Demand Access for Deep Space Operations

Marc Sanchez Net, Jay Wyatt, Joseph Lazio, Rebecca Castaño,
Mark Johnston, Costin Radulescu, Michael Levesque

FISO Telecon 08-04-2021

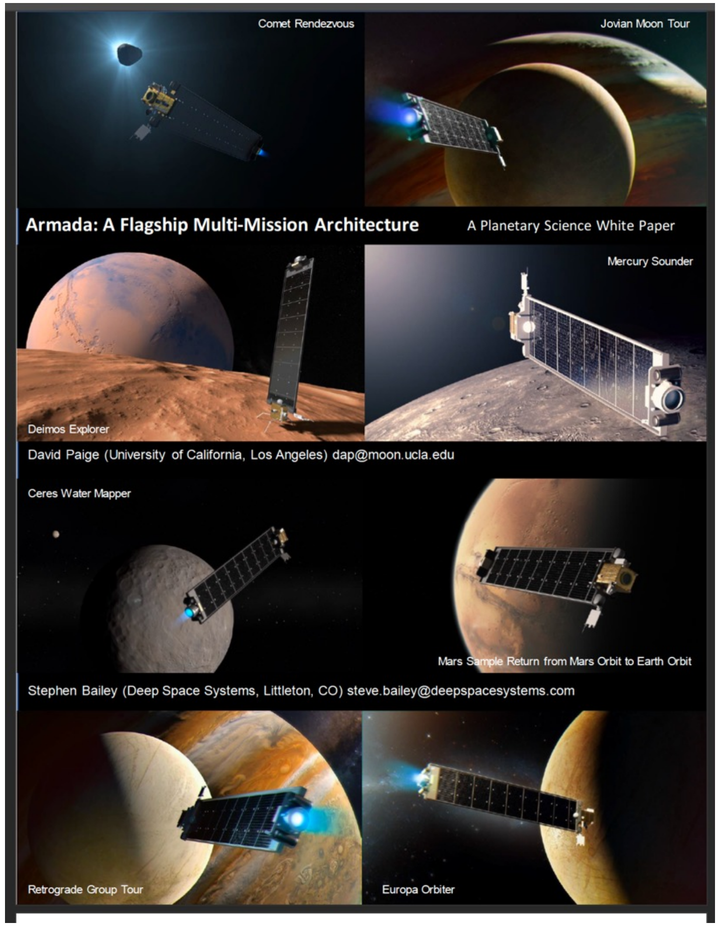
Jet Propulsion Laboratory
California Institute of Technology

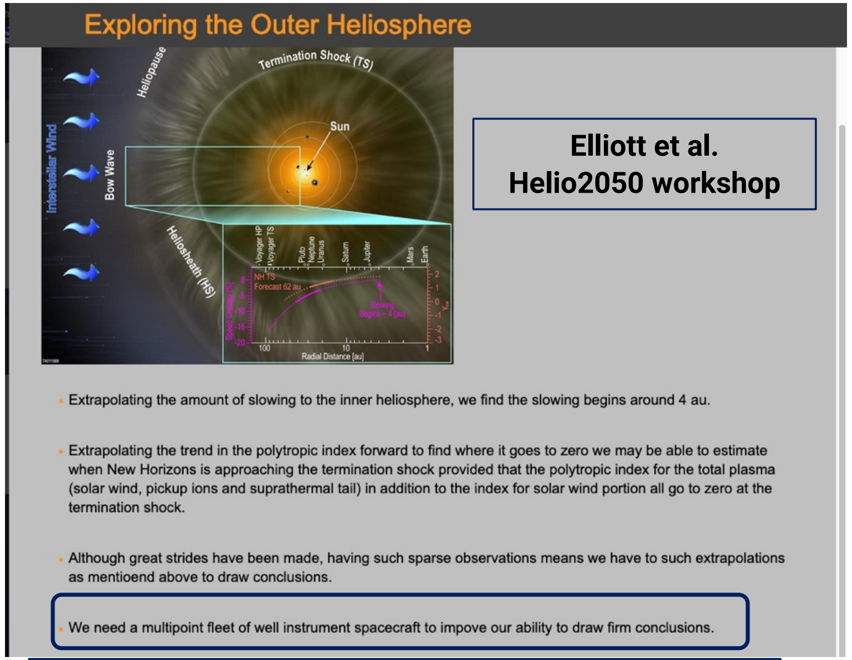
Outline

- **Introduction & Motivation**
- **Concept Architecture**
- **Concept Capabilities**
  - On-demand Deep Space Network service
  - On-demand Deep Space Network scheduling
  - On-demand Ground Data System
- **Who Benefits?**

Future Deep Space Mission Suite:

- Market forces leading to large expansion of deep space mission suite over next decades
- More agile and efficient operations opportunities for spacecraft across the Solar System





"We need a multipoint fleet of [well-instrumented] spacecraft to improve our ability to draw firm conclusions."

- Small spacecraft across the Solar System
  - Planetary Science: e.g., Armada concept, BAOBOB concept
  - Heliophysics: Earth-Sun Lagrange points, high ecliptic latitude
- Astrophysics Probes
  - Multiple missions operational at Sun-Earth L2 point
  - Pending Astro2020 recommendations

Motivation for On-Demand Operations:

Future

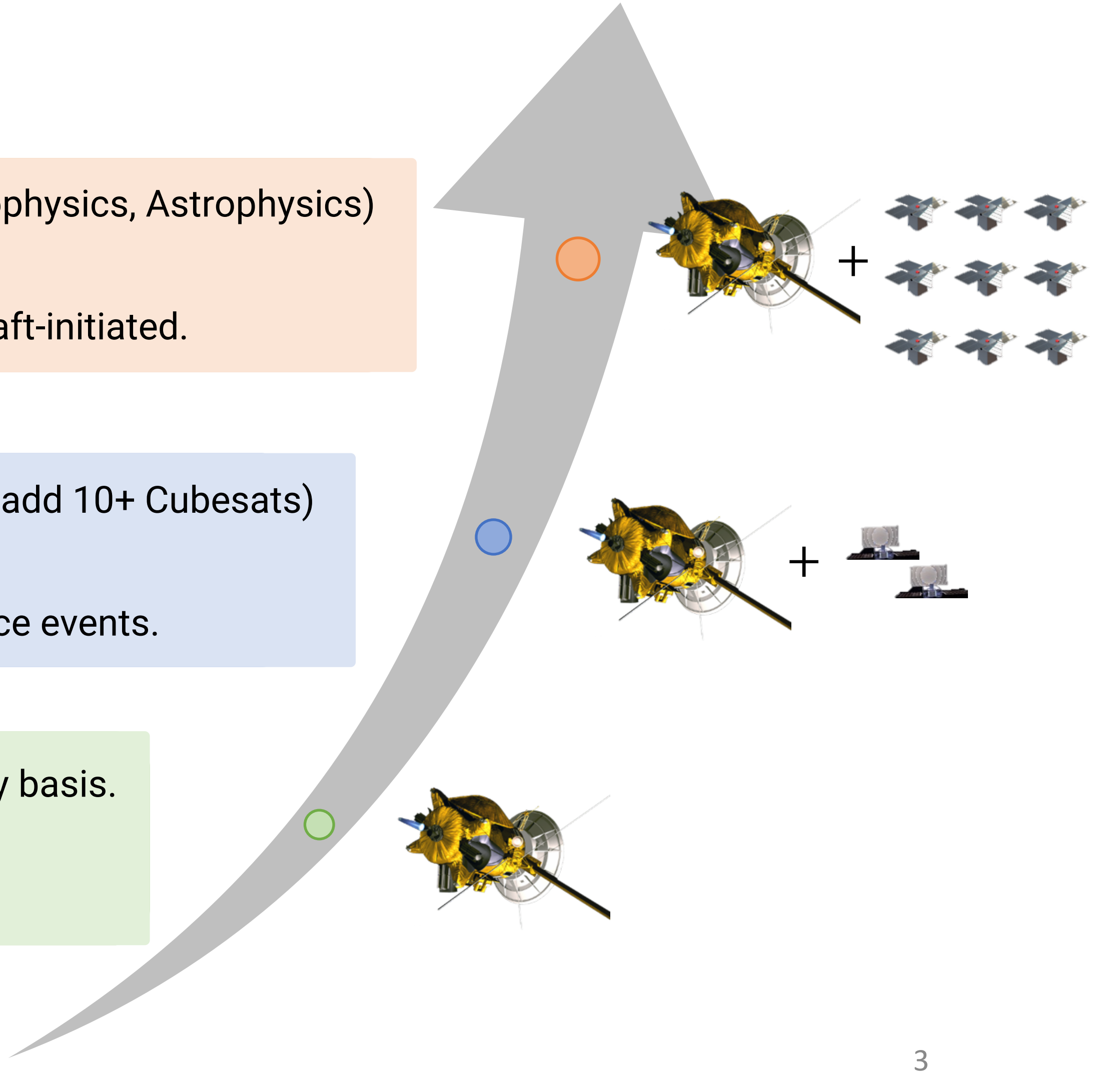
- Explosion of smallsats (Moon, Mars, Heliophysics, Astrophysics)
- Spacecraft have system-level autonomy.
- Agile science operations that are spacecraft-initiated.

Tomorrow

- Many more spacecraft (ARTEMIS-1 launch will add 10+ Cubesats)
- Spacecraft have subsystem-level autonomy.
- Some spacecraft can identify interesting science events.

Today

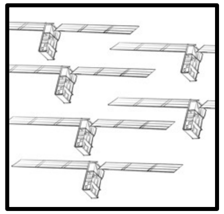
- Deep Space Network supports ~ 40 spacecraft on a daily basis.
- Spacecraft have limited/no autonomy.
- Mission and science operations are mostly scheduled.



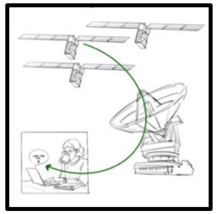
Current challenges to supporting future needs:

Lack of support for agile science.

Need to scale current infrastructure.



Exponential organizational coordination effort.



Lack of on-demand service to allow spacecraft-initiated services for agile science operations.

Lack of flexible scheduling for agile science operations.

Need to be able to scale Ground Data System as number of missions increase.

Need to be able to scale Ground Data System as data volume and data processing needs vary.

Point-to-point links and transfer-level protocols do not scale and are difficult to coordinate.

Projects need to interface with and coordinate multiple ground systems

Scientists have limited insight to know where their data are at any time.

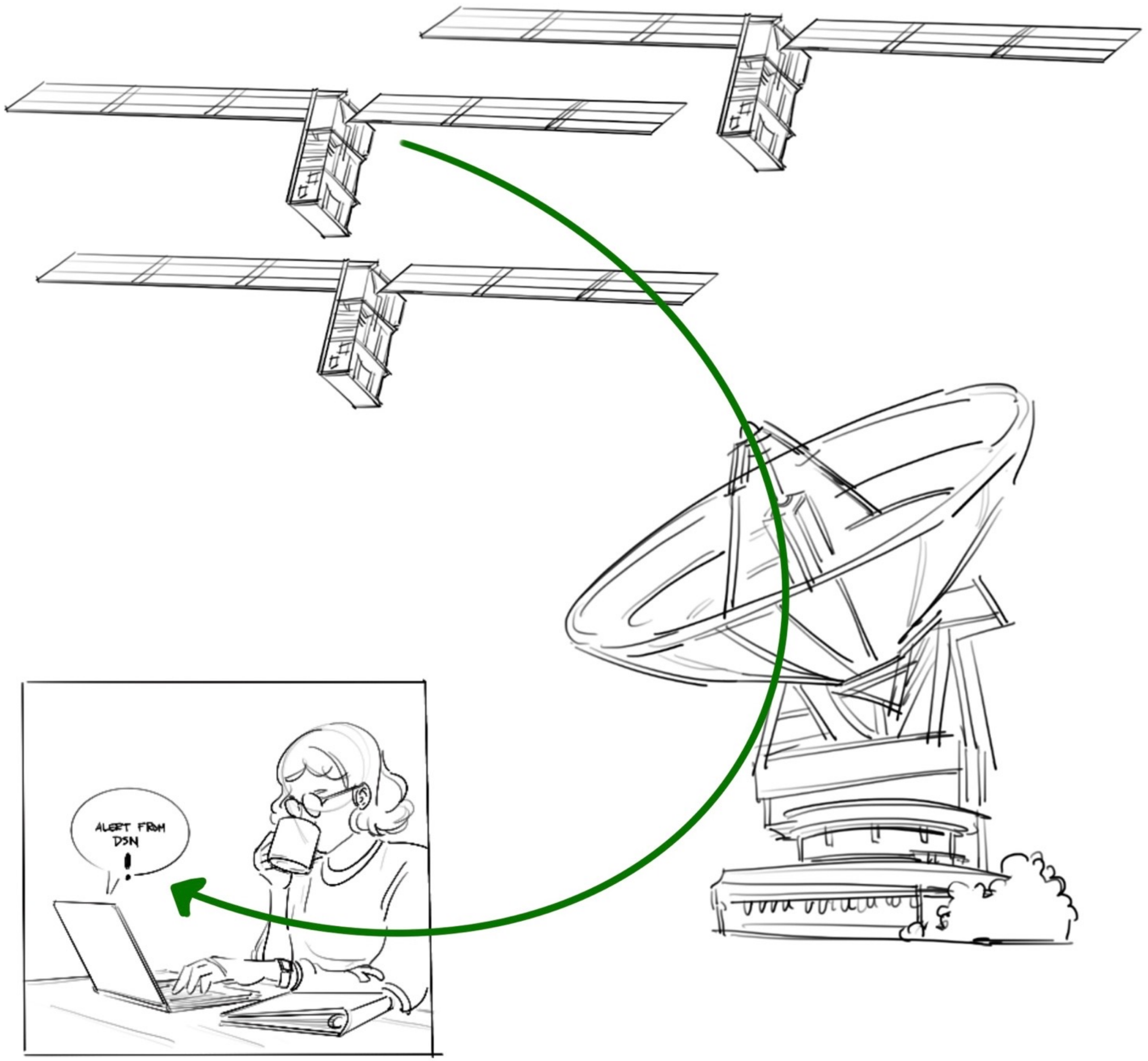
On-demand Operations Concept:

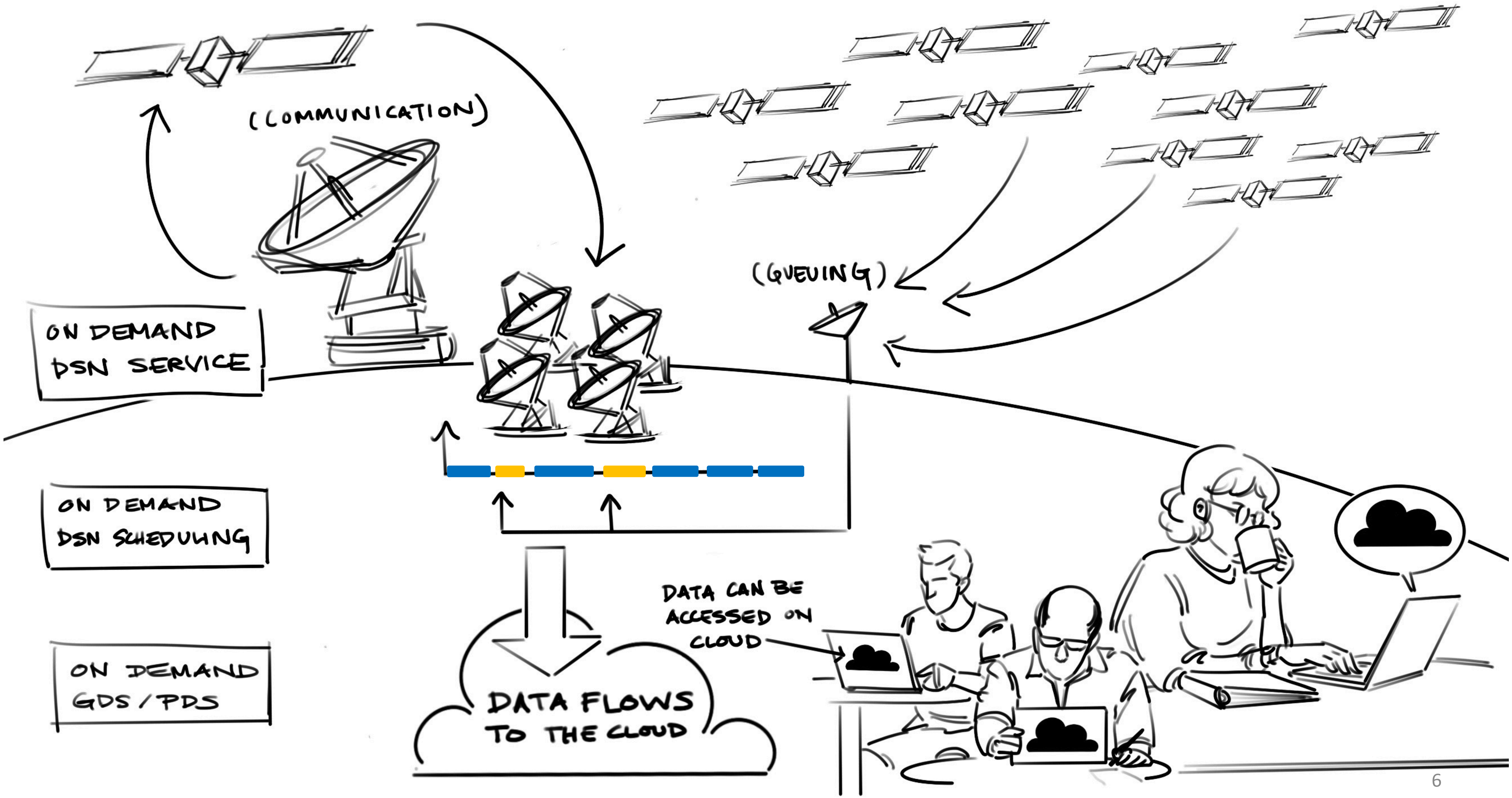
Spacecraft can request DSN and ground data system support time in near real-time.

Coordination required to service mission is fully integrated and automated, providing a **seamless end-to-end service**.

This on-demand architecture **does not replace** the current paradigm of pre-scheduled operations; it complements it.

The on-demand architecture is an **end-to-end system** that encompasses the DSN (Deep Space Network), GDS (Ground Data Systems), mission operations, scientists, and the PDS (Planetary Data System).




(COMMUNICATION)
(QUEUING)
ON DEMAND DSN SERVICE
ON DEMAND DSN SCHEDULING
ON DEMAND GDS / PDS
DATA CAN BE ACCESSED ON CLOUD
DATA FLOWS TO THE CLOUD

On-demand DSN service:

- ✓ The spacecraft places request using same signaling scheme as current DSN Beacon Service:
  - ✓ Spacecraft transmits subcarrier to indicate its state (no bits are exchanged).
  - ✓ Simple to implement, power efficient.
  - ✓ Only downlink direction (spacecraft does not know if tone has been received).
- ✓ **DSN Beacon Service is already operational and has been demonstrated** during New Horizons cruise to Pluto.

NOMINAL	All functions are performing as expected. No need to downlink engineering telemetry.
INTERESTING	Establish communication with the ground when convenient to obtain data relating to an event. ***Example: Device Reset***
IMPORTANT	Spacecraft needs servicing within a certain time or spacecraft state could deteriorate or critical data could be lost. ***Example: solid state memory near full or non-critical hardware failure***
URGENT	Ground intervention is required immediately. ***Example: A critical component has failed and the spacecraft cannot adequately recover.***
NO TONE	Beacon mode is not operating, telecom is not Earth-pointed, or a spacecraft anomaly prohibited tone from being sent.

On-demand DSN service:

Currently, the DSN has one 70m antenna and four 34m antenna at each of the three complexes.

Larger DSN antennas used for normal communications with the spacecraft (TT&C, science data).

For the on-demand DSN service, an additional queuing antenna (smaller than 34m) could be built by DSN or partners.

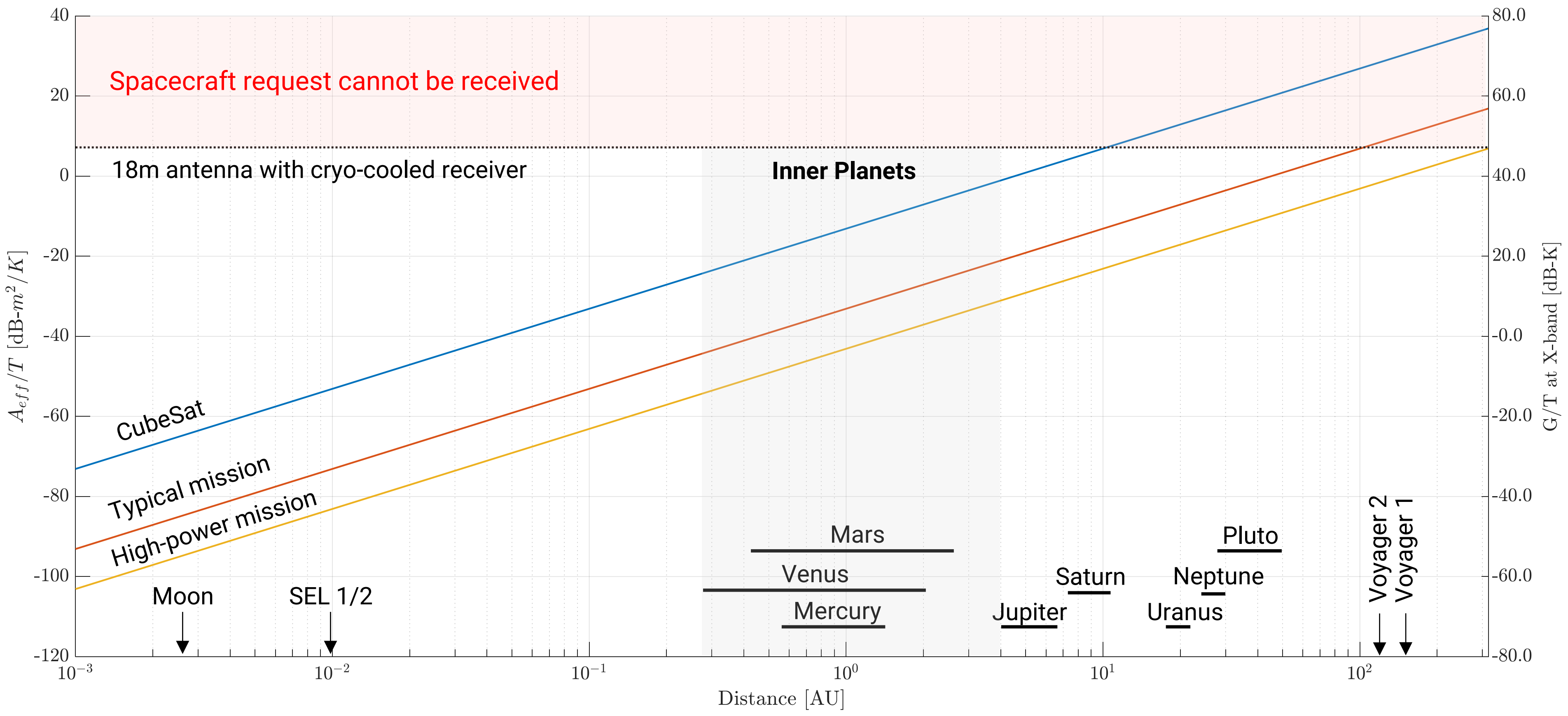
Initially, one queueing antenna is envisioned. Ultimately, multiple queueing antennas will be available providing 360° coverage.

DSN 70m antenna

DSN 34m antenna

18m or 22m queuing antenna, made by DSN or made by partners (universities, etc.)

On-demand DSN service: Queuing Antenna



On-demand DSN scheduling:

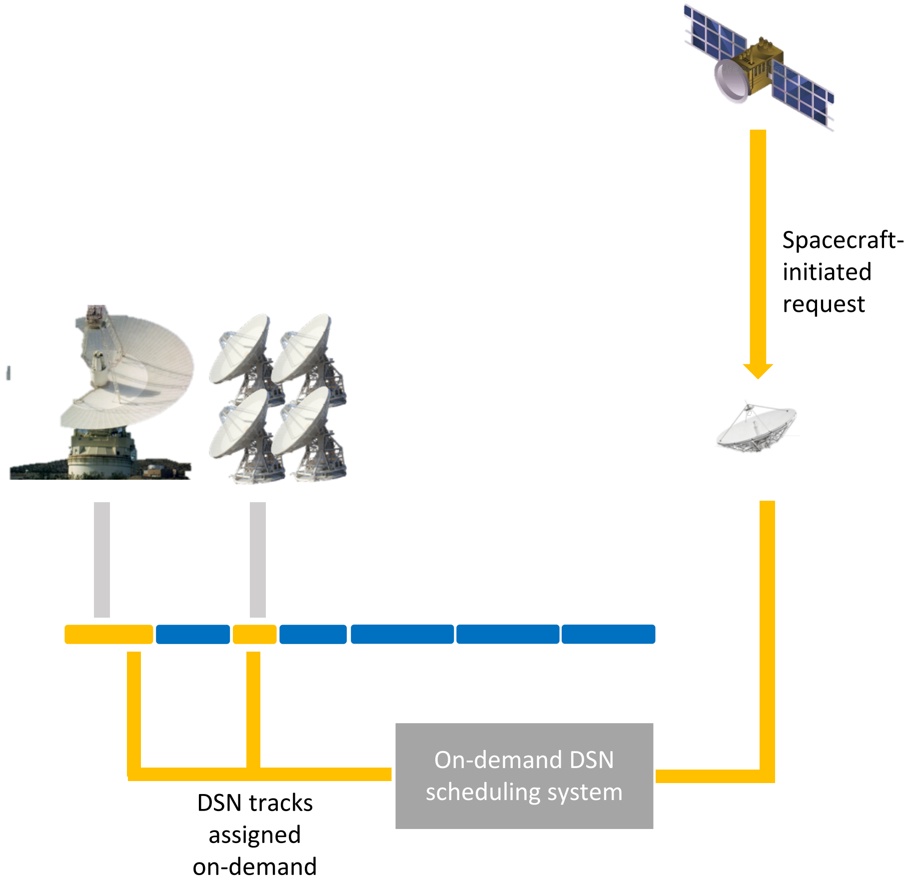
Current spacecraft operations are based DSN tracks that are pre-scheduled by the mission operations team weeks/months in advance.

On-demand DSN scheduling is built to complement traditional scheduling and causes no disruptions to current missions.

DSN time on 34m or 70m antenna is allocated to a spacecraft in near real-time after a request is received.

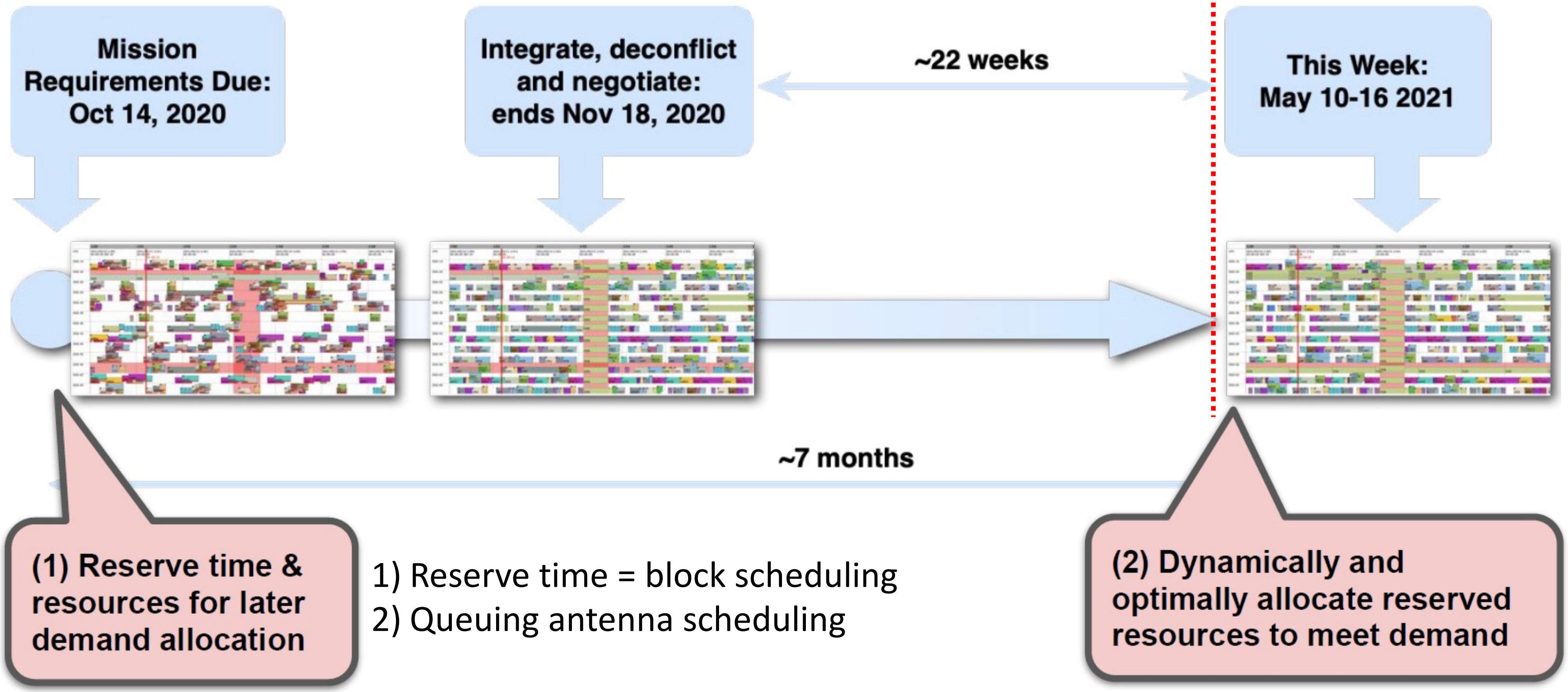
On-demand scheduling is fully automated.

Multiple scheduling tools will match tracks to spacecraft requests.



Mission planning and scheduling | Near real-time operations

On-demand DSN scheduling:



1) Reserve time = block scheduling
2) Queuing antenna scheduling

1) Near real-time block allocation
2) Opportunistic gap fill

Slide credit: Mark Johnston and Tim Hackett

On-demand DSN scheduling:

Simulation experiment assumes fleet of 1 to 10 smallsats deployed to scout several near-Earth asteroids.

Each smallsat requests 1.25, 1.5, 2.0 or 3.0 tracks per week on average, which lasts at most 4 hours.

Fleet is supported using:

- DSS-17 antenna (21 meters) acting as queueing antenna.
- DSN-34m antennas for TT&C.

	Static Scheduling	On-Demand Access
Mean science downlink delay	7 days	3 days
Dropped science %	5%	0%
Tracks Utilized %	75%	100%

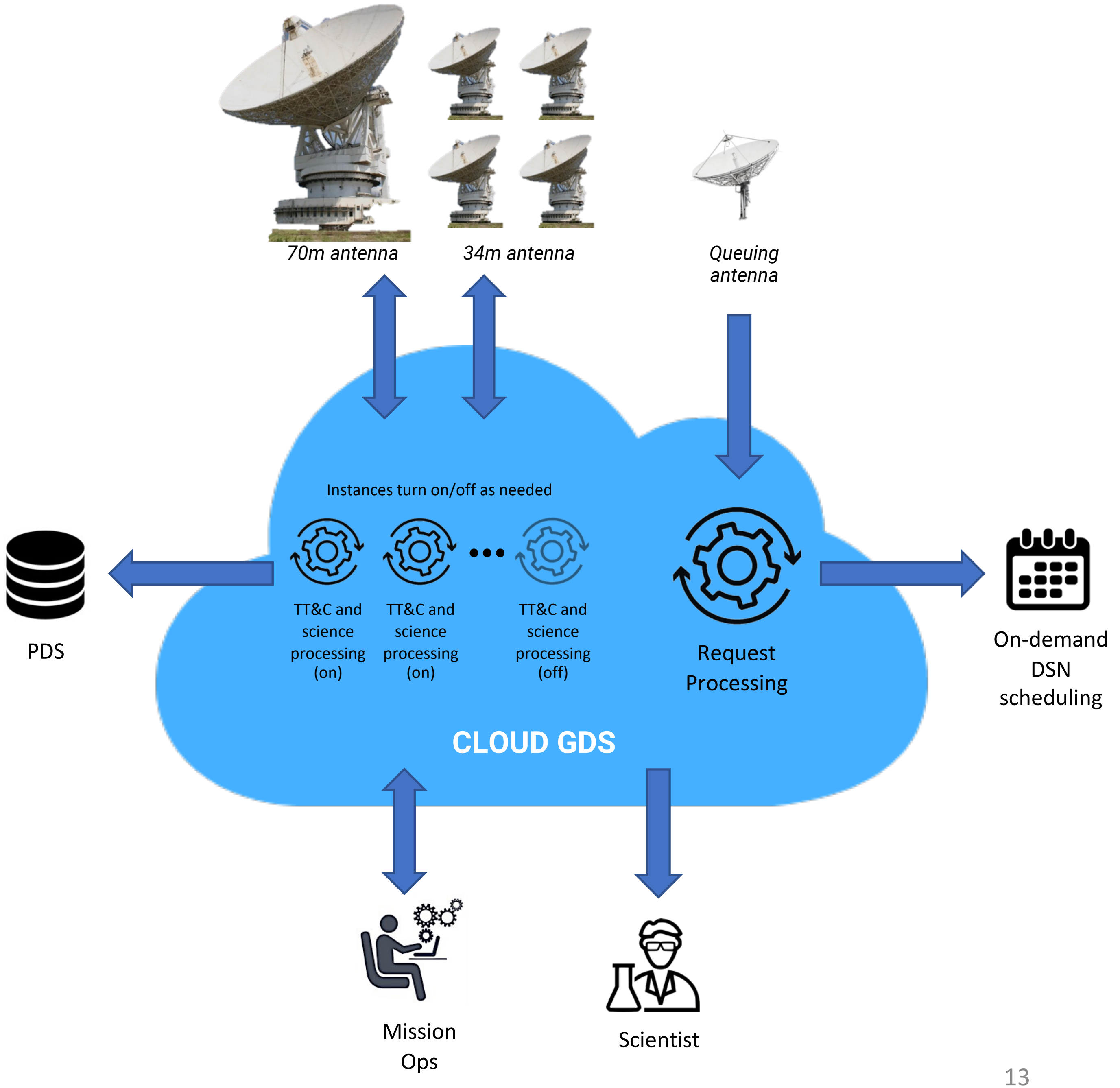
On-demand GDS:

GDS and PDS connections spin up/down automatically before/after each on-demand pass.

Coordination between cloud-based GDS and incoming spacecraft requests is fully automated.

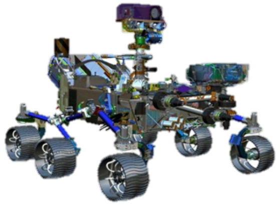
Cloud-based GDS can be implemented using **AMMOS in the cloud**, which is already under development.

End-to-end networked system can deliver data to/from mission ops and scientists using **delay tolerant networking (DTN)**, but it is not required.

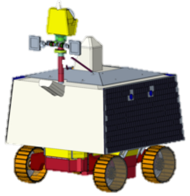


Who Benefits?

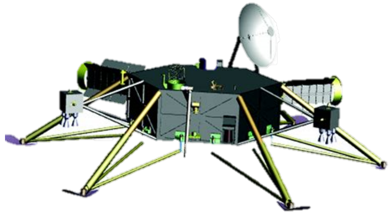
Legacy Flagship



Legacy Rover

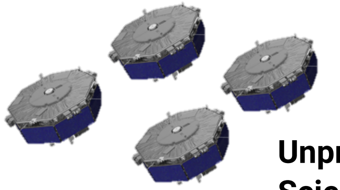


Telecommand



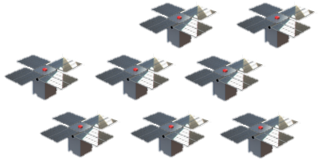
Autonomous Spacecraft

Pathfinder Smallsats



Unpredictable Science

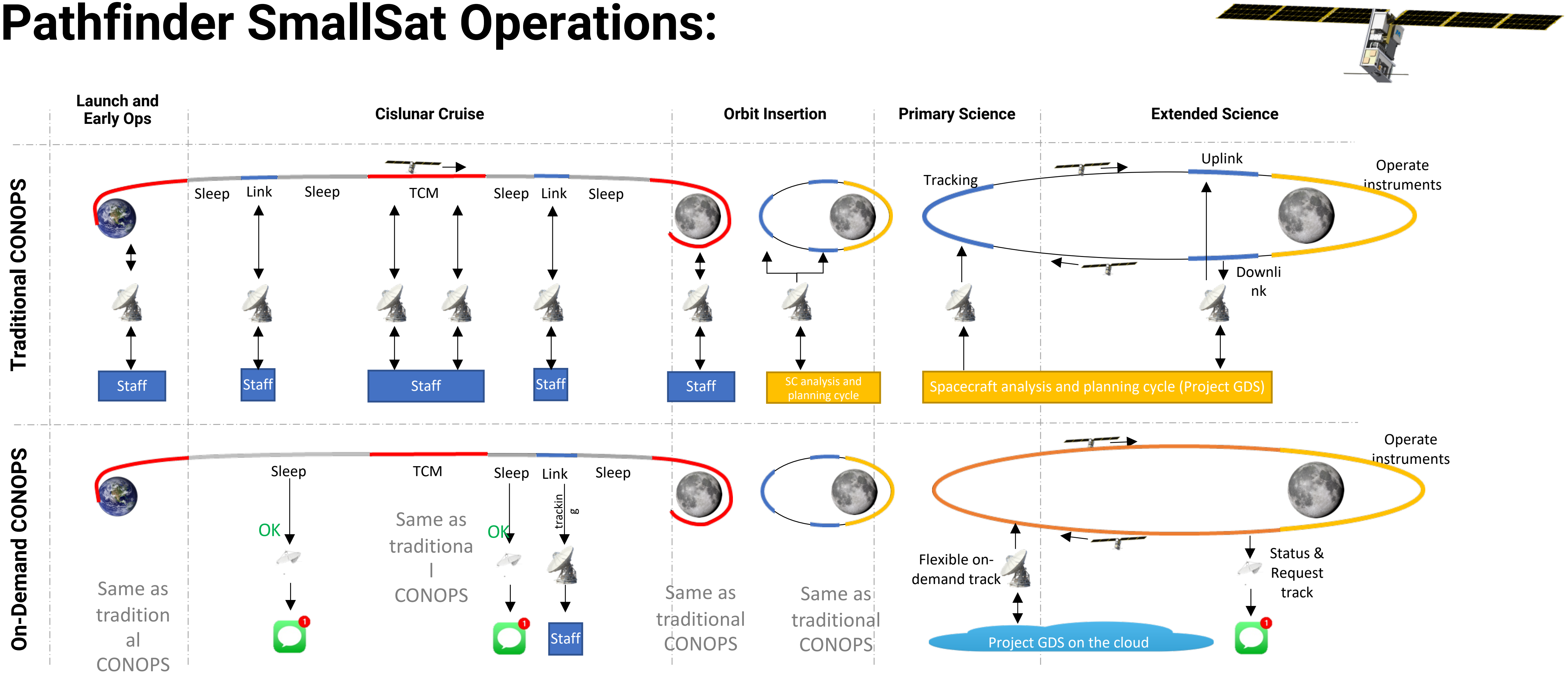
Radio Science



Fleet of Smallsats

- **All mission categories leverage a common demand access architecture.**
- Each mission category can use all proposed capabilities, or just a subset.

Pathfinder SmallSat Operations:



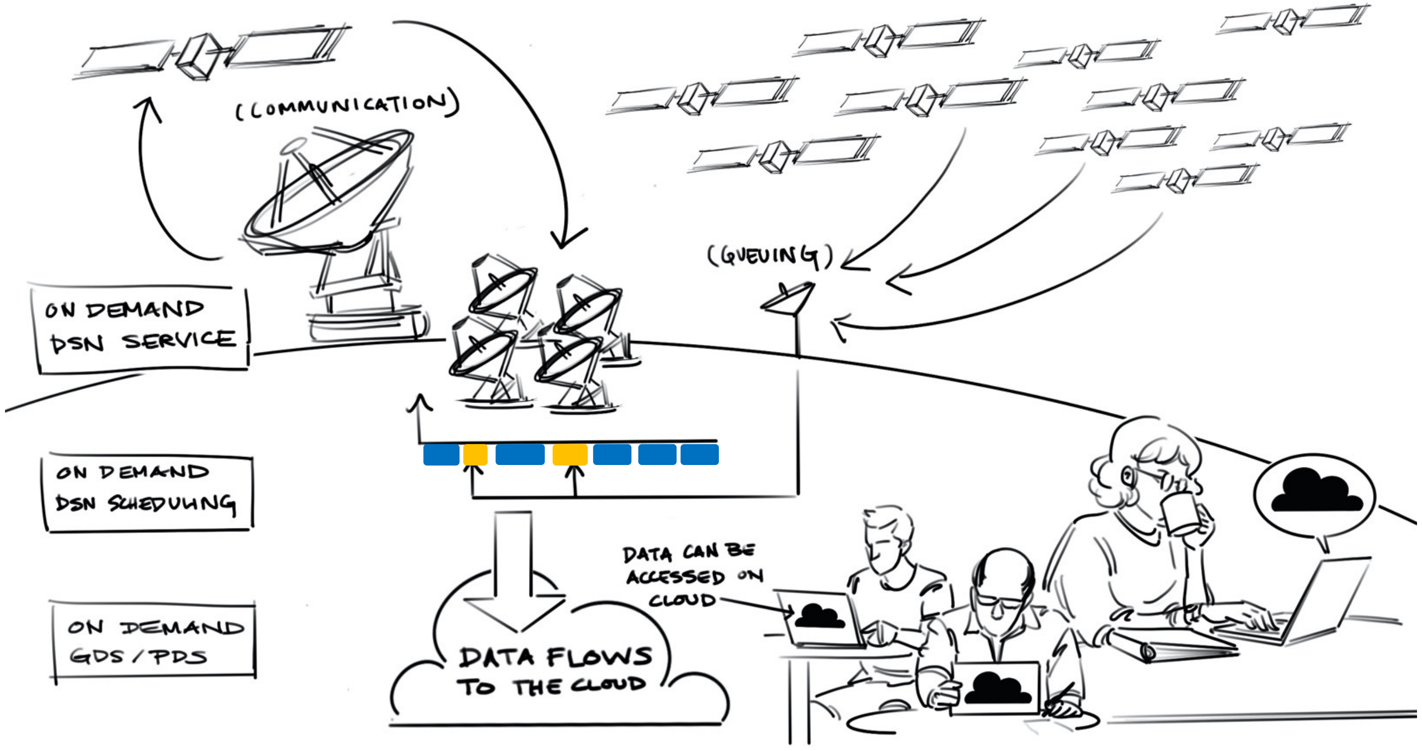
Demand Access for Deep Space Operations

Enabling a larger, more diverse deep space mission suite for the future.

On-demand architecture is an **end-to-end system** that encompasses the DSN (Deep Space Network), GDS (Ground Data Systems), mission operations, scientists, and the PDS (Planetary Data System).

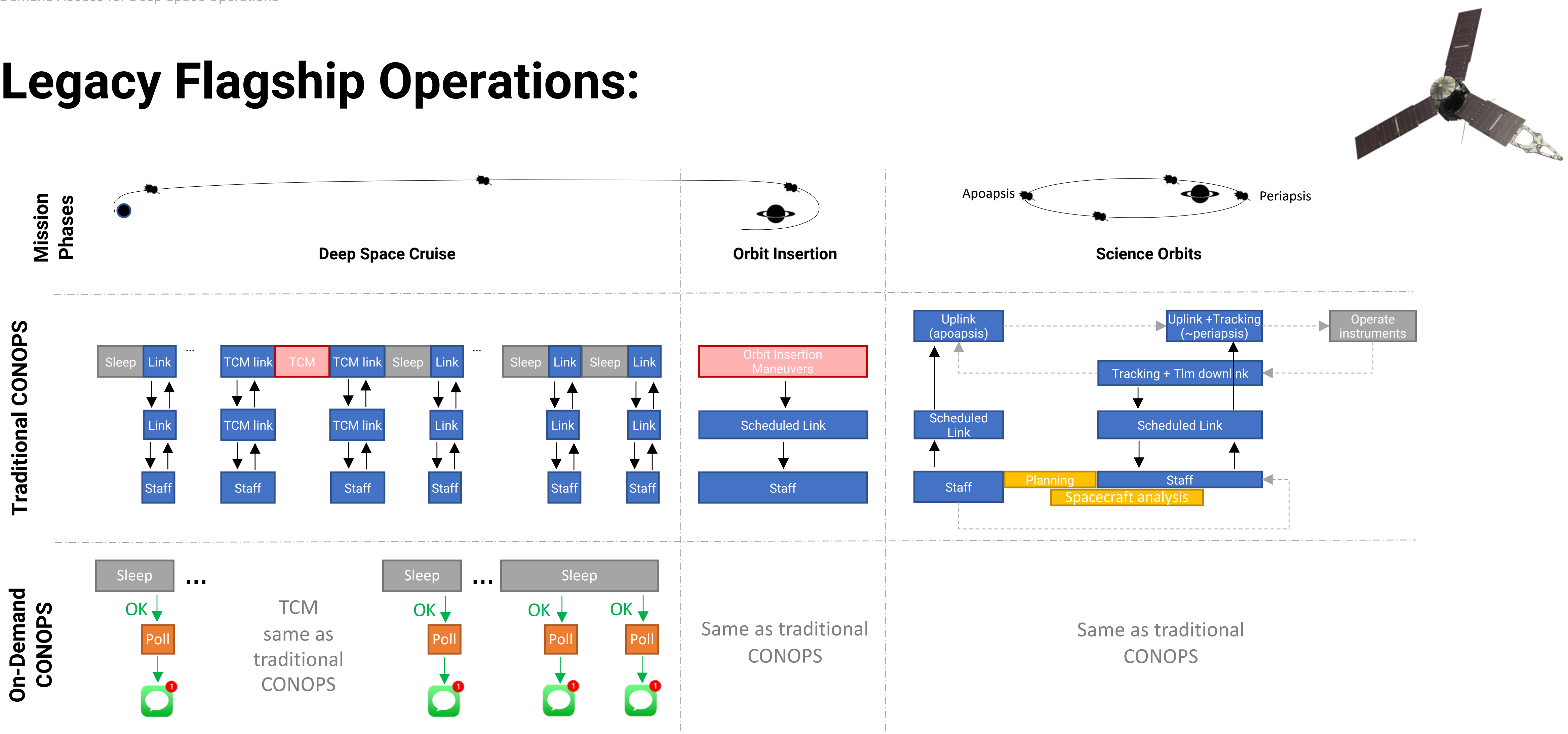
On-demand architecture **complements and expands upon** current paradigm of pre-scheduled operations

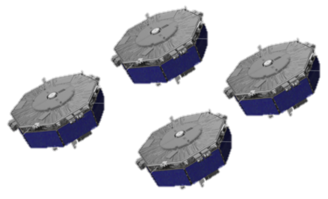
Multiple components in development and testing.



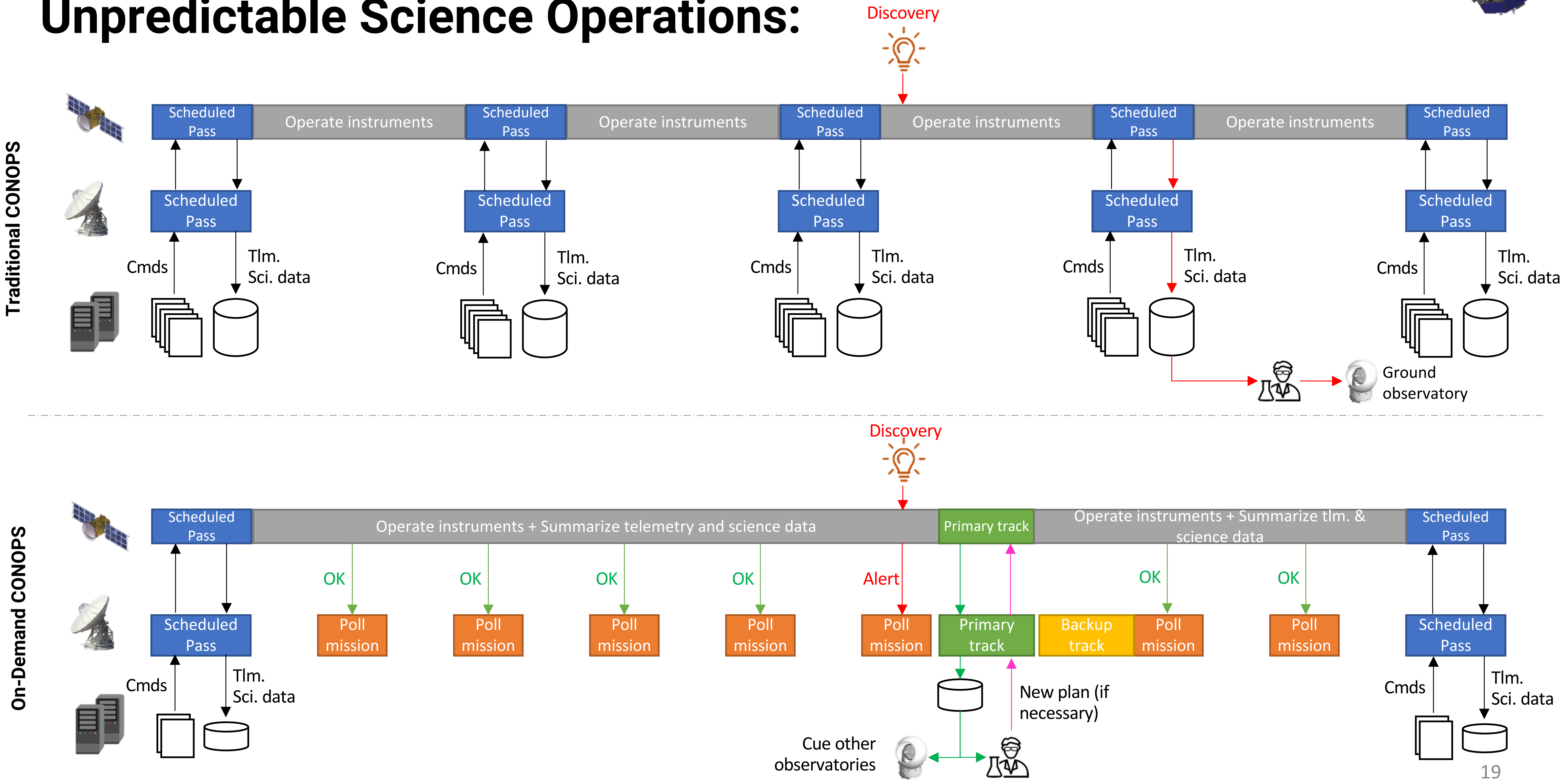
Jet Propulsion Laboratory
California Institute of Technology

Legacy Flagship Operations:





Unpredictable Science Operations:



Demand Access for Deep Space Operations

Enabling a larger, more diverse deep space mission suite for the future.

On-demand architecture is an **end-to-end system** that encompasses the DSN (Deep Space Network), GDS (Ground Data Systems), mission operations, scientists, and the PDS (Planetary Data System).

On-demand architecture **complements and expands upon** current paradigm of pre-scheduled operations

Multiple components in development and testing.