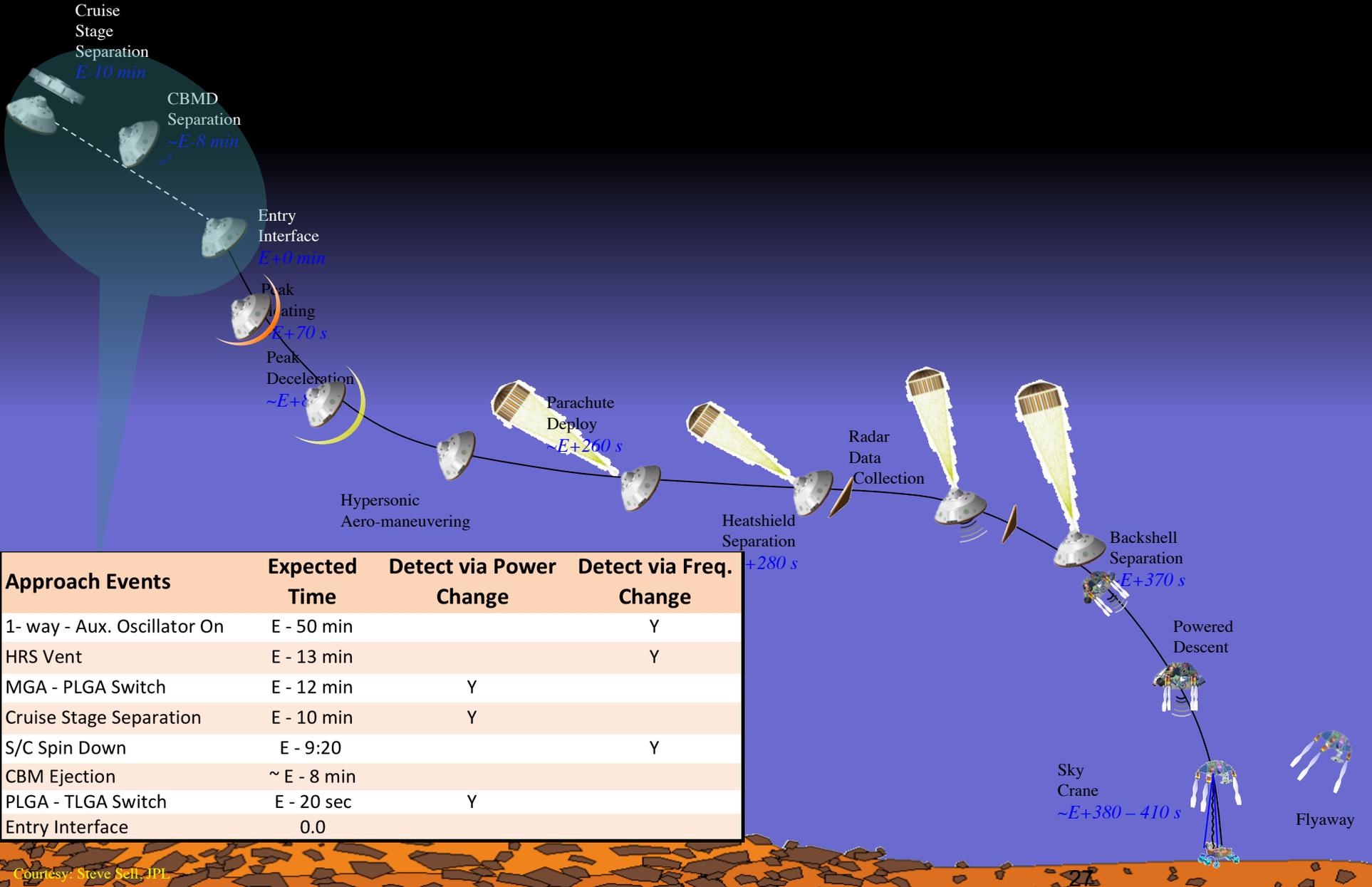
# Example Timeline during DSN L1 Support



# Example Timeline during DSN L1/L3 Support



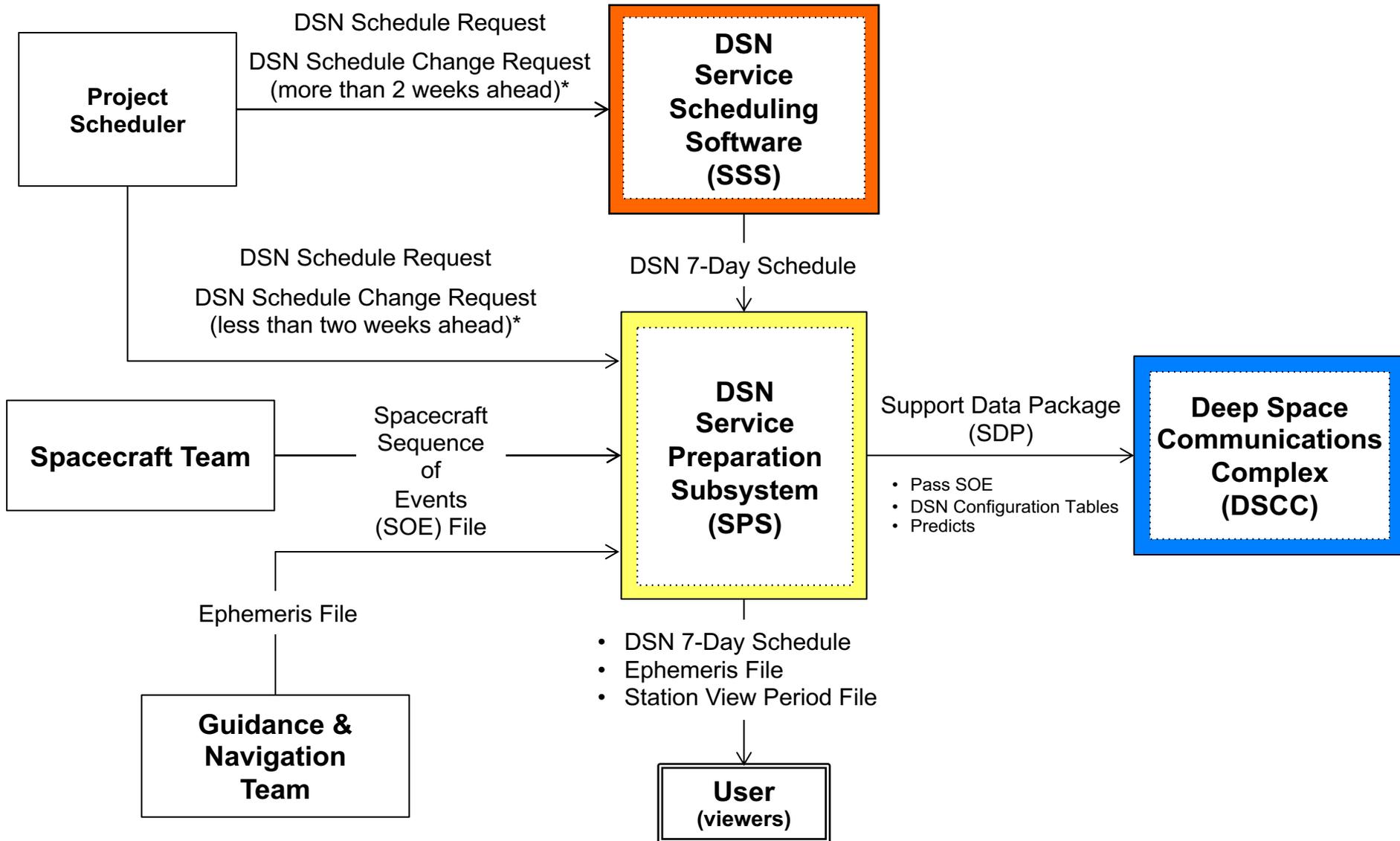
# Critical Events Example: Landing on Mars



**Acknowledgement:  
Some Material Contributed by Felicia Sanders**

**Back-up**

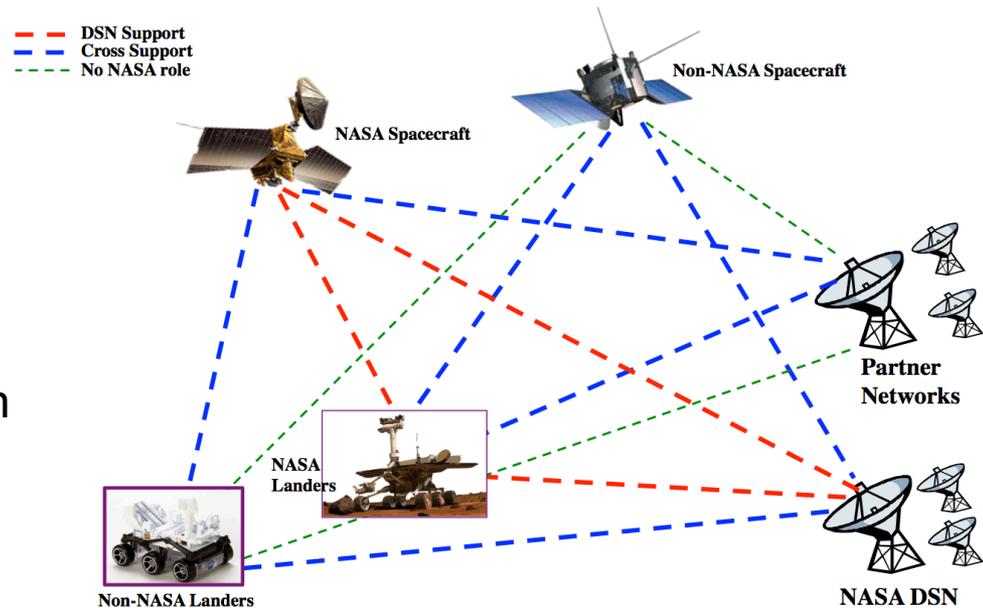
# DSN Service Management



• DSN upgrades in development to allow all scheduling via SSS

# Benefits of International Collaboration

- **Cost Benefits**
  - Meet redundancy requirements for critical events or DDOR
  - Agencies utilize existing partner assets to balance their needs
- **Mission Benefits**
  - Quick response to reduce risks
  - Enable or enhance science
- **Collaborative Benefits**
  - Foster international collaboration to benefit agencies and science community
  - Share valuable experience and share in discoveries and excitement



# Game of

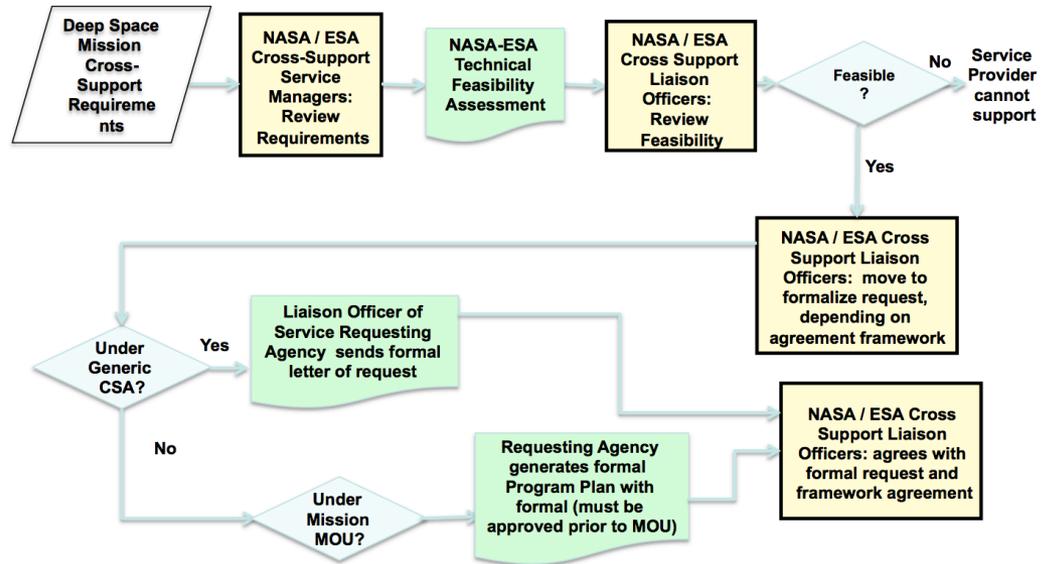
## Which Document Goes with Which process

*Example of complex processes and documentation*

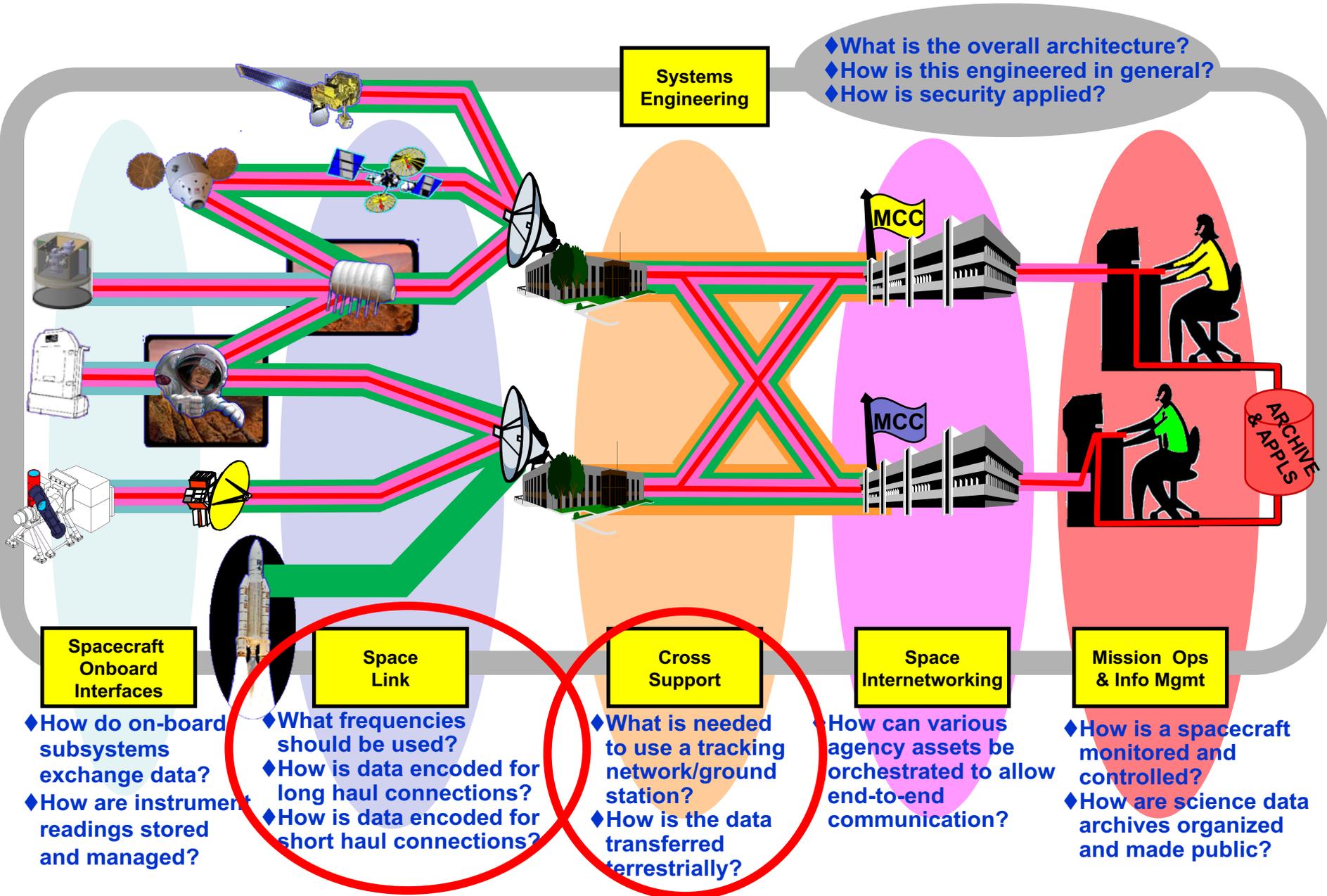
*Consult your local Cross Support Manager*

- Space Act Agreement
- Cross Support Agreement
- Abstract
- Task Plan
- Technical Assistance Agreement
- Generic Cross Support Interface Control Document
- Management Policy Document
- Mission-Specific Implementation Arrangement Document

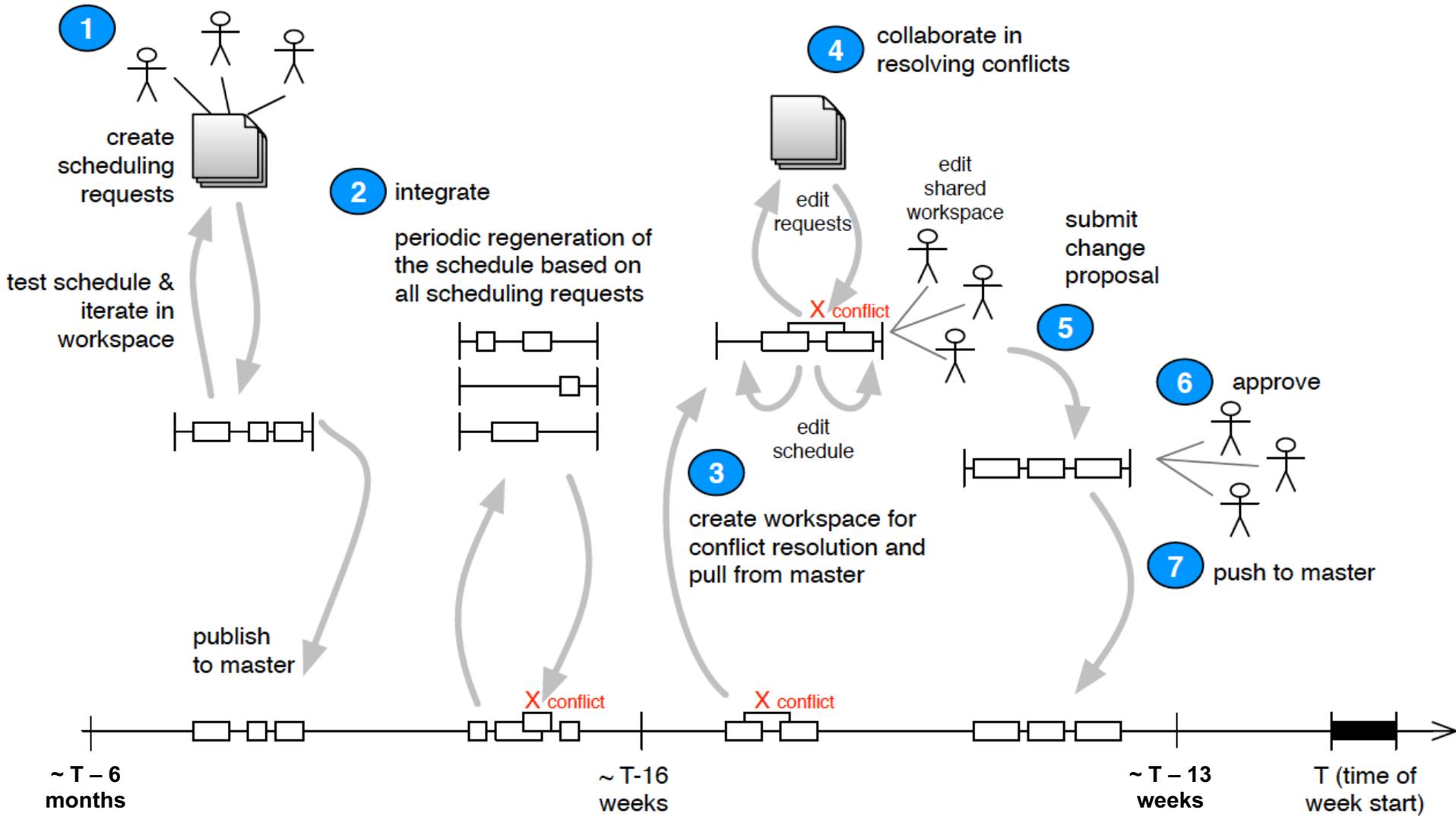
- Memorandum of Understanding
- Letter of Agreement
- Technical Understanding
- Technology Cross Support Agreement
- Generic Navigation Cross Support Interface Control Document
- Commerce License
- Mission-Specific Interface Control Document



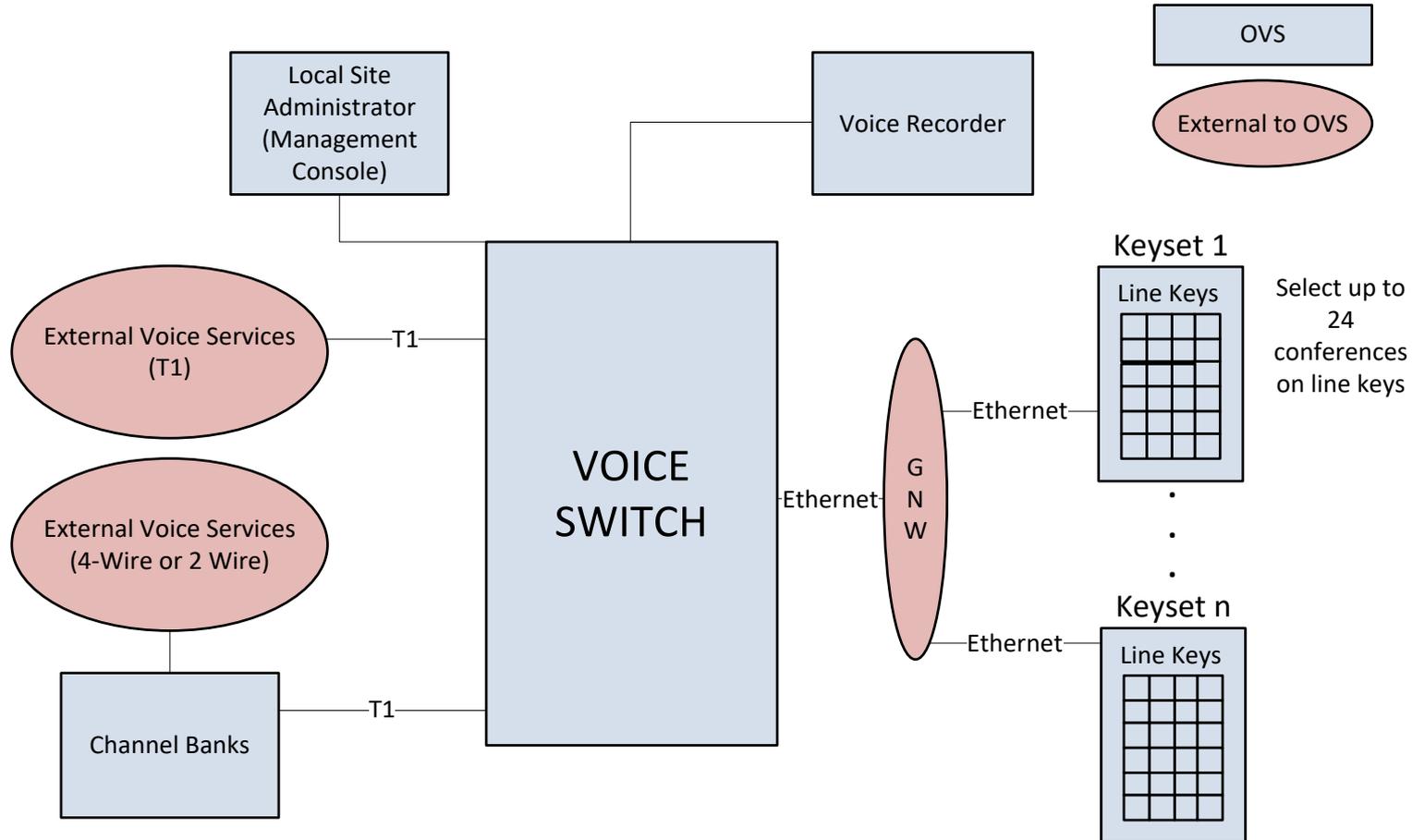
# Standards That Affect DSN Inter-Operability



# DSN Scheduling Process



# Mission Operational Voice Subsystem (OVS)



- The Mission Operational Voice Subsystem provides the voice communication between remote operational locations and teams.
- For UAE, it is recommended to have redundant Voice Switches, one for the site, and the other for the control site.