

Our Motivation

 Reduce pressure on Science Mission Directorate budgets without limiting science mission objectives

 Provide science-enabling capabilities through efficient spacecraft delivery methods



Origin Story

- Exploration Systems Development Mission Directorate is investing in lunar NRHO space logistics capabilities via the Gateway Program and Deep Space Logistics (DSL)
- Investment will result in a space vehicle capable of performing multiple mission conops, including other destinations in xGEO, and payload manifesting flexibility
- NASA Goddard and NASA Kennedy have teamed up to apply this investment into efficient launch services to key points of interest in xGEO space for a science mission customer base
- New capability provides multi-mission capacity to maximize opportunities per flight, therefore reducing cost per customer mission
- While evaluating for efficiency, we have also discovered an inherent mission-enabling aspect that has potential to revolutionize the approach to science mission design



Science, Technology, External Relevance

Strategic Focus Area opportunities, collaboration

- Explorers Program
 - Small Explorers (SMEX)
 - Medium Explorers (MIDEX)
 - Missions of Opportunity
- ROSES, NRAs
 - Lunar science (non-Artemis hosted)

- Smallsat proposals
- Cislunar, Lagrange science
- xGEO heliophysics (ex: HERMES, heliocentric orbits)
- Earth-Moon based Earth Science (ex: DSCOVR)
- Distributed Systems Missions

Awarded and Directed Science

- Space Weather
- Low Lunar Orbiter
- Deep SpaceObservatory

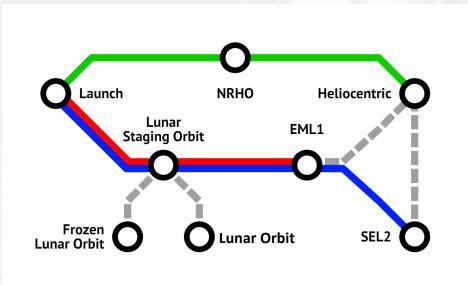
Technology and External

- STMD Lunar Technologies
- Comm & Nav infrastructure at cislunar, Lagrange
- Human Space Flight (partial-load logistics, international partner element deliveries)
- Non-NASA government partners

Return

The Idea

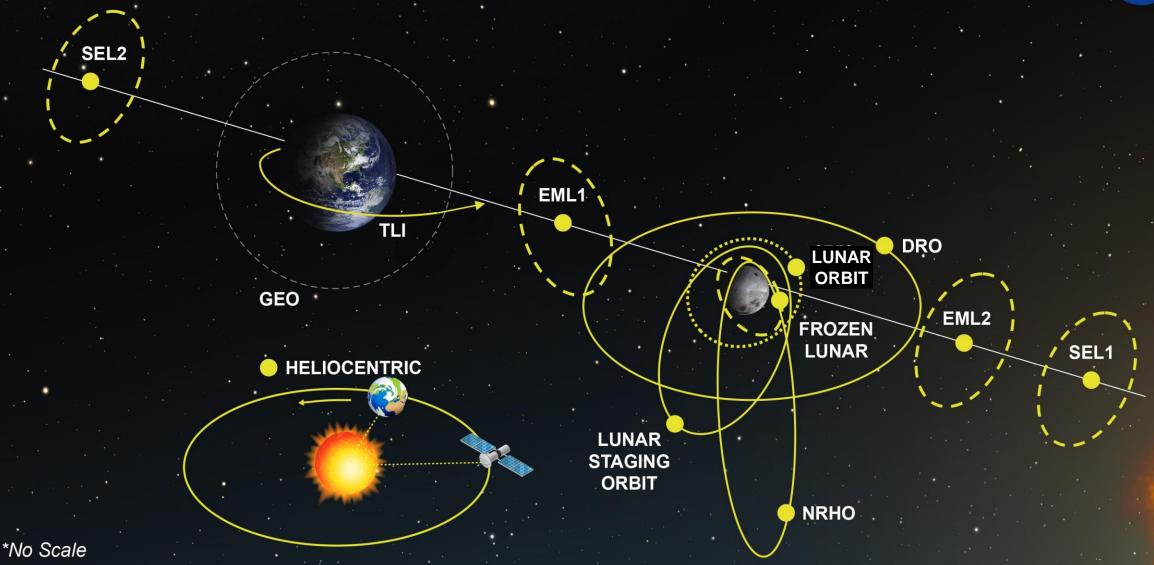
- Traveling around Washington D.C. you can...
 - Take an Uber (\$\$\$, △), or
 - Take the D.C. Metro (\$,



- Proposed xGEO METrO is the railway satellite transport service to regions beyond geostationary orbit
 - Each colored line is a reference flight design (lines created based on specific mission manifest)
 - METrO "stops" are either at mission destinations or at accessible orbits (ex: Lunar Staging Orbit)
 - Efficiencies come from a) sharing fixed launch services costs, and b) using recurrent capability for a multitude of destinations

Expected Service Destinations





What are the parts of METrO?

The **Multi-Element Transfer Orbiter (METrO)** transportation system combines core skills and capabilities from NASA Kennedy and NASA Goddard.



ENABLER – Science multi-mission recruitment, requirements assessment, aggregation, and manifesting

SCIENCE MISSION SYSTEMS ENGINEERING



IMPLEMENTOR – NASAmanaged cargo delivery services to xGEO space using commercial acquired service module (awarded & active contract)

DEEP SPACE LOGISTICS

FOUNDATION – U.S.-based launch vehicle insight and analytical capabilities

LAUNCH SERVICES PROGRAM

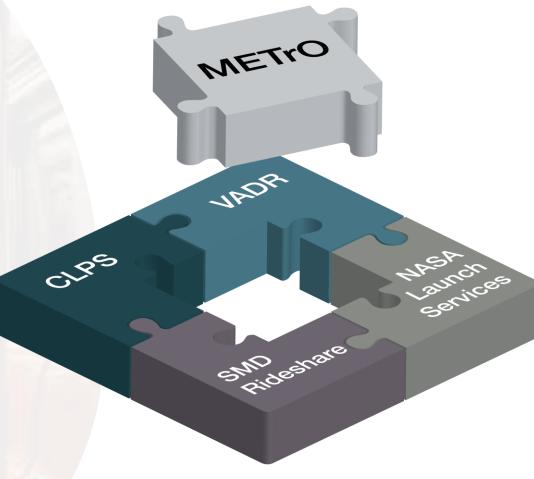
Multi-class, multi-size, multiple destinations – one launch.

METrO Multi-Mission Carrier

DSL Logistics Module

Where does METrO fit in?

- Lower cost per kg than individual launch services acquisitions
- Schedule certainty NASA-managed launch vehicle integration schedule
- No "primary payloads" manifest developed to all mission stakeholder requirements
- Capabilities/Capacities beyond VADR (Class D, smallsats) and CLPS (Class D, lunar proximity)
- Appropriate for payloads of variable size and mission class (Class B through D) on same flight
- Same Category 3 (Low Risk) launch vehicles, technical processes utilized by NASA Launch Services Program



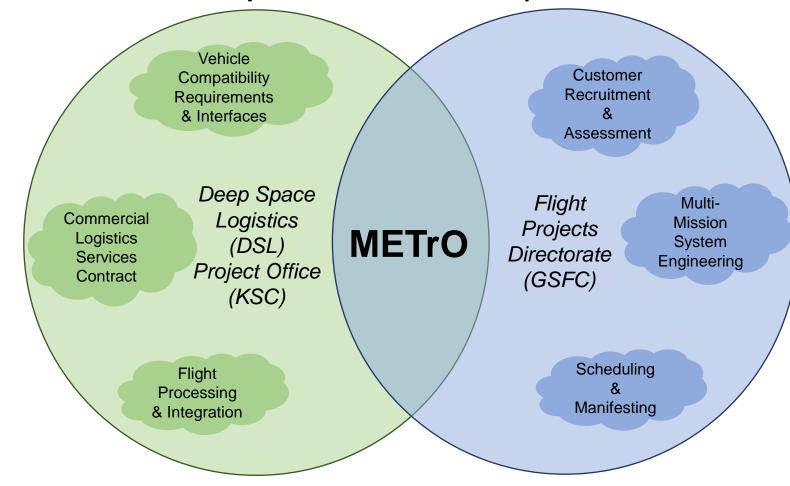
VADR: Venture-Class Acquisition of Dedicated and Rideshare contract

NLS II: NASA Launch Services II contract **CLPS**: Commercial Lunar Payload Services

SRO: SMD Rideshare Office

NASA Goddard and Kennedy Partnership

- A history of collaboration for science opportunities
- Provides NASA Kennedy the right partner to contribute solutions to Agency science budget pressures
- Goddard Flight Projects
 Directorate will provide a
 customer-focused mission
 systems engineering approach
 to flight planning and
 manifesting.



Did you know? – KSC and Goddard were collaboration partners on multiple Space Shuttle programs, providing recurring manifesting opportunities for science and exploration.





Deep Space Logistics at Kennedy Space Center





- Deep Space Logistics is part of NASA's Moon to Mars architecture
- We leverage the technical excellence and experience of Earth's Premier Spaceport, to provide reliable, cost-effective, access to cislunar space
- Our vision is to enable a vibrant commercial supply chain in deep space
- To achieve our vision, we invest in commercial spaceflight services that are safe, reliable, on-time and low-cost







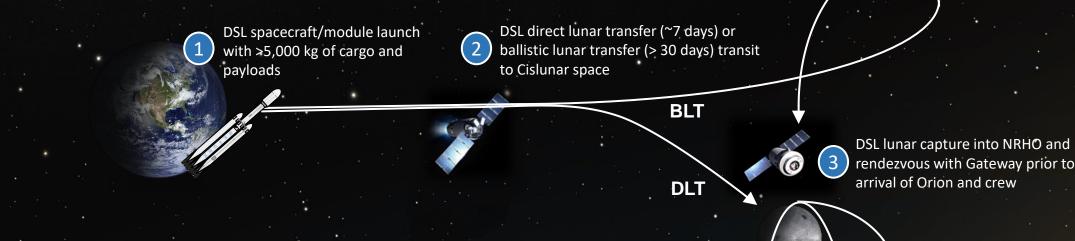






Artemis, Gateway and Deep Space Logistics: Laying the rail for a xGEO METrO





HELIOCENTRIC



DSL nominal departure and disposal into heliocentric orbit, followed by decommissioning

- DSL Gateway missions will, deliver cargo and payloads to the Gateway as a commercial service
- Development of first Gateway mission has begun with launch onschedule in 2027
- Annual Gateway logistics missions are planned to support each crewed mission beginning with Artemis IV

DSL docking to Gateway as a visiting vehicle, remaining for 3-12 months to support crew, science, lunar surface missions and other needs before undocking and departure

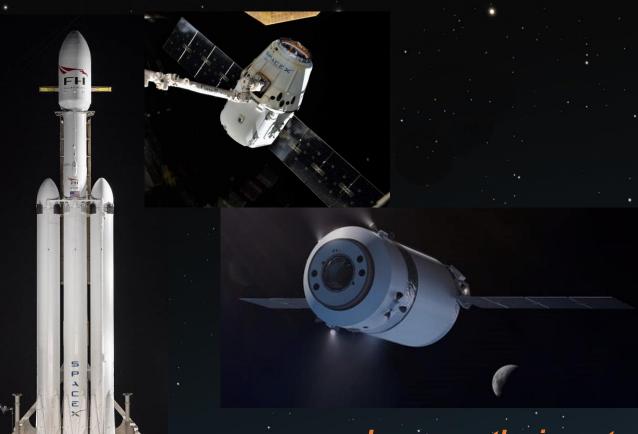
NRHO

Did you know? Before the building of the Transcontinental Railroad, it cost nearly \$1,000 dollars to travel across the country. After the railroad was completed, the price dropped to \$150 dollars.

METrO Missions Will Leverage NASA's Artemis Investments

Current Delivery System Heritage

- Falcon 9/Heavy
 - Cargo Dragon to ISS -> Dragon XL



Non-recurring Engineering for Dragon XL

- Service Section Design = METrO Carrier
- Concurrent Gateway need for Carrier to delivery high value elements (e.g. robotic arm)
- Life Cycle Design Reviews
- System Test & Verification

KSC/DSL/LSP Organization and Expertise

- Mission delivery concept development
 - Collaboration with mission development
 - Concept studies with service vendors
- Insight and Surveillance for commercial services
- Contract and mission management
- Customer payload processing and integration

Leverage the investments already made

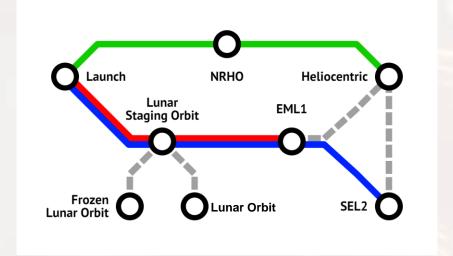
Building a METrO

- Points of Interests (POIs) → customer mission operational destinations
- Stops → staging locations to drop off/deliver customer missions
- "METrO Line" → flight plan/conop showing expected stops and accessible points of interest

METrO Construct			Planned POI Access						
METrO Lines Trajectory		NRHO	DRO	Lunar Staging Orbit	Frozen Orbit	Lunar Orbit	EML1 Halo Orbit	SEL2 Halo Orbit	Heliocentric Orbit
Red Line	Direct			X	X	X	X		
Blue Line	Direct			X	X			X	
Green Line	Direct	X							X

Why "Stops" and POIs? Why not just take me to my destination? For public transportation to be efficient, the user/customer may need to expend some of their own resources (i.e., walking that final city block) to complete the full journey. The benefit is the ride only cost a token.

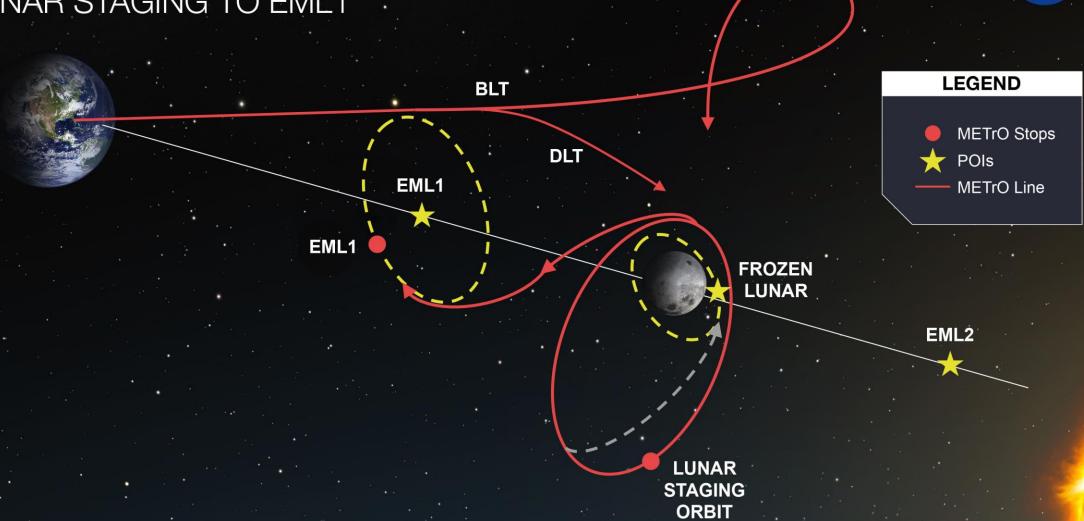
 Let METrO do the work: Missions save delta-v by taking METrO to closest stop

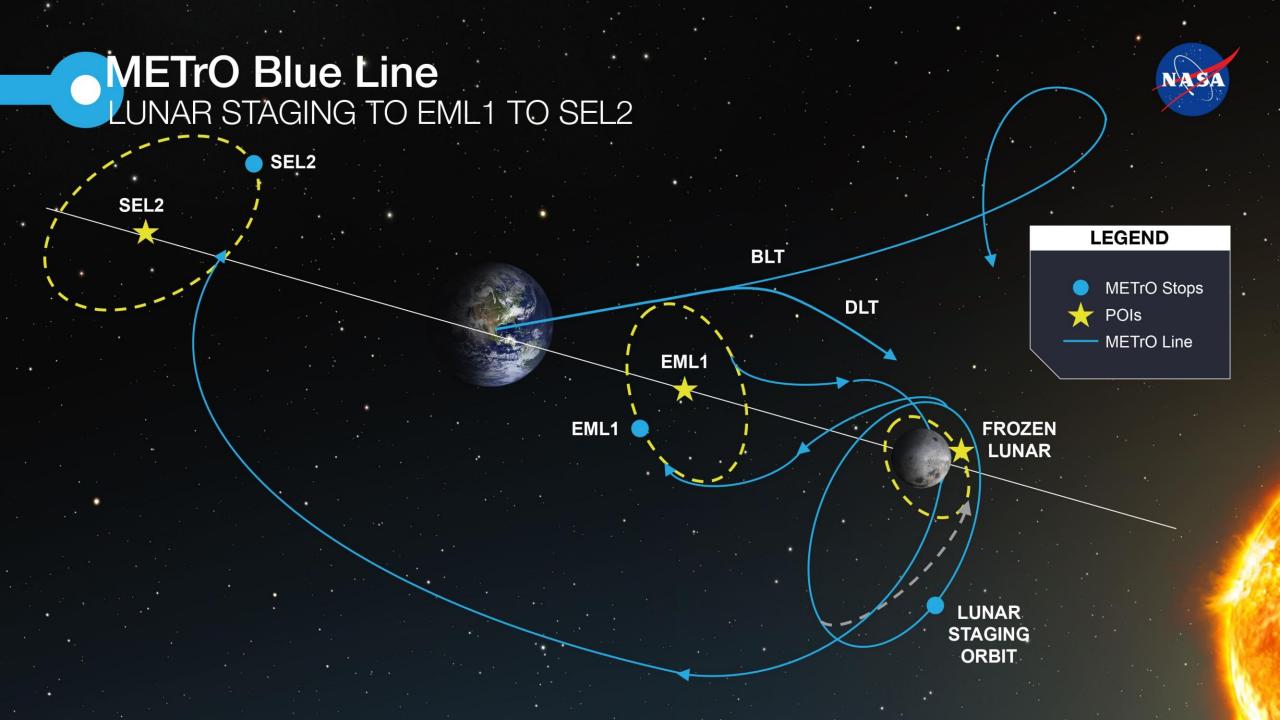


New POIs, Stops and METrO Lines can be added/modified as customer mission requirements are revealed

METrO Red Line LUNAR STAGING TO EML1







METrO Green Line NRHO TO HELIO **LEGEND** BLT METrO Stops DLT POIs EML1 METrO Line HELIOCENTRIC EML2 NRHO

		Mass Capability (kg)				
	Transfer Type (Total Duration)	NRHO	Lunar Staging Orbit**	EML1 Halo Orbit	SEL2 Halo Orbit	Heliocentric Orbit
Red Line	Direct (165 days)	-	1400-4900	700-2800	-	-
	BLT (265 days)		2100-5600	700-4200	-	-
Blue Line	Direct (135-265* days)	-	700-4200	700-4200	700-4200	1
	BLT (235-365* days)	-	700-4900	700-4900	700-4900	-
Green Line	Direct (30 days)	700-4900	-	-	-	700-4900
	BLT (130 days)	700-6300	-	-	-	700-6300

Assumed minimum payload mass is 700kg with transport ring and minimum 1 payload delivery at each stop

^{*}Depends on separation location between EML1 and SEL2

^{**}Provides customer access to frozen lunar orbits, lunar elliptical orbits

Interfaces & Resources for METrO Payload Passengers

- Common multi-manifest payload adapter hardware mechanical (mass, volume, attachment) interfaces
- Standard METrO xGEO Carrier Spacecraft Electrical and Telemetry (SEAT) allocation
 - Electrical Power
 - Distribution tailored to multi-manifested payloads
 - Total Payload Power: Minimum 1.8 kW continuous power, 4kW peak, via solar arrays and batteries
 - Regulated 28V to payloads with independent load switches
 - Command & Data Handling
 - Payload and downlink > once per 24 hours during transit
 - Transmission and confirmation of commands to payloads
 - 4 kbps low-rate telemetry / 40 kbps high-rate telemetry
 - Data storage available based on payload passenger needs

Mission Phase	Resource Availability			
Ground	Payload passenger access to facility or launch vehicle (LV) power			
Launch	Payload passengers on internal battery power from encapsulation through METrO xGEO Carrier deployment from LV; Power to payloads available after METrO xGEO Carrier solar array deployment			
Transit	Power and daily Health & Status data downlink to ground provided by METrO xGEO Carrier, internal battery usage by payload passengers permitted			
Deployment	Payload passengers on internal battery power 18			

Design Trades and Benefits for the xGEO METrO Payloads

METrO Line	Payload	Benefits and Trades
Red	Frozen Lunar Orbit satellites	delivery of multiple satellites in a constellation on a single launch, and lower prop mass required per satellite
	EML1 satellites	propellant savings for mass reduction or increased maneuvering/station-keeping
Blue	Frozen Lunar Orbit and EML1 satellites	same benefits and trades as for Red Line
	SEL2 satellites	access to destination without mass, propellant or prop system required to reach this orbit
Green	NRHO satellites	access to destination without paying for full ride
	Heliocentric satellites	delivery of multiple satellites in a constellation on a single launch, and access to destination without mass, propellant or prop system required to reach this orbit

What xGEO METrO trades and benefits would you consider?

Let's Talk

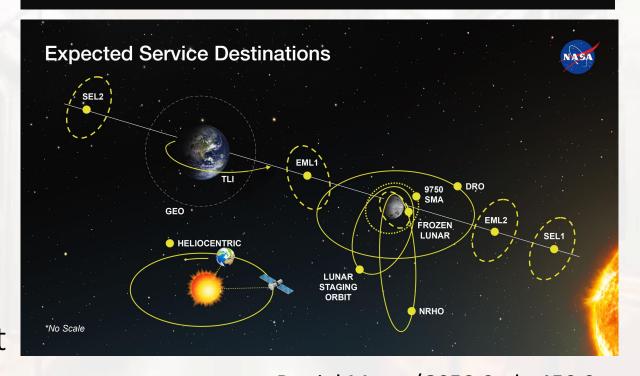
- Partnering / Sponsoring by Mission Directorates requires:
 - Benefit modeling
 - Endorsement by PIs, mission planners
- We want your DRMs, use cases



QR code to visit xGEO METrO online

How would you design your METrO line?





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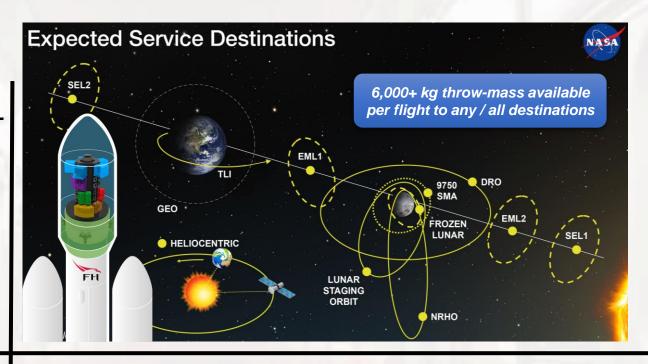
xGEO METrO

Description

- Science-enabling, govt-managed, commerciallyacquired launch and delivery service
- Multi-class, multi-size, multiple destinations, one launch
- In collaboration with NASA Kennedy
- Target customers: SMD, STMD, human space flight, non-NASA payloads

Differentiators

- Not rideshare each delivery per mission unique requirements, not filling excess capacity
- Multiple reliability classes on same flight expands customer payload options
- Meet and exceed LV risk categories, technical process standards at same price points



Science-Enabling Relevance

- SMEX: expanded destination options, similar \$/kg
- MIDEX: lower LV costs, retain more delta-V
- Lunar Science: LExSO, non-Artemis hosted
- Comm & Nav, Distributed Systems Missions
- Same-mission constellation deployment

METrO Risk Posture

Deep Space Logistics

Launch Services Program

***** xGEO METrO Carrier risk is scalable to customer risk posture via:

- Tailored NPR 7120.5 lifecycle reviews for system certification and mission specific configurations with NASA approval
- Initial Mission ATP to Launch: 48 months (in work for Artemis IV Gateway Logistics Module)
 - Initial mission executes the design life cycle for a common carrier configuration (SRR > PDR > CDR > VBR > FRR)
 - SRR anticipated late CY24 or early CY25
- Subsequent mission of common carrier configuration is a 30 months integration cycle to launch
 - Mission specific reviews: MSSRR > MSPDR > MSCDR > SAR > FRR

◆Launch Vehicle Services projected to be a Cat 3 (Low Risk) capability

 DSL Specialized Missions require three successful launches of the same LV configuration prior to DSL mission use

- NASA Technical Authority processes (ERP, SRP) to identify and characterize risk
- DSL Risk Management Plan to guide Project/Mission risk mitigation or acceptance
- Current on-contract: Cat 3 (Low Risk) Launch Vehicle [Falcon Heavy]

