

The Impact of Delayed Communication on NASA's Human- Systems Operations: Preliminary Results of a Systematic Review

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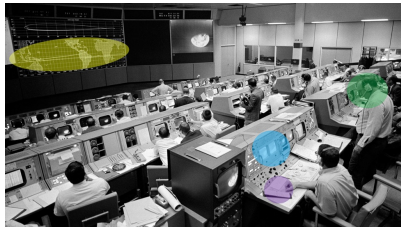
¹NASA Ames Research Center, ²San José State University and ³KBR

Impact of Delayed Comm on NASA's Human-Systems Operations:

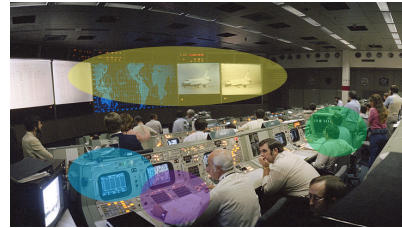
- 1. Current spaceflight paradigm**
- 2. Future spaceflight paradigm**
- 3. Literature review method**
- 4. Preliminary findings**
- 5. Next steps**



Apollo
1961 - 1972



Space Shuttle
1981 - 2011



ISS
2000 - present



Current Mission Paradigm

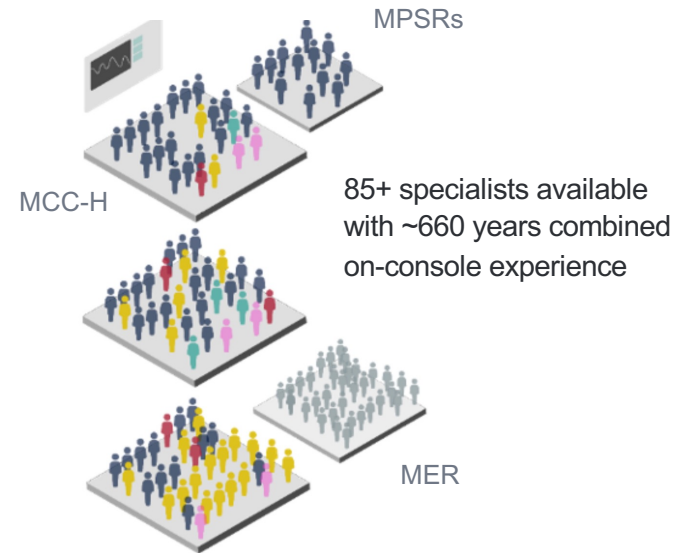
Safety-critical operations are managed from the ground:

Direct control

Oversight and guidance

Decision making

Problem solving



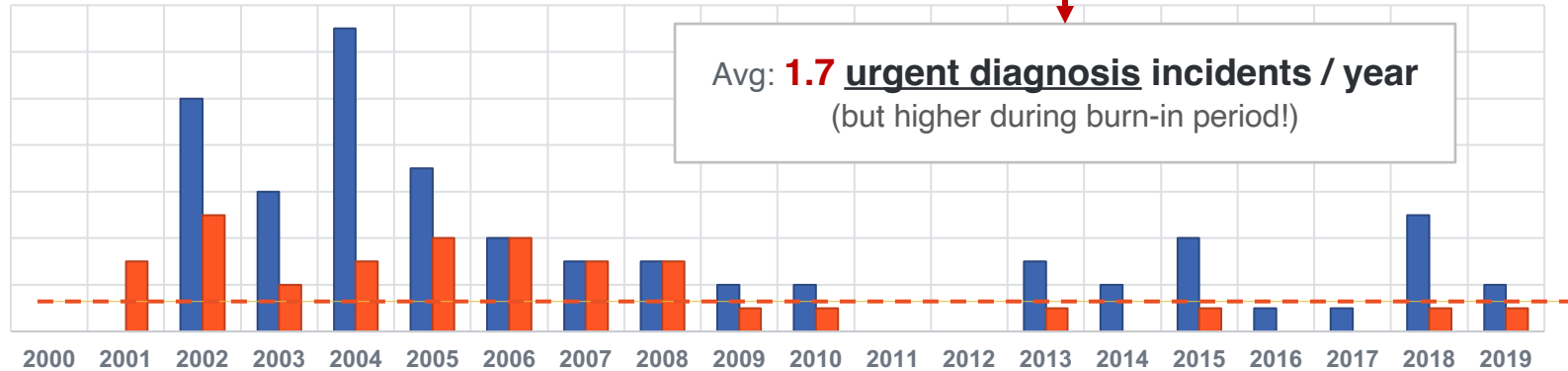
Anomaly Response on the ISS

Time-Critical Anomalies on the ISS, 2001 - 2019

68 Total High Priority IFIs

33 Vehicle incidents
requiring urgent diagnosis:

**Unanticipated
Urgent
Unknown Origin**



Avg: **1.7** urgent diagnosis incidents / year
(but higher during burn-in period!)

Missions Beyond LEO: A Paradigm Shift



communications delay will range from ~4 to 24 mins one-way during a Mars mission

COMM:

Increasingly high-latency communications prohibit real-time operational and medical support

communications delay may range from ~3 to 10 secs one-way on the surface of the Moon

SUPPLY:

Reduced resupply

EVAC:

Fewer opportunities for evacuation or rescue

ADDITIONAL CHALLENGES:

Environmental factors: dust, partial gravity, dormancy, low light

Increased mission complexity

Longer surface stays



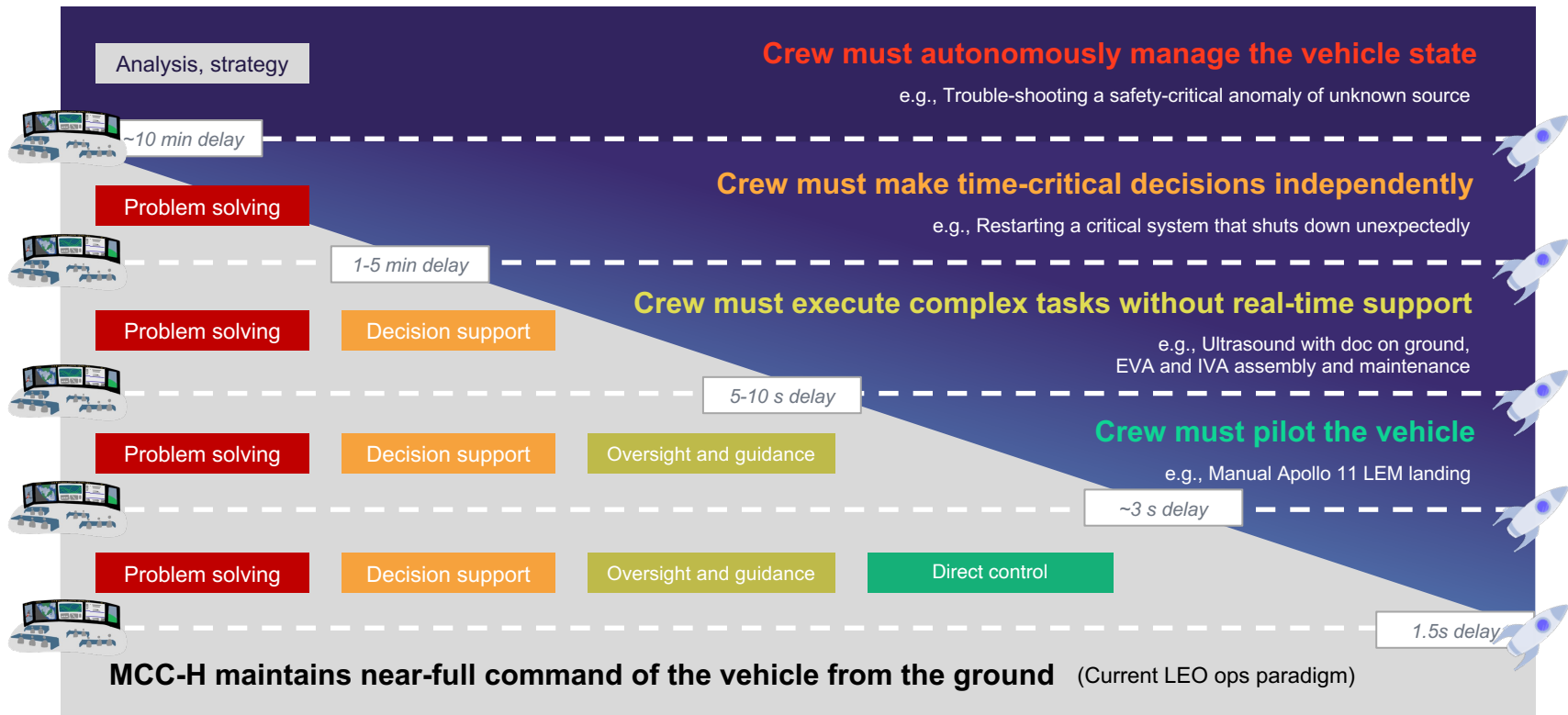
Comm delay example

Apollo 16 EVA with simulated 12-second round-trip delay

Ground-to-onboard shift of safety-critical operations with increasing comm delay

ROLE OF GROUND TEAM

ROLE OF FLIGHT CREW

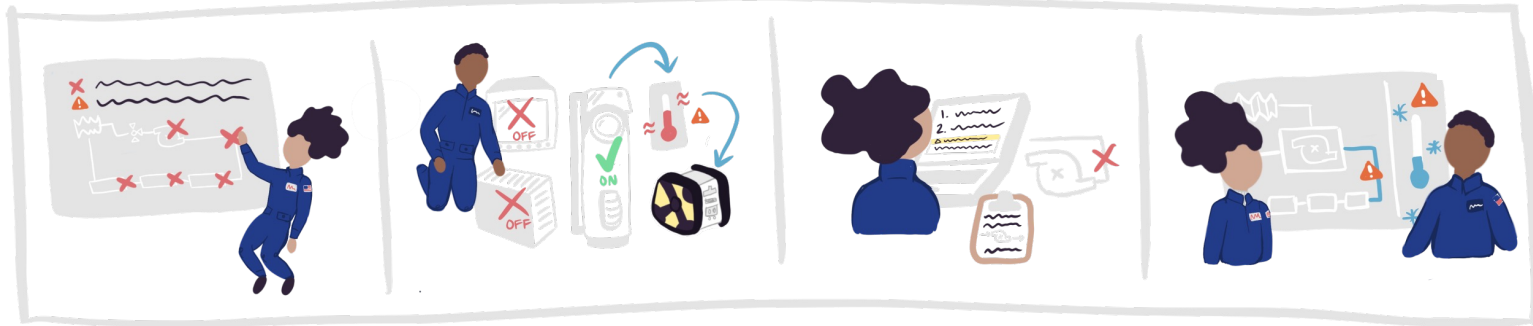


Ground will always have more expertise and personnel; anything that can be worked at a pace that allows interaction with the ground will utilize those resources

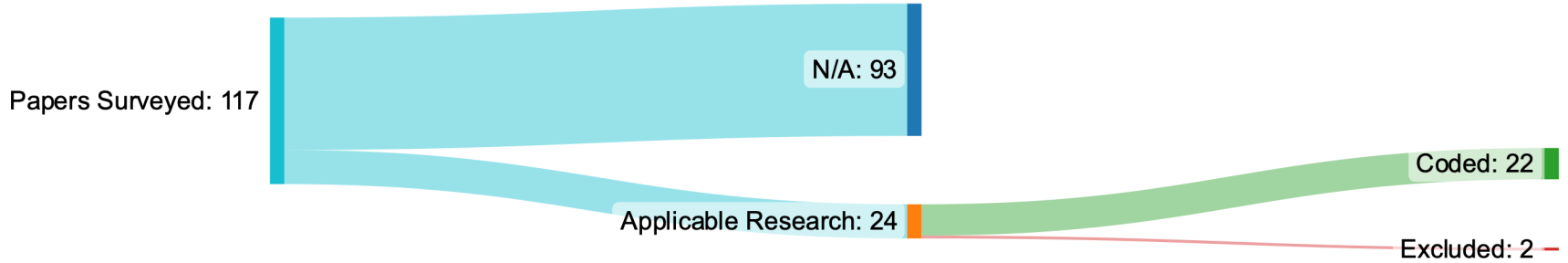
Current Work

NASA has been exploring this shift in operational responsibilities for decades, but the last comprehensive assessment of the state of comm delay literature took place in 2013.

An updated overview of the research landscape is needed. The purpose of this work is to examine the evidence generated through 20 years of communication delay research



Literature Review



Excludes

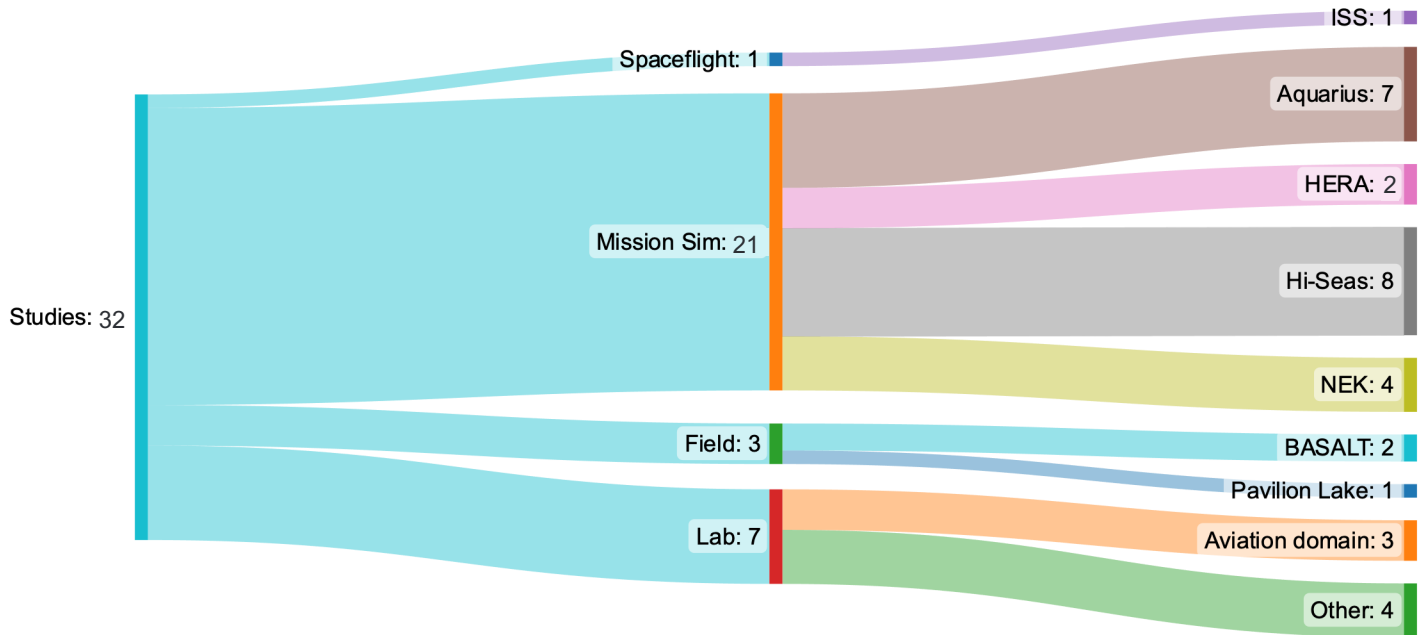
- Theses/dissertations, posters, conference abstracts
- Review, summary, thought papers
- Demos (collection of different activities)
- Papers with no comm delays
- Papers with no task

Includes

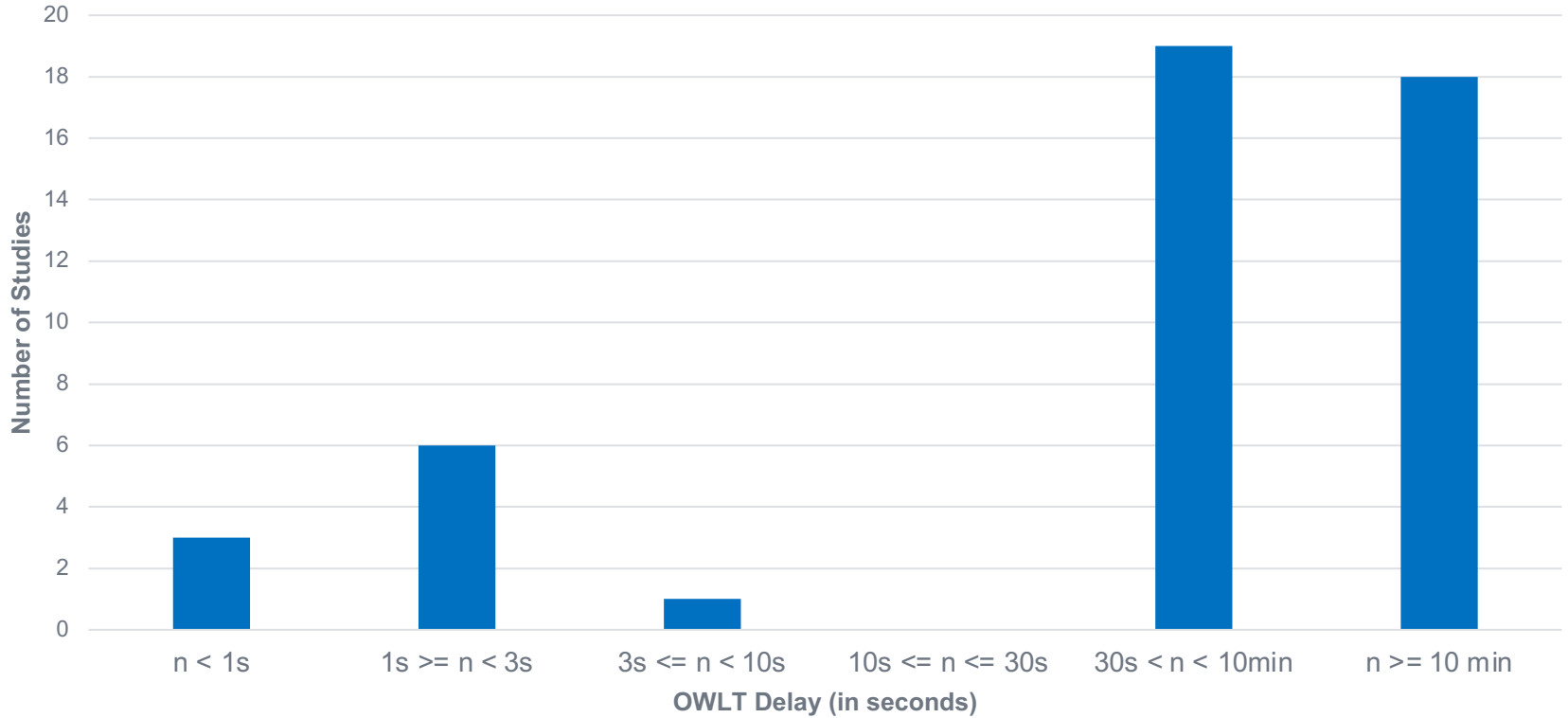
- Research papers (in general with a method section)

Studies

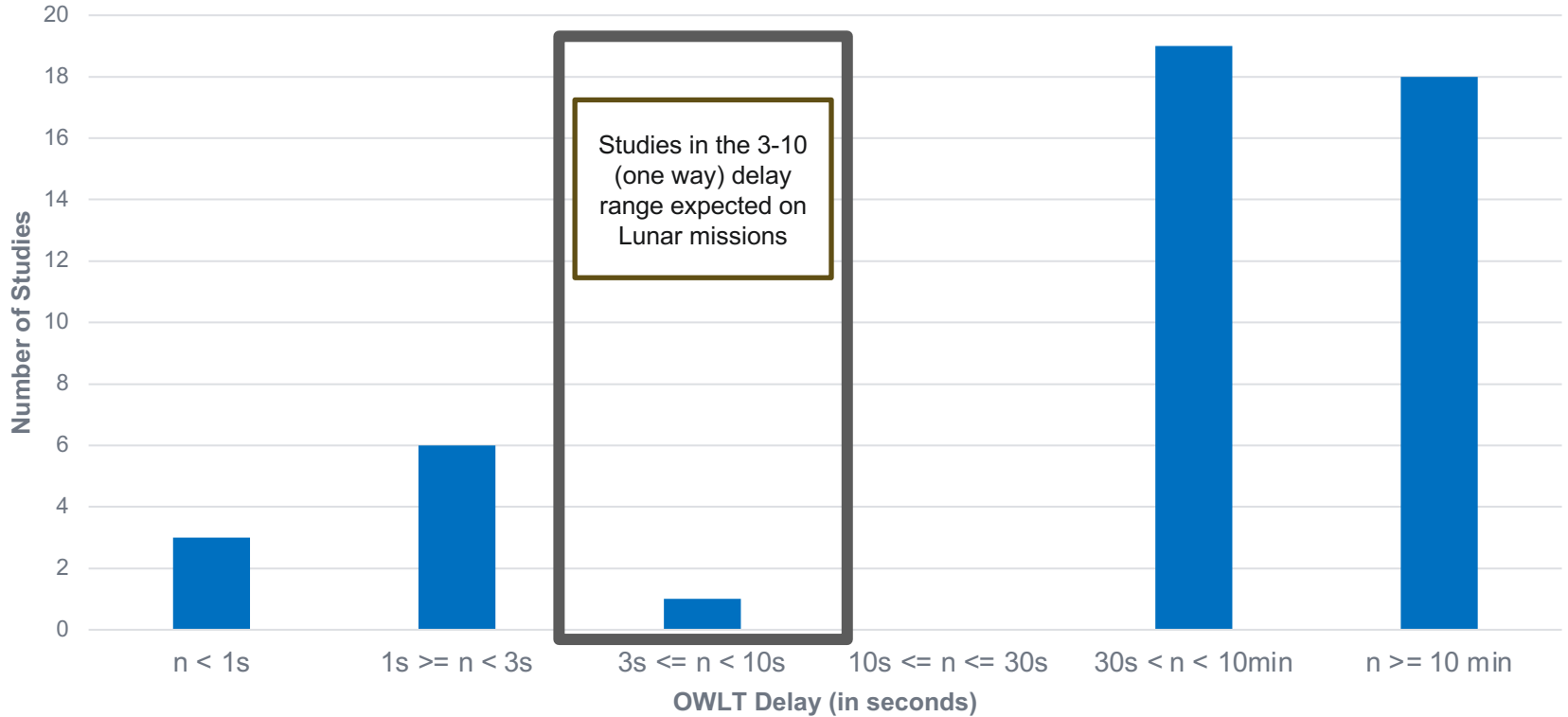
1 study = instance of studying the impact of comm delay in a specific mission / campaign / environment. Note: some papers were split into multiple “studies” if they featured multiple campaigns that had different comm delays.



Comm Delays Included in Studies



Comm Delays Included in Studies



LEO

LUNAR

MARS

Tasks Studied

- Surface EVA Traverse
- EVA Science Activities
- System Anomaly Response
- Air Traffic Control
- Planning & Scheduling
- Routine Maintenance
- Network Intelligence Analysis
- Generic Mission Ops
- Emergency Response
- Conference with Ground
- Assembly
- N/A to Study

Excludes

Studies with no task mentioned

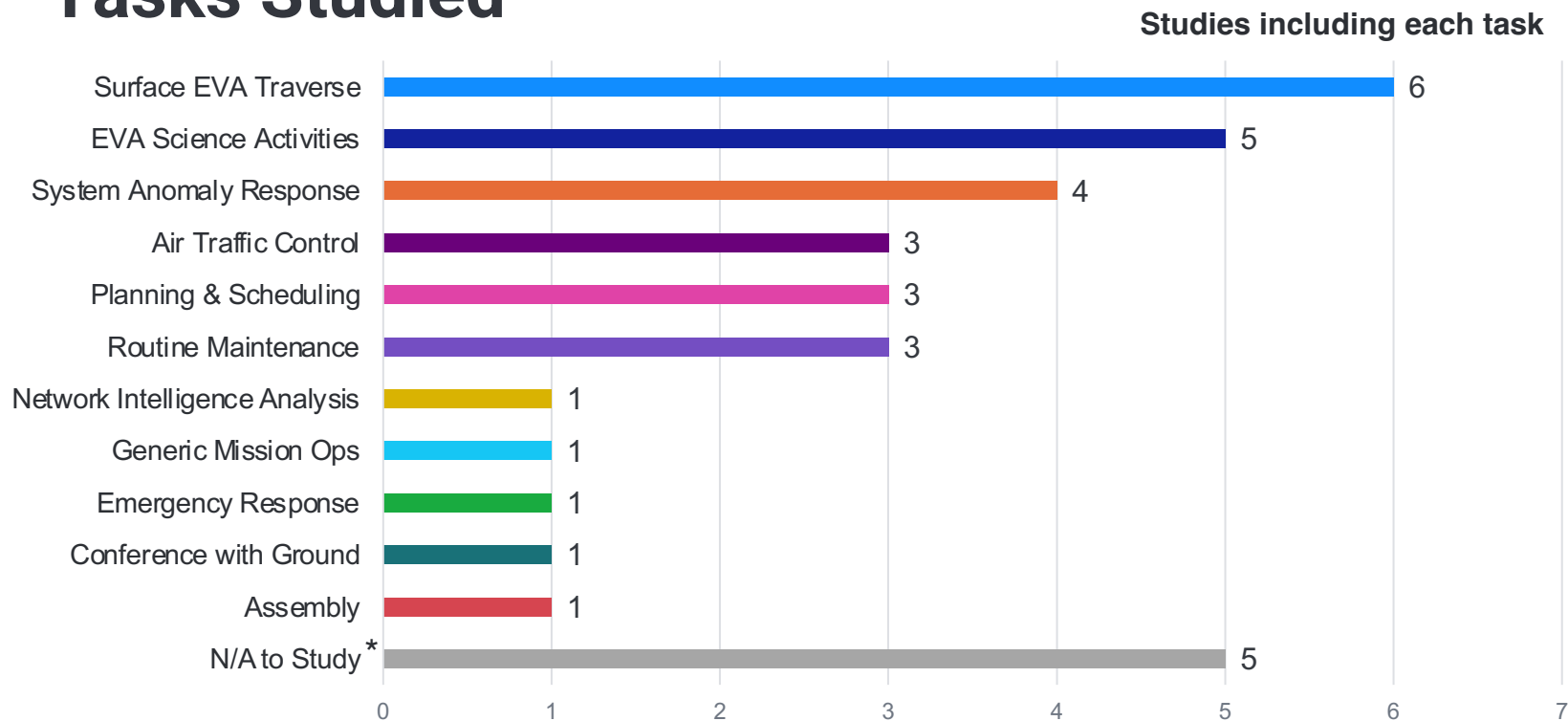
Studies in which the tasks conducted in the analog environment did not relate to the focus of the study

Example: Autonomous, Computer-Based Behavioral Health Countermeasure Evaluation at HI-SEAS Mars Analog

Includes

Studies in which participants performed tasks and the findings of the study were in some way related to their performance

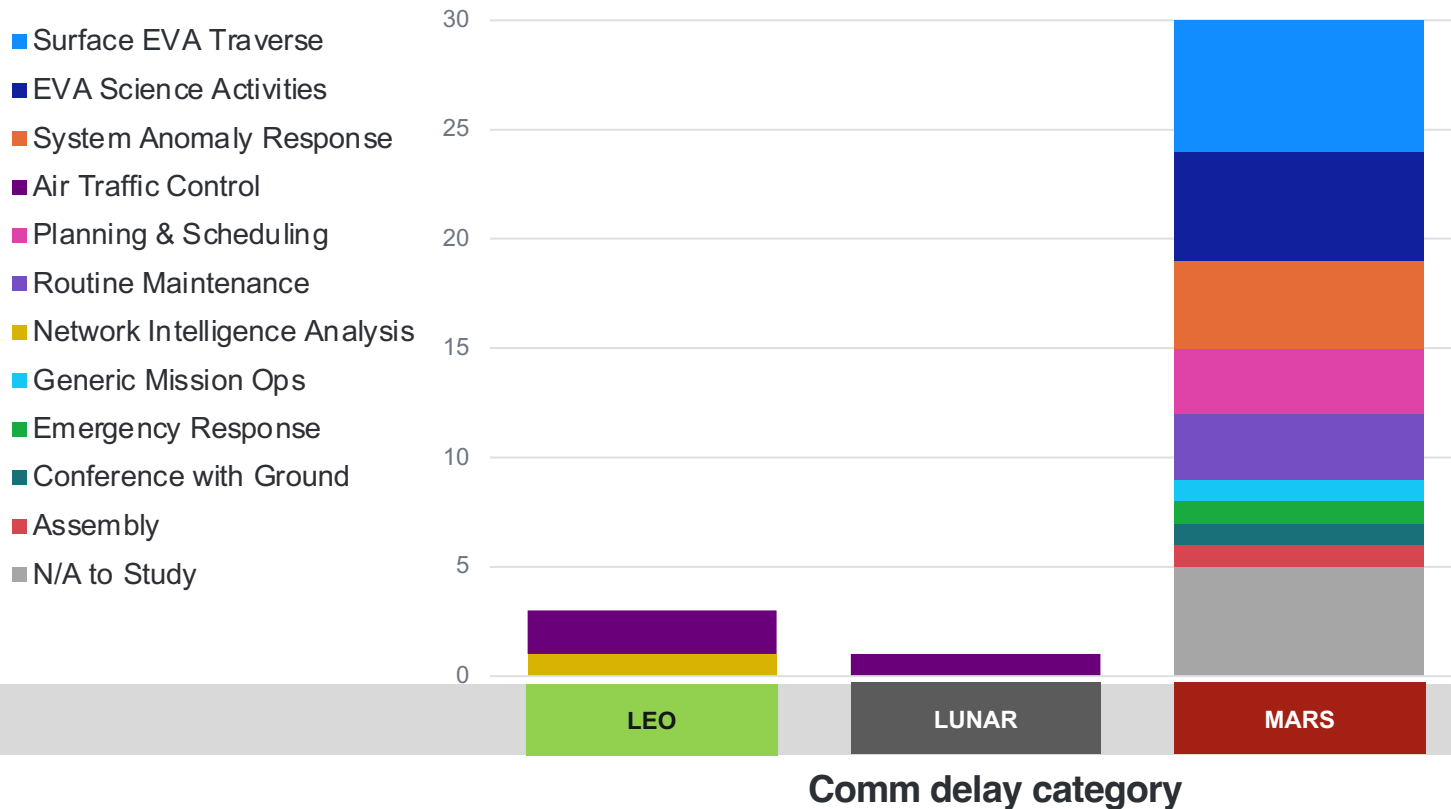
Tasks Studied



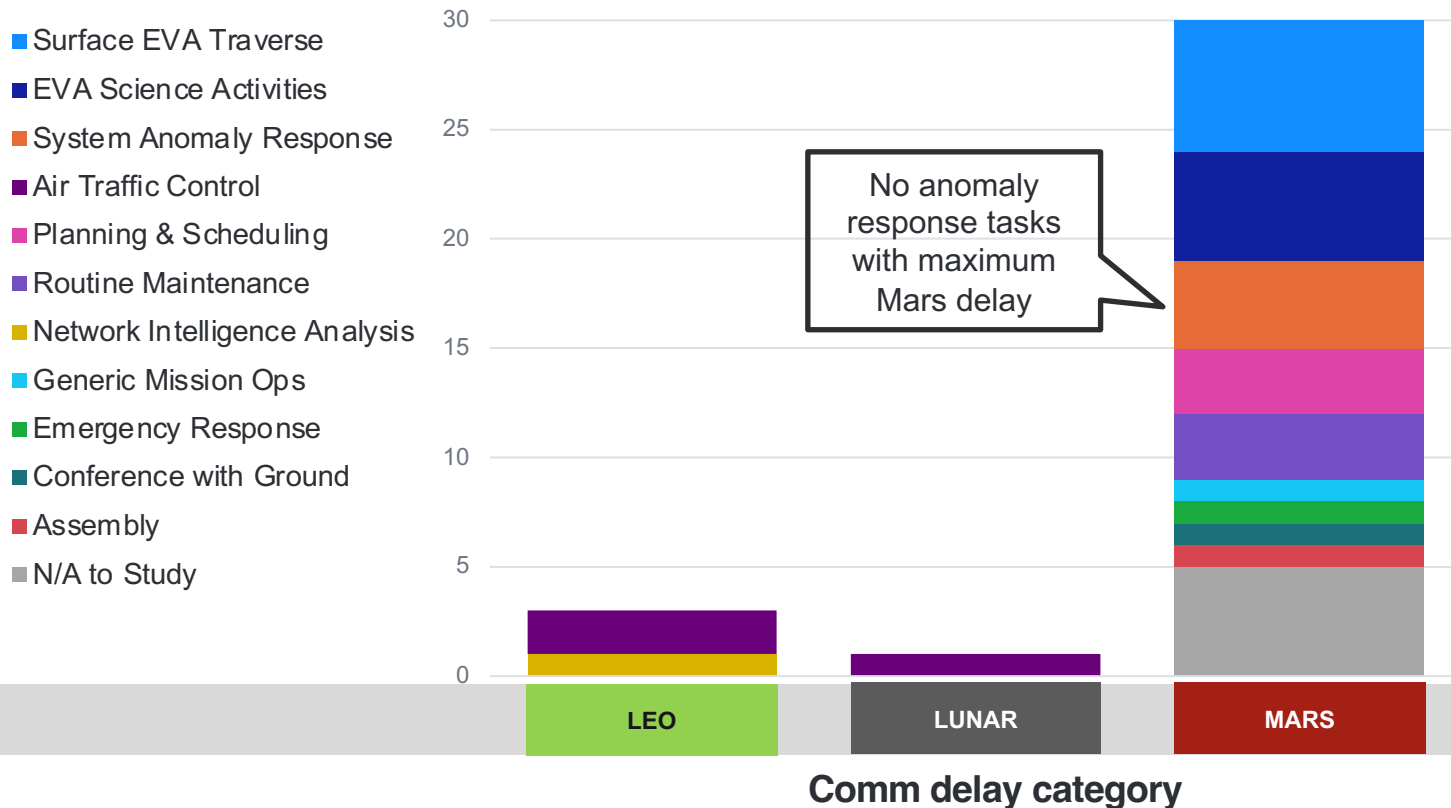
* Studies in which the tasks conducted in the analog environment did not relate to the focus of the study

Example: Autonomous, Computer-Based Behavioral Health Countermeasure Evaluation at HI-SEAS Mars Analog

Tasks Studied by Comm Delay



Tasks Studied by Comm Delay

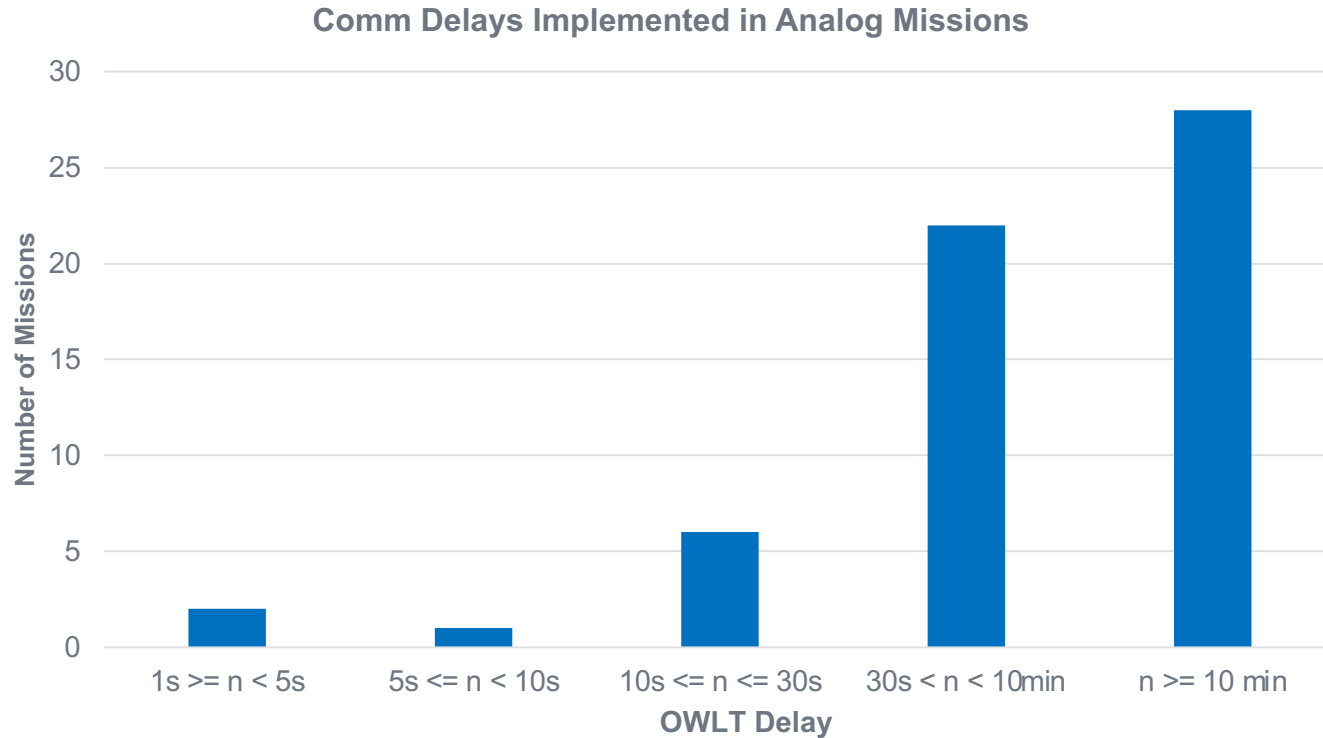


Analog Survey

Supplemented literature review with survey of analog mission conditions

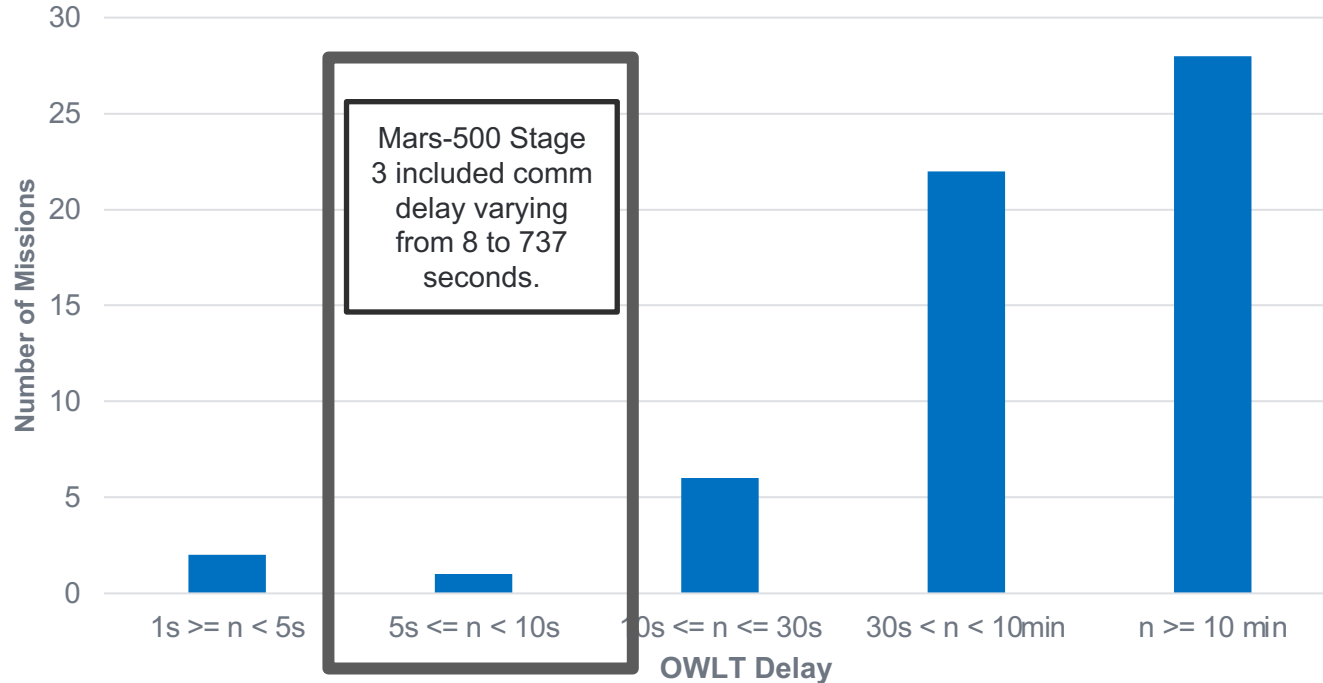
	A Campaign/Mission	Habitat	A Analog_size	# Duration...	Comm_regime	Comm_delays
1	Mars-500 Stage 1	NEK	553 m3	14		no delay
2	Mars-500 Stage 2	NEK	553 m3	105	The first ten weeks used r...	20 minutes
3	Mars-500 Stage 3	NEK	553 m3	520	The first eight weeks wer...	12 minutes
4	SIRIUS 17	NEK	553 m3	17	N/A	no delay
5	SIRIUS 19	NEK	553 m3	120	No delay on first and last ...	5 minutes
6	SIRIUS 21	NEK	553 m3	240	Comm delay "up to five m...	5 minutes
7	SIRIUS 23	NEK	553 m3	360	"one-way delay of five mi...	5 minutes
8	HERA C1	HERA	148.6 m3	7	10 min OWLT delay on Mi...	10 minutes
9	HERA C2	HERA	148.6 m3	14	MD5: 5 minute one-way d...	10 minutes 5 minutes
10	HERA C3	HERA	148.6 m3	30	MD13 – 30 sec MD14- 1 ...	30 seconds 1 minute
11	HERA C4 (M1, M2, M3, & ...	HERA	148.6 m3	45	MD1 - MD15 - RT MD16 - ...	30 seconds 1 minute
12	HERA C4 (MM4)	HERA	148.6 m3	23	MD1 - MD15 - RT MD16 - ...	30 seconds 1 minute
13	HERA C5	HERA	148.6 m3	45	MD16: 30 seconds MD17:...	30 seconds 1 minute
14	HERA C6	HERA	148.6 m3	45	MD 1-7: no delay MD 8-11...	30 seconds 1 minute

Analog Survey



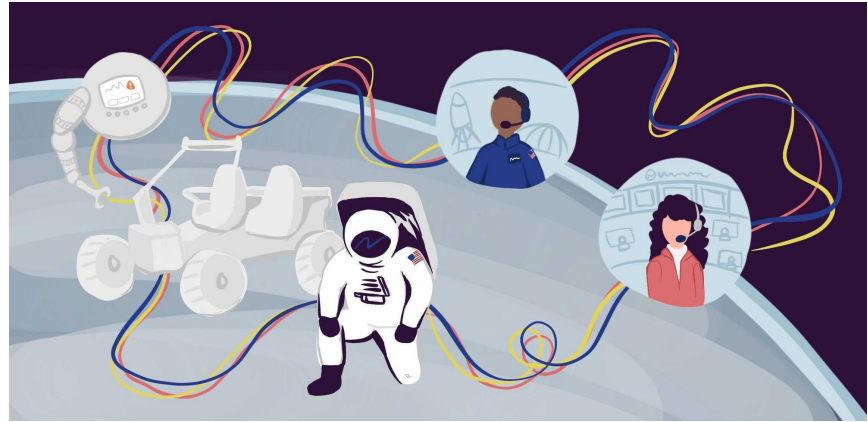
Analog Survey

Comm Delays Implemented in Analog Missions



Preliminary Conclusions

- Gap in research for expected lunar delays
- Gap in research for problem-solving tasks at maximum Mars delay



Next Steps

- Incorporating broadened literature search + continued survey of analog missions.
- Conducting interviews with relevant researchers, analog participants, and mission operations personnel.
- Planning studies investigating the effects of lunar-like delays on relevant spaceflight tasks.

Thank you | megan.e.parisi@nasa.gov

