Jet Propulsion Laboratory
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Proximity Link Telecommunication and Tracking Scenarios for a Potential Mars Sample Return Campaign

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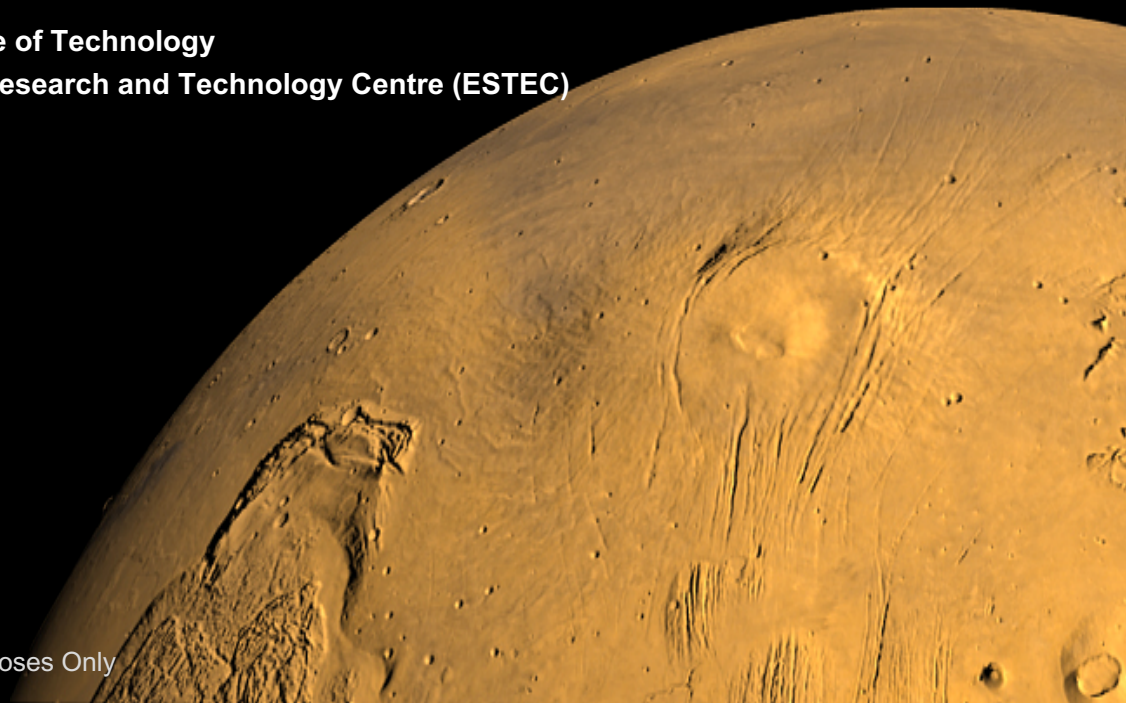


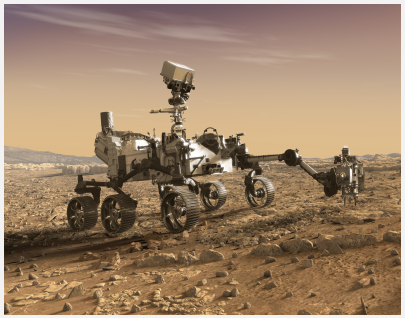
Pre-Decisional Information – For Planning and Discussion Purposes Only

Outline

- Notional Mars Sample Return Architecture
- Existing Relay Infrastructure and Plans for Extended Operations
- MSR Relay Scenarios
- Summary

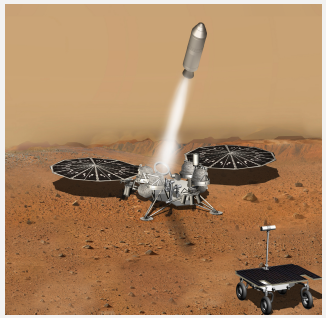
Notional Mars Sample Return Architecture

- Three flight elements plus one ground element



Sample Caching Rover (Mars 2020)

- *Sample acquisition*
- *Sample caching*

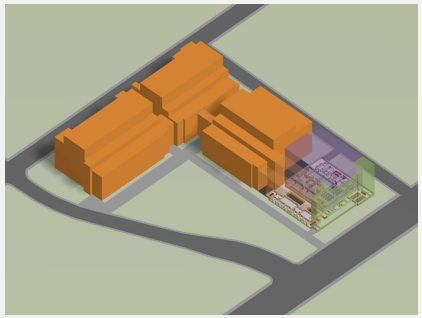


Sample Retrieval Lander*

- *Fetch Rover*
- *Orbiting Sample container (OS)*
- *Mars Ascent Vehicle*

Earth Return Orbiter*

- *Rendezvous and On-Orbit Capture System*
- *Earth Entry Vehicle*



Mars Returned Sample Handling*

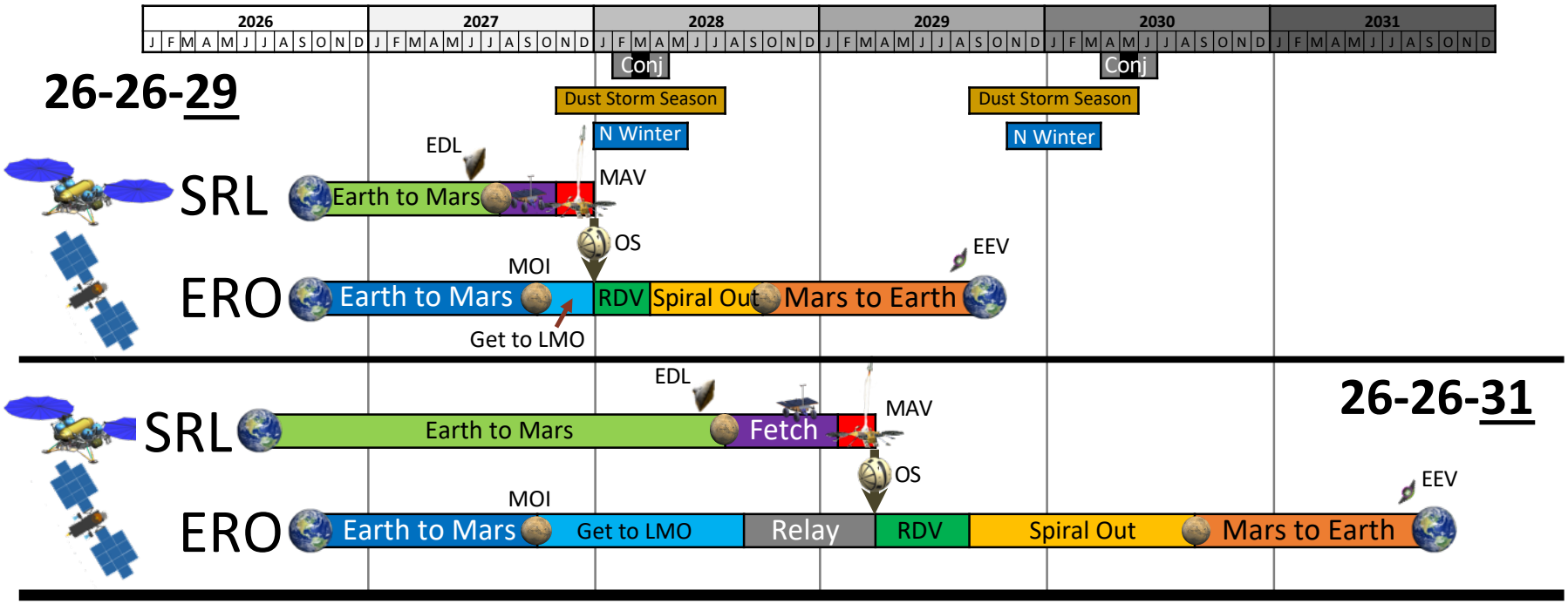
- *Sample Receiving Facility*
- *Curation*
- *Sample science investigations*

Flight Elements

Ground Element

*Concepts

Notional MSR Timelines

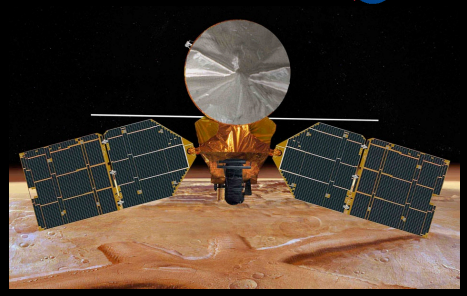


- Fast 26-26-29 Campaign timeline has significant technical challenges
  - SRL would arrive before ERO would be available for relay service; would require one or more existing Mars Relay Network assets to still be operational or a replenishment orbiter
  - Mars fall arrival would limit time to complete surface sample retrieval prior to Northern winter and dust storm season
- Alternative 26-26-31 timeline would eliminate these concerns
  - Type 3/4 Earth-Mars transfer for SRL would allow SRL EDL to occur after ERO would be in Mars orbit
  - Would allow ERO to serve as primary MSR relay asset
  - Any existing relay orbiters still operational in SRL timeframe would offer additional comm bandwidth and add robustness, but would not be required

Current Mars Relay Network

Odyssey (2001)

MRO (2005)



ESA ExoMars
Trace Gas Orbiter (2016)

Image: ESA

Mars Express (2003)

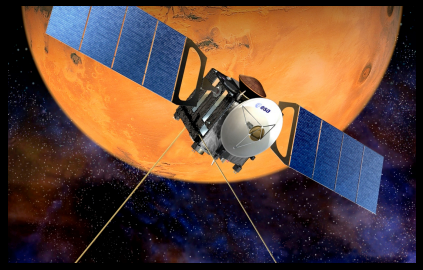
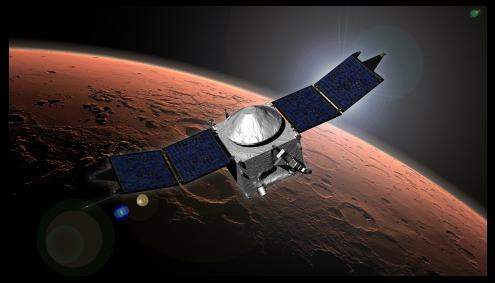


Image: ESA

MAVEN (2013)



Baseline Mars Relay Network Specifications

	ODY	MEX	MRO	MAVEN	ExoMars/TGO
Agency	NASA	ESA	NASA	NASA	ESA/RSA
Launch Date	2001	2003	2005	2013	2016
Orbit	400 km 93 deg inclination	298 x 10,100 km 86 deg inclination	255 x 320 km 93 deg inclination	~220 x 4500 km[1] 74 deg incilnation	400 km 74 deg inclination
UHF Transceiver	CE-505	Melacom	Electra	Electra	Electra
Antenna	Quadrifilar Helix	Quadrifilar Helix	Quadrifilar Helix	Quadrifilar Helix	Quadrifilar Helix
Max Data Rate	256 kbps	128 kbps	2048 kbps	2048 kbps	2048 kbps
Transmit Power	12 W	8.5 W	5 W	5 W	5 W
Adaptive Data Rate Capable?	N	N	Y	Y	Y

[1]MAVEN orbit reflects current plan for orbit modification prior to the arrival of Mars 2020

Mars Relay Network Availability for Potential MSR Support

- ODY and MEX are unlikely to remain operational in the late 2020's time frame; focus on MRO/MAVEN/TGO
- MRO (2005)
  - ~200 kg remaining propellant, ~10 kg/yr usage
  - Dual-string Electra payload
  - All-stellar ACS implemented to preserve IMU life
  - Managing battery lifetime; may require move to later LMST
  - S/C redundancy largely intact (exception is X-band high-rate downlink, due to a stuck Waveguide Transfer Switch)
- MAVEN (2013)
  - Single-string Electra payload
  - Aerobraking planned to transition from 6200x150 to 4500x230 km orbit for improved relay performance and longer orbital lifetime (through 2030)
  - Excellent spacecraft health, w/ full s/c redundancy
- ExoMars/TGO (2016)
  - Dual-string Electra payload
  - Aerobraking completed in 2018; now operating in final 400-km circular science/relay orbit
  - Excellent spacecraft health, w/ adequate propellant for operations through 2030

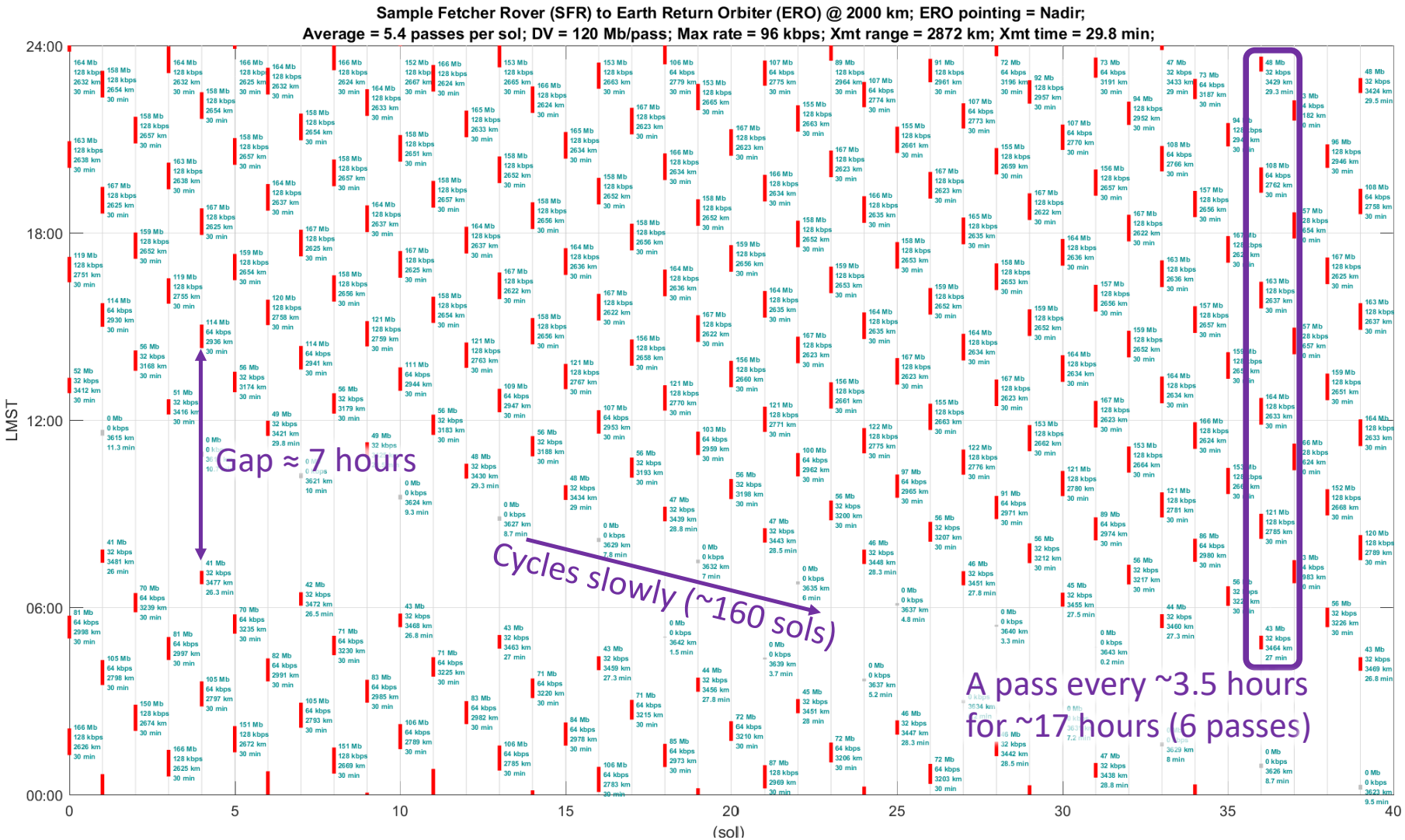
Relay Performance Analysis

- We applied JPL's Telecom Orbit Analysis and Simulation Tool (TOAST) to assess relay performance for ERO and for the existing relay orbiters to support the MSR landed elements
  - Assume NASA would provide an Electra UHF Transceiver to ESA for integration on ERO
  - Provides standard relay services, fully compatible with existing Mars Relay Network capabilities
- Key assumptions:
  - Heritage Electra UHF Transceiver capability on ERO
  - 6 dBic orbiter UHF antenna gain, either nadir pointed or steered to the user
  - 30 min maximum pass duration (due to energy/thermal considerations)
  - 3 dB link margin

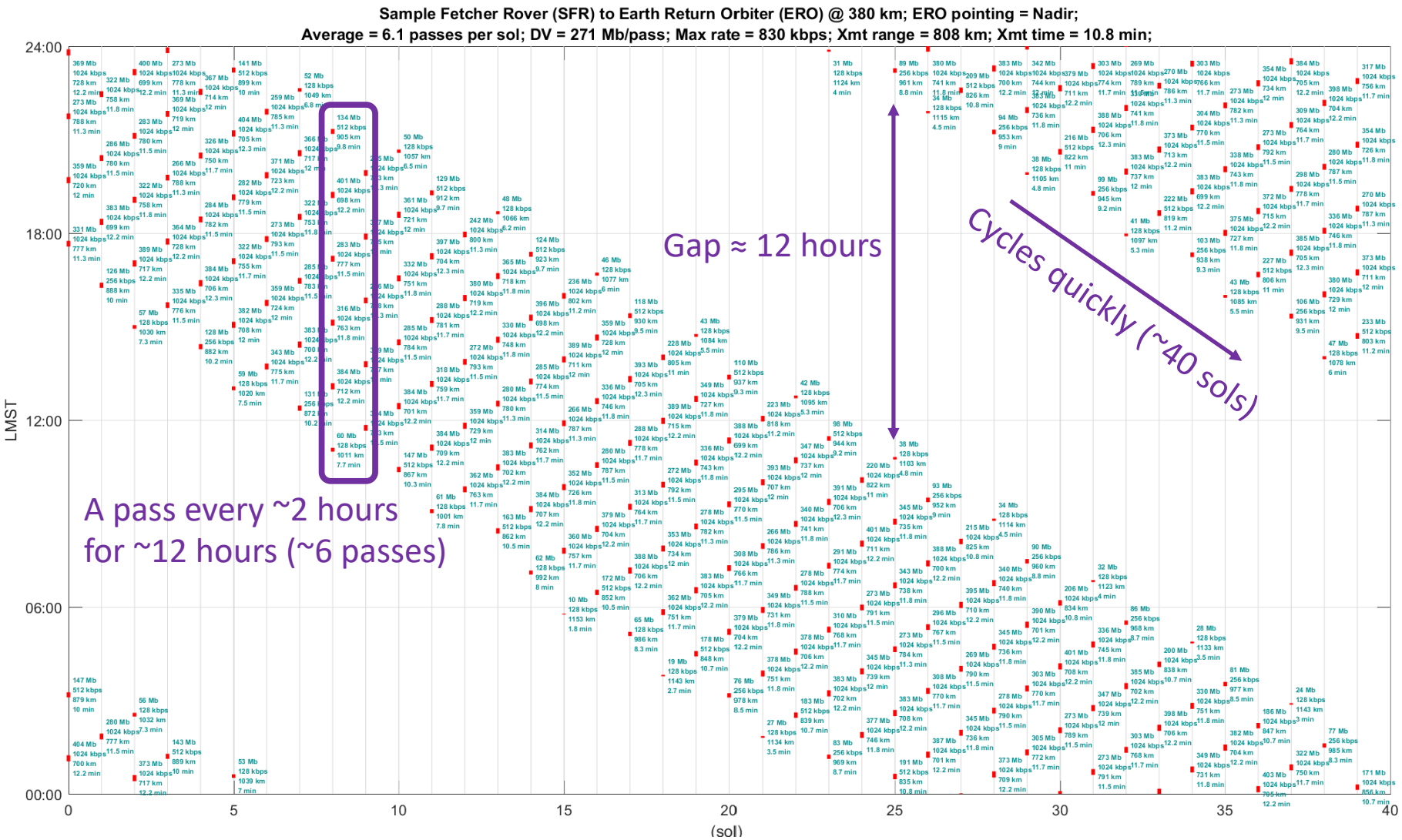
	M2020	SRL	SFR
UHF Transceiver	Electra-Lite	Electra-Lite	QinetiQ
Transmit Power (W)	8.5	8.5	4.0
Coding	(7,½), LDPC	(7,½), LDPC	(7,½)
Max Data Rate (kb/s)	2048	2048	1024
Antenna	Quadrifilar Helix	Quadrifilar Helix	Dipole

Assumed landed asset relay capabilities

Relay Contact Pattern for ERO @ 2000 km

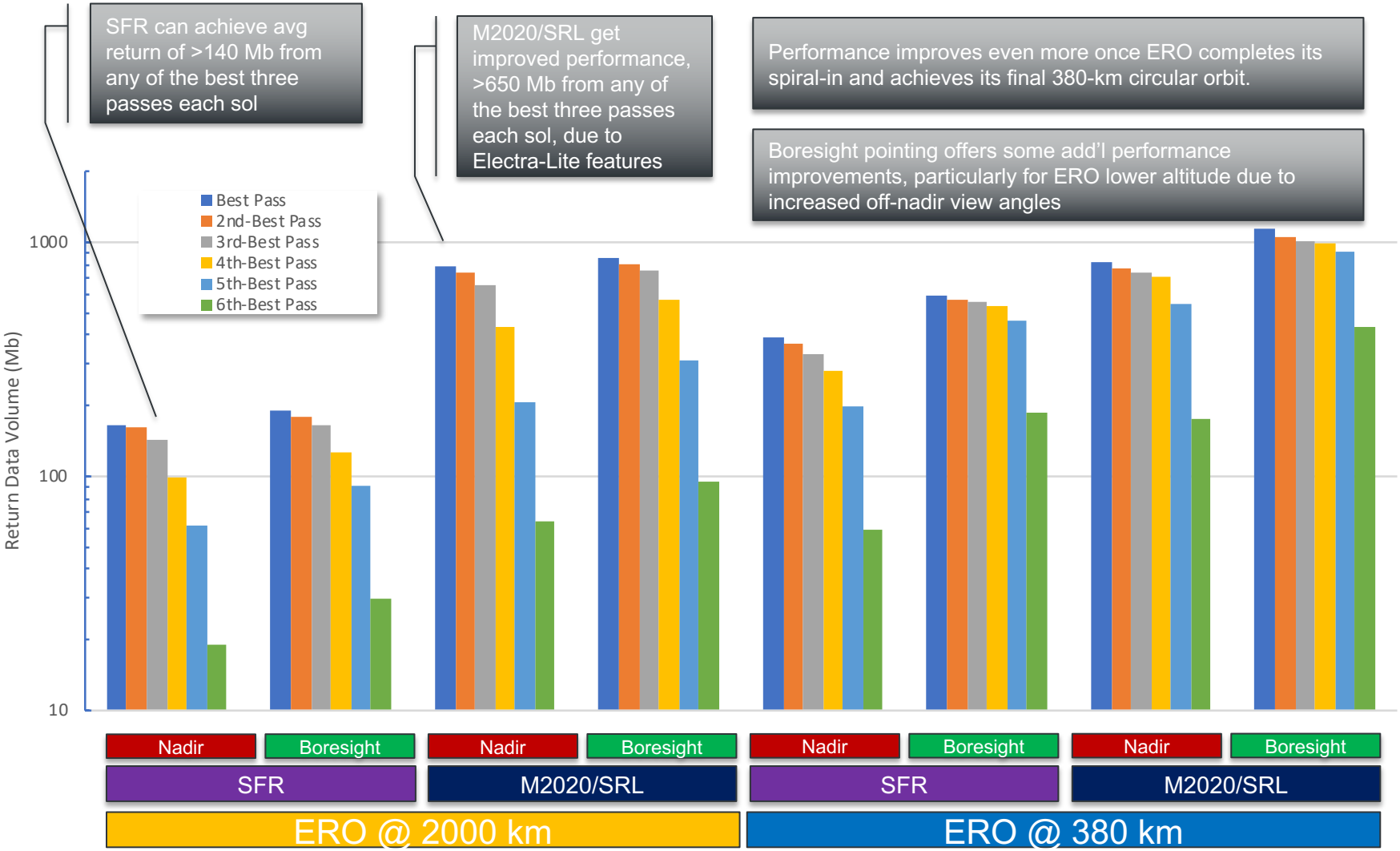


Relay Contact Pattern for ERO @ 380 km



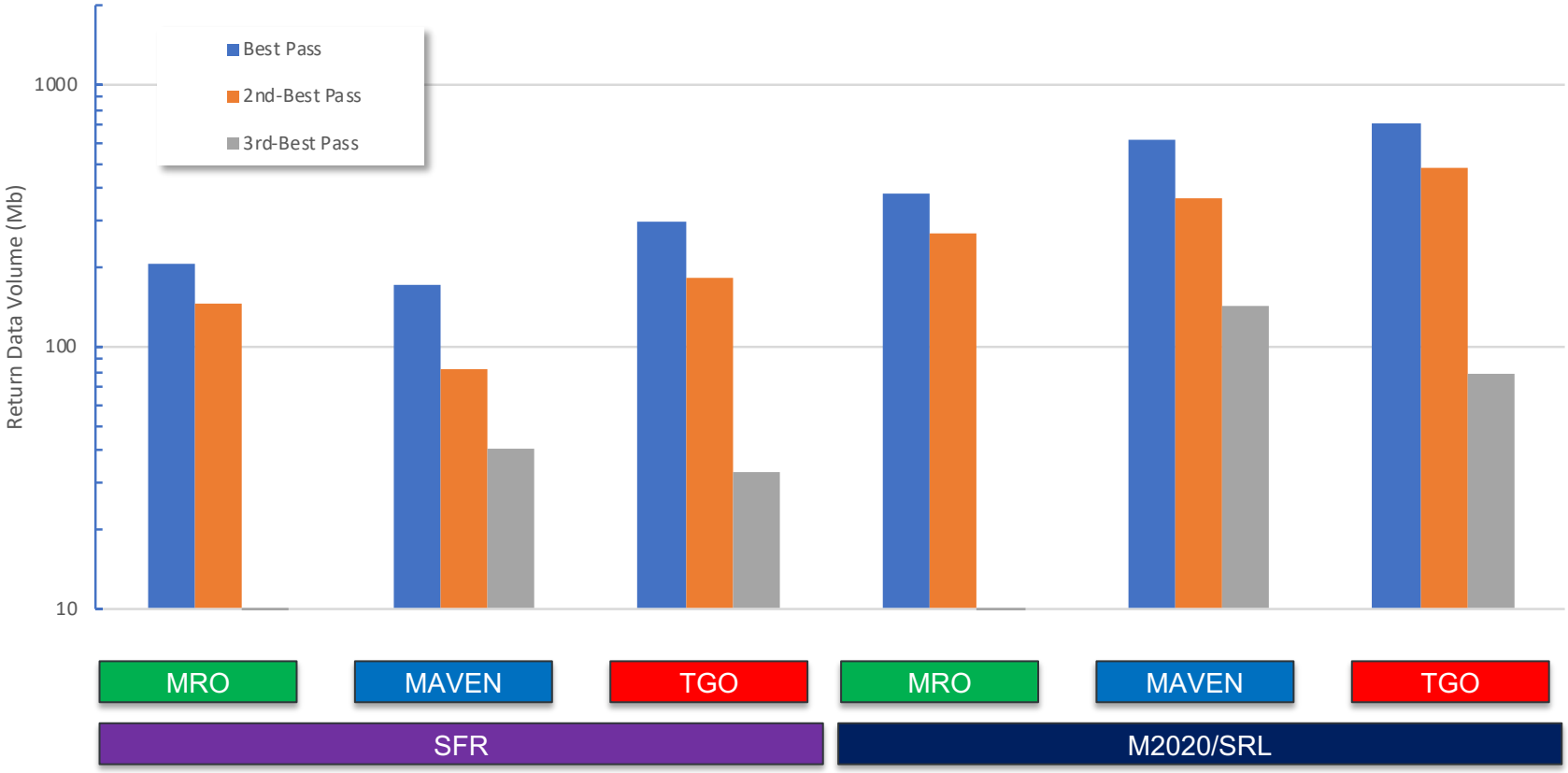
ERO Relay Performance Results

- ERO's excellent relay coverage translates into robust relay support for the multiple surface spacecraft engaged in MSR surface operations



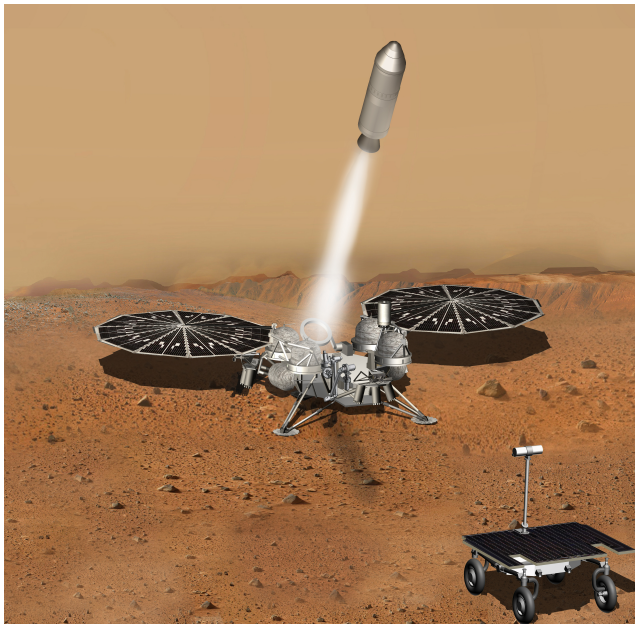
Existing Mars Relay Network Performance for MSR

- MRO, MAVEN, and TGO – if still operational - could augment ERO performance or provide a contingency relay capability in the event ERO relay services are unavailable
  - The higher inclination of these orbiters limits overflights to 2-3 contacts per sol



MAV Launch Support

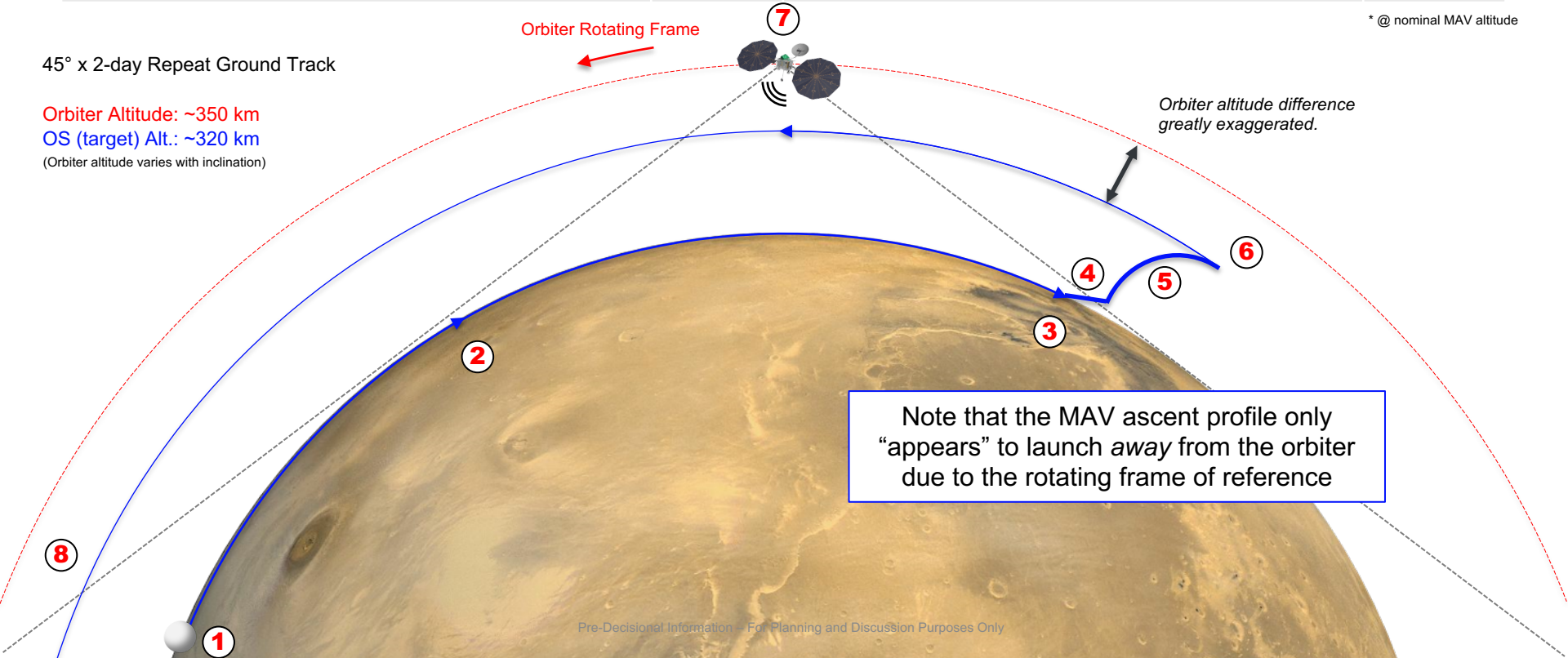
- MAV launch would represent a critical event – like EDL – where there is a programmatic requirement to acquire tracking and telemetry data that could support fault reconstruction in the event of a launch anomaly
- MAV tracking and telemetry is also key to providing an initial orbit solution for the released OS
  - OS has no radio capability, so must be acquired by ERO using passive optical cameras; accurate initial orbit is critical to enable rapid OS acquisition
- MAV would transmit carrier and modulated telemetry, and would be acquired with full-spectrum (aka open-loop) recording, for ground post-processing
  - If launch is successful, additional MAV telemetry can be returned after OS release



Notional MAV Launch Sequence

Event	Time	Event	Time
1 MAV Ready for Launch	L-2d	5 Ascent Coast Phase	L+15m
2 MAV-Orbiter In-View (Go / No Go)	L-20m	6 2nd Burn / OS Separation	L+16m
3 MAV Launch	L-0	7 OS Passes under Orbiter	L+15h*
4 Ascent 1st Burn	L+2m	8 OS Occulted by Mars	L+39h*

* @ nominal MAV altitude



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Summary

- Relay communications would play a critical role in the successful execution of an MSR campaign
  - Simultaneous operation of three landed assets – M2020, SFR, and SRL
- The current Mars relay network, including orbiters from both NASA and ESA, provides highly capable, interoperable relay services
  - MRO, MAVEN, and TGO are all healthy and have the potential for operations through 2030, but would be operating well beyond its original design lifetime
- A reference MSR architecture has been selected for which ERO arrives on-orbit in time to support SRL EDL and the sample retrieval surface mission
- ERO's low-inclination orbit would offer frequent relay contacts per sol, key to providing sufficient relay support to multiple MSR landed assets
- ERO relay support would also play a critical role during the MAV launch,
  - Critical event tracking and telemetry data to support fault reconstruction
  - MAV IMU telemetry and Doppler tracking data to generate an initial estimate of the MAV/OS orbits, key to supporting the optical search for the OS by ERO

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