NASA Relay Planning for the 2016 Mars Mission Opportunity

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IEEE Aerospace Conference, Big Sky, MT
March 8, 2015

Outline

- Mars Relay Network Overview
- Relay Support to the InSight Lander
  - EDL
  - Surface Relay
- ExoMars Trace Gas Orbiter
  - NASA Relay Support to EDL Demonstrator Module
  - Long-term TGO Relay Service Using NASA-provided Electra UHF Transceiver Payload
- Summary

Current Mars Relay Network

Odyssey

NASA
- Launched 2001

Orbit:
- 400 km sun-synch

Deep Space Link:
- X-band
- 15 W SSPA
- 1.3 m HGA

Prox Link:
- CE-505
- Single UHF Cannel
- 8, 32, 128, 256 kbps return link
- (7,1/2) CC

Mars Express

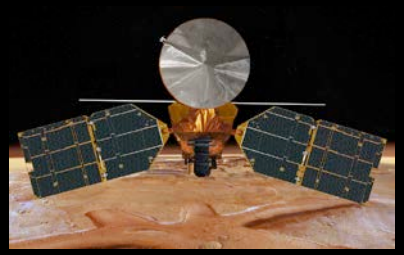
ESA
- Launched 2003

Orbit:
- 330x10,530 km elliptical orbit

Deep Space Link:
- X-band
- 65 W TWTA
- 1.65 m HGA

Prox Link:
- Melacom (QinetiQ)
- Single UHF Channel
- 2, 4,…, 128 kbps return link
- (7,1/2) CC

MRO



NASA
- Launched 2005

Orbit:
- 255x320 km sun-synch orbit

Deep Space Link:
- X-band
- 100 W TWTA
- 3 m HGA

Prox Link:
- Electra
- Freq-Agile (390-450 MHz)
- 1, 2, 4,…, 2048 kbps return link
- (7,1/2) CC
- I/Q open loop recording
- Suppressed Carrier Modulation
- Adaptive Data Rates

MAVEN

NASA
- Launched 2013

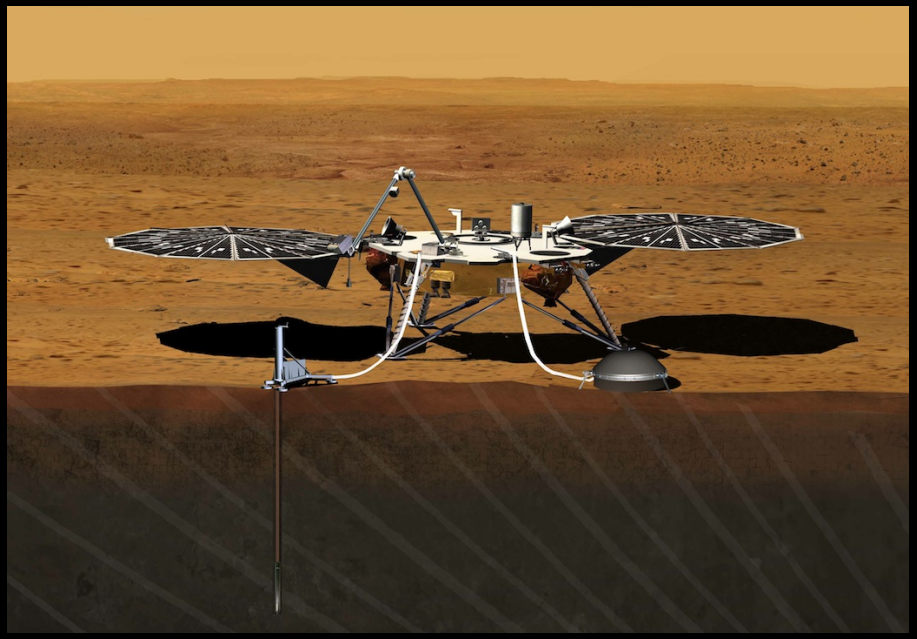
Orbit:
- 150-6200 km elliptical orbit

Deep Space Link:
- X-band
- 100 W TWTA
- 2 m HGA

Prox Link:
- Electra (single-string)
- Freq-Agile (390-450 MHz)
- 1, 2, 4,…, 2048 kbps return link
- (7,1/2) CC & LDPC
- I/Q open loop recording
- Suppressed Carrier Modulation
- Adaptive Data Rates

InSight Lander

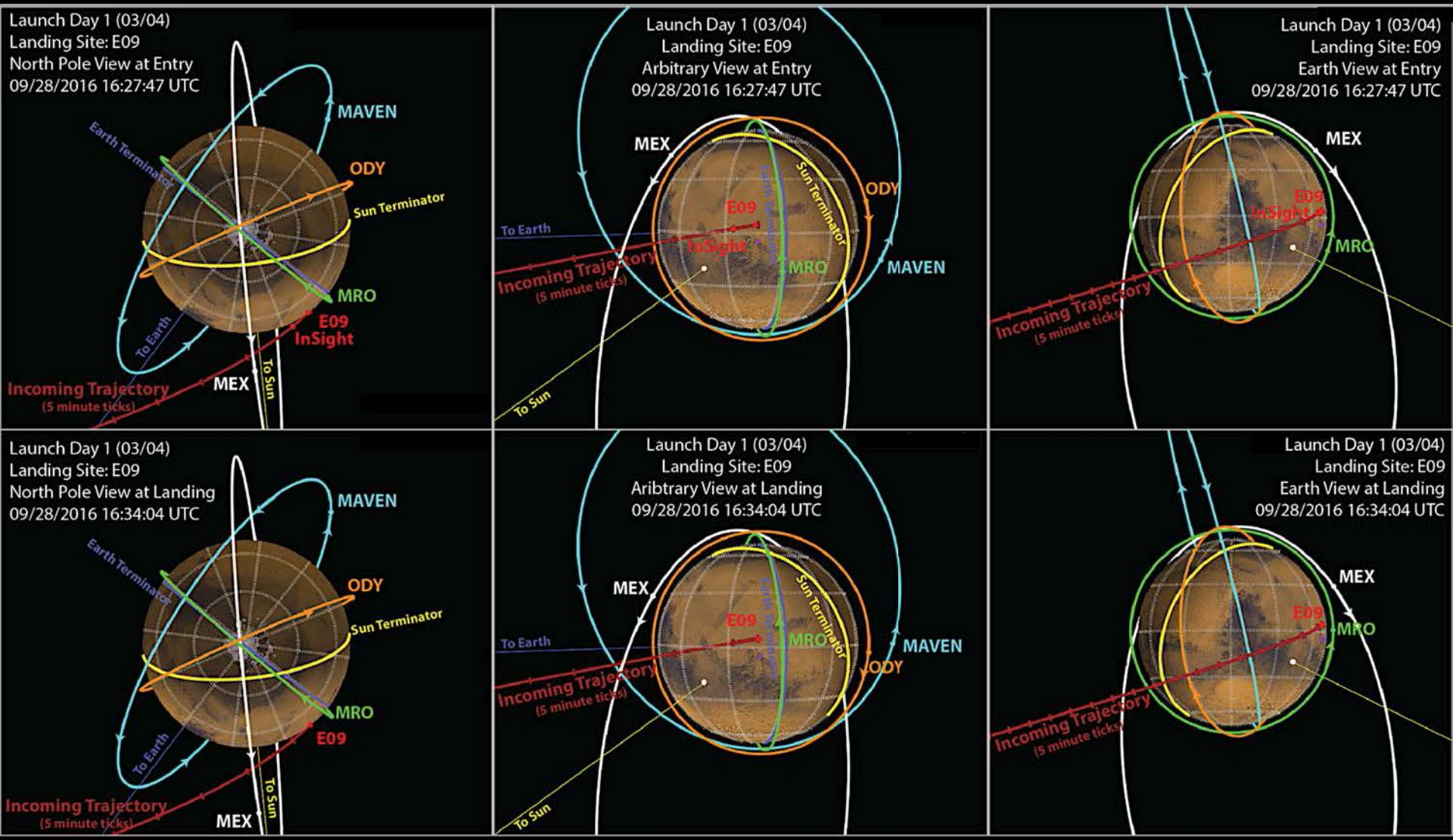
- Mission overview
  - Competitively selected, PI-led mission under NASA Discovery Program
  - Launch: March 2016
  - Arrival: Sep 2016
  - One Mars year primary mission
  - Science focus on geophysics of Martian deep interior
- Driving relay requirements
  - MRO critical event communications during EDL
  - Two passes/sol, >40-60 Mb/sol during initial instrument deployment (80 sols)
  - Average one pass/sol, >40 Mb/sol during remaining surface mission
- Challenges
  - InSight landing site is only ~365 km from Curiosity, resulting in contention for relay service



Science Investigations:

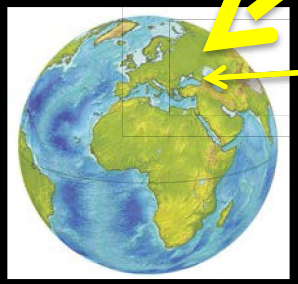
- *Seismic Experiment for Interior Structure (SEIS)*
- *Heat Flow and Physical Properties Package (HP3)*
- *Rotation and Interior Structure Experiment (RISE)*

InSight Arrival Geometry

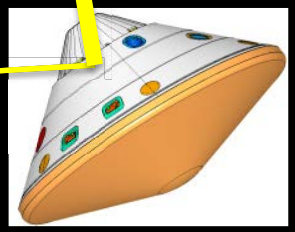


Baseline InSight EDL Strategy

MRO:
- Electra open-loop recording
- Post-EDL playback to Earth
- Ground post-processing to generate spectrogram and recover InSight telemetry



DTE:
- Receive InSight UHF signal at:
  - Effelsberg (GER)
  - Jodrell Bank (GBR)
  - GMRT (IND)

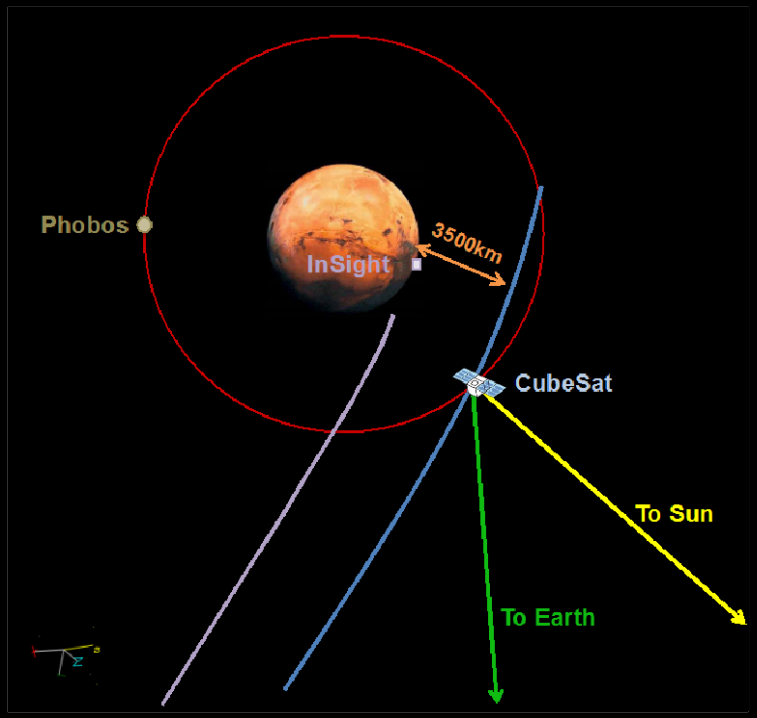


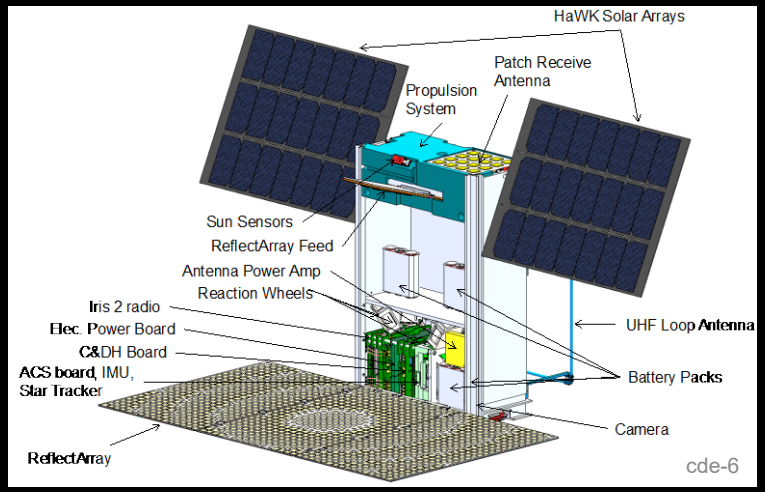
InSight:
- UHF transmission from from cruise stage separation until L+5 min
- 8 kbps engineering telemetry beginning @ E-2 min

ODY: *Not in view (6:45 PM node)*
MAVEN: *Not in view (nominal science orbit)*
MEX:
- *Not in baseline*
- *Appears to be in geometric view (based on planned phasing for EDM EDL support*
- *Could provide canister mode recording*

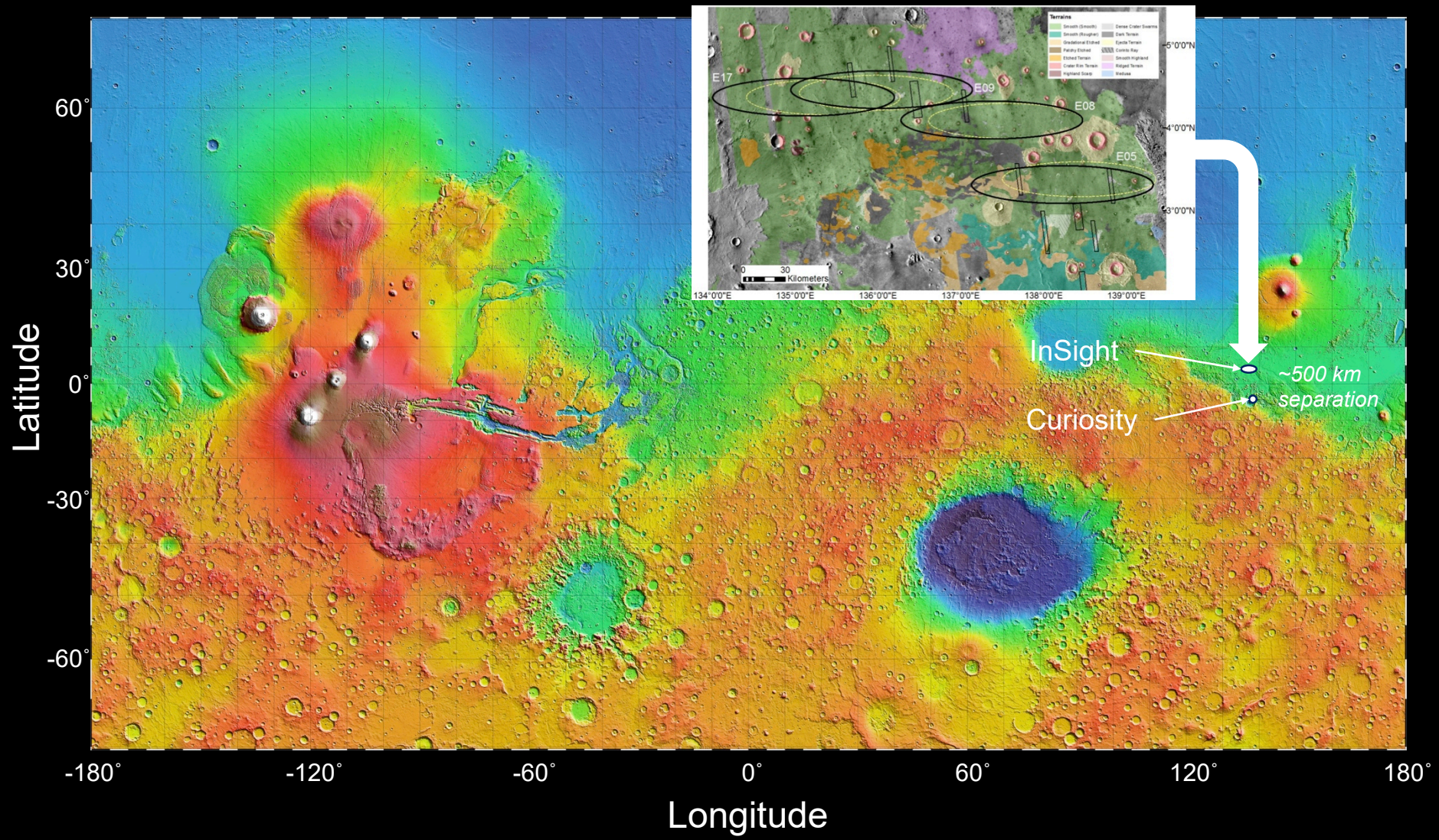
MarCO

- MarCO (Mars CubeSat One) JPL project underway with internal institutional funding
  - Managed within JPL Solar System Exploration Directorate (outside MEP)
- Mission summary
  - Deploy two CubeSats from InSight LV
  - Overfly InSight EDL trajectory
  - Provide bent-pipe return of InSight 8 kbps EDL telemetry
- LV go/no-go decision gate by mid-Apr'15





InSight-Curiosity Collocation

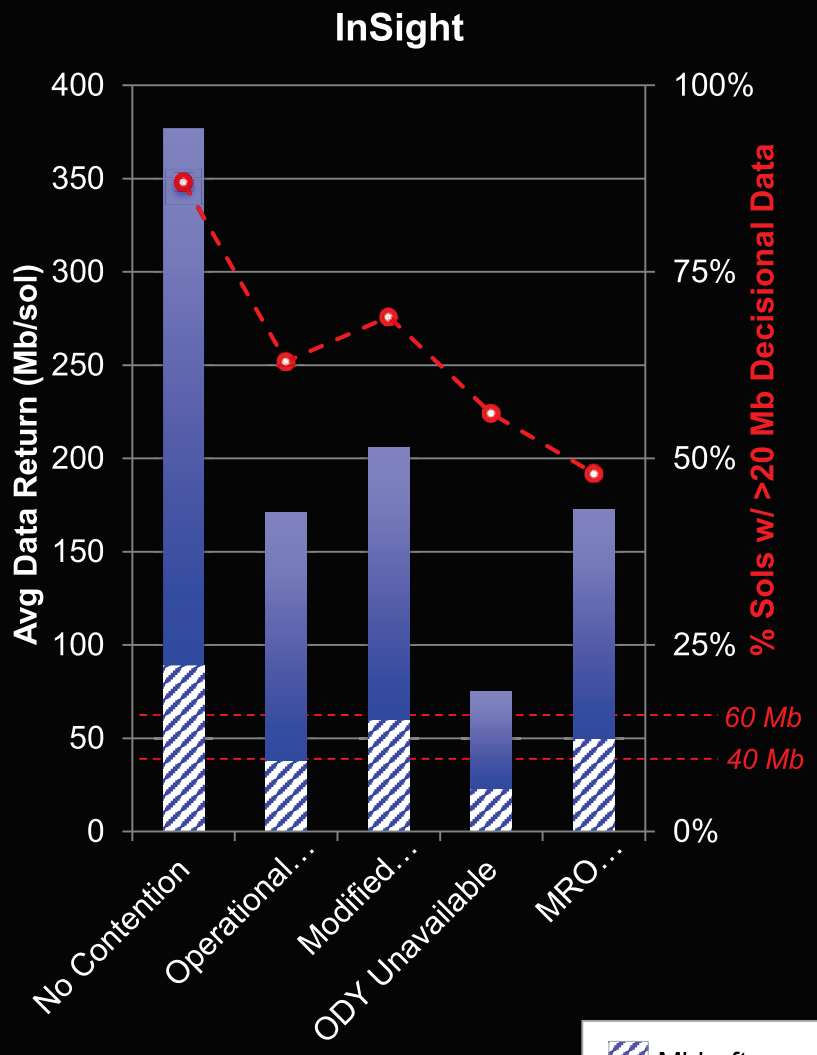


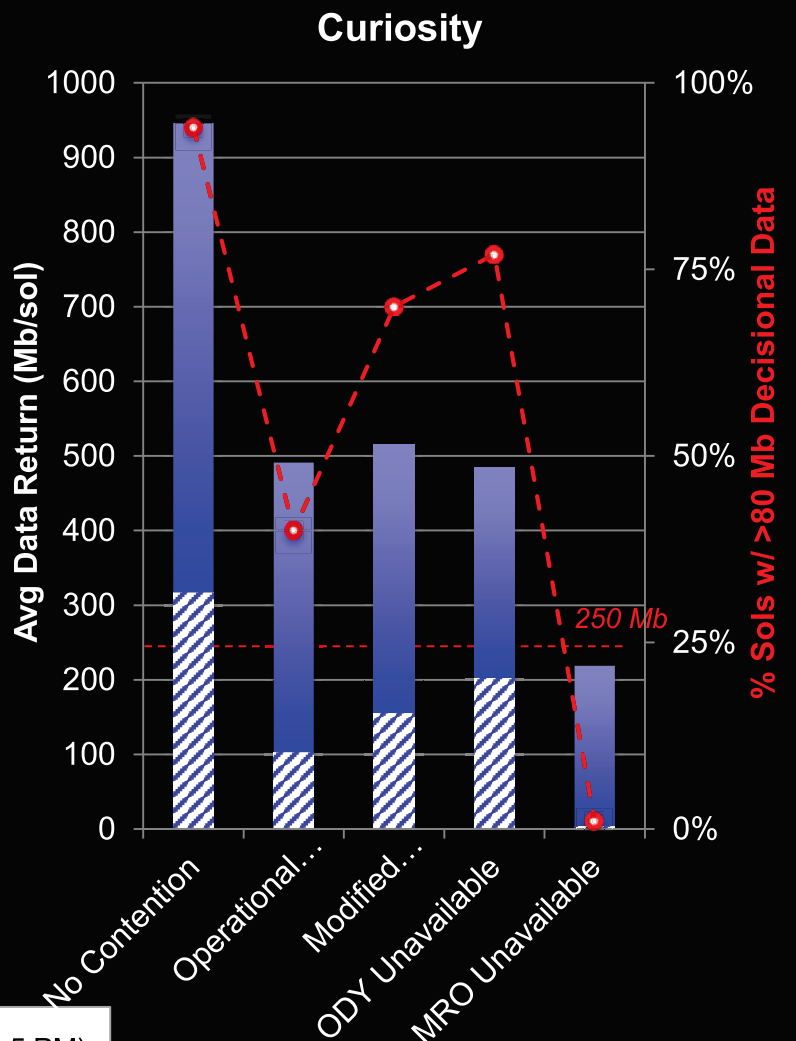
Collocation Analysis

- To quantify impact of InSight-Curiosity collocation, we performed a detailed analysis of relay service over the critical InSight instrument deployment period
  - During this time, both projects need mid-afternoon relay contacts to support 1-sol planning cycles

- Cases considered:
  1. No contention (support capability in absence of collocation issue)
  2. Operational Baseline (InSight gets preference for MRO PM passes)
  3. Modified Operational Baseline (Split MRO PM passes to allow mid-afternoon support to both landers each sol
  4. Contingency Scenario #1: ODY unavailable
  5. Contingency Scenario #2: MRO unavailable

Summary Analysis Results

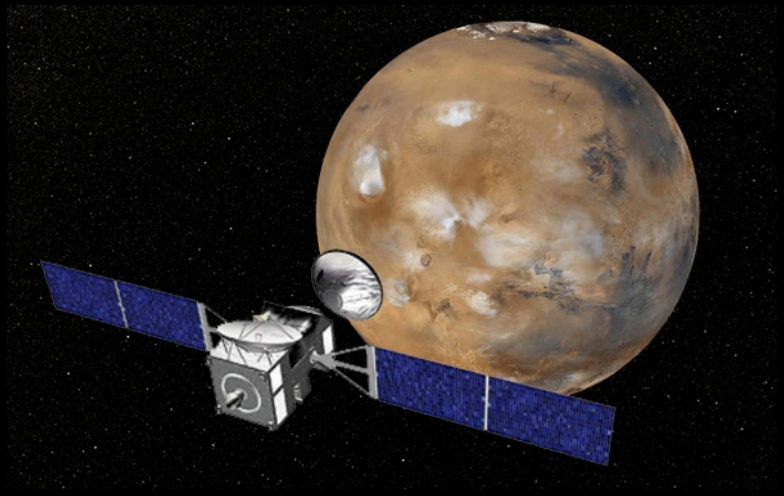




Mid-afternoon (1-5 PM)

ExoMars/Trace Gas Orbiter

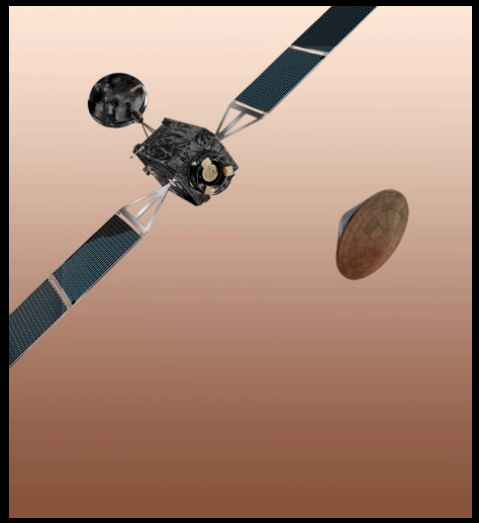
- Key elements:
  - ESA-led orbiter mission
  - Science focus on detection of trace gases
  - Launch: Jan 2016
  - MOI: Oct 19, 2016
  - One Mars year primary science phase
  - Extended relay ops through Dec 2022
  - NASA providing redundant Electra UHF relay payloads
    - Identical to MAVEN Electra design
  - Orbiter delivers EDL Demonstrator Module



	ExoMars/TGO
Agency:	ESA
Launch:	Jan 7-27, 2016
Orbit:	• 400 km circular • 74 deg inclination • Non-sun-synchronous
Deep Space Link:	
- Band	• X-band
- Power Amplifier	• 65 W TWTA
- High Gain Antenna	• 2.2 m HGA
Proximity Link:	
- Transceiver	• Electra (dual string)
- Protocol	• CCSDS Proximity-1
- Antenna	• Quadrifilar Helix (2)
- ***Forward Link***	
- Frequency	• 435-450 MHz
- Data Rate	• 8, 32, 128 kbps
- Coding	• (7,½) Convolutional
- Return Link	
- Frequency	• 390-405 MHz
- Data Rate	• 1, 2, 4, …, 2048 kbps
- Coding	• (7,½) Convolutional, LDPC
- Other	• 8-bit I/8-bit Q open loop recording • Suppressed Carrier Modulation • Adaptive Data Rates

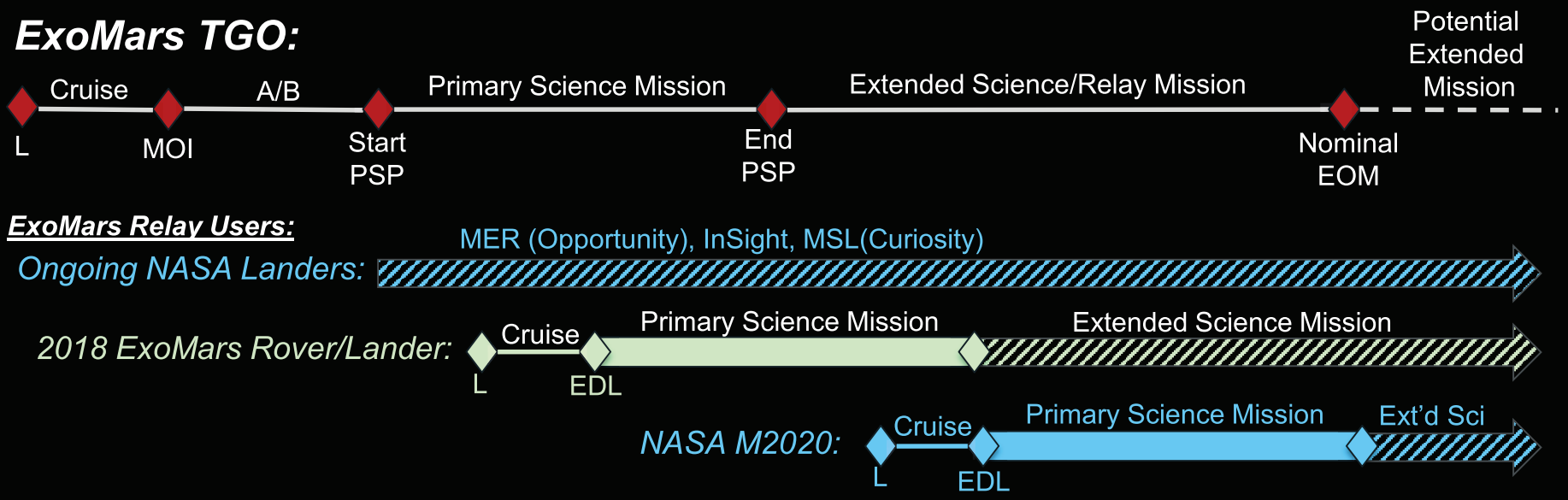
2016 ExoMars EDL Demonstrator Module (EDM)

- Mission overview
  - Demonstration of ESA EDL technology
  - Deployed by ExoMars/TGO prior to MOI
  - Battery powered lander
  - Short 4-sol nominal mission lifetime
- Driving relay requirements
  - Baseline is for TGO to provide critical event communications during EDL while orbiter performs MOI
  - All surface communications via UHF relay; no DTE link
- Challenges
  - Short mission lifetime demands thorough V&V testing to ensure successful relay ops on Sol 1
  - TGO post-MOI orbit precludes relay support during EDM lifetime; NASA relay orbiters (ODY/MRO/MAVEN) are baselined



TGO Relay Services

- TGO will aerobrake to its final science orbit
  - 400 km circular; 74 deg inclination (non-sun-synch)
  - Expect to complete aerobraking and begin science operations in Nov 2017
- Key relay users:
  - Ongoing NASA landers (MER, MSL, InSight) beginning at start of PSP (Nov 2017)
  - 2018 ExoMars Rover/Lander
  - NASA Mars 2020 Rover



Summary

- 2016 will be a busy year for Mars relay operations!
  - InSight
    - MRO will provide EDL critical event coverage
    - MRO pass-splitting will allow improved service to collocated InSight/Curiosity landers
  - ExoMars/TGO, EDM
    - NASA relay orbiters to provide primary relay support to ~4-sol EDM surface mission
    - TGO to serve as key Mars Relay Network asset for ESA and NASA users into the 2020's

Jet Propulsion Laboratory
California Institute of Technology

InSight-Curiosity Relay Data Return

Scenario	Orbiter	InSight		Curiosity	
		Mid-Afternoon Data Vol (Mb) (1-5 PM LMST)	*Total Data Volume (Mb)*	*Mid-Afternoon Data Vol (Mb) (1-5 PM LMST)*	*Total Data Volume (Mb)*
1: Non-Contention	ODY	0	125	0	165
	MRO	37	72	214	417
	MAVEN	52	180	103	364
	Total	***89***	***377***	***317***	***946***
2: Baseline	ODY	0	58	0	85
	MRO	37	37	0	202
	MAVEN	1	76	103	204
	Total	***38***	***171***	***103***	***491***
3: Split MRO PM Pass	ODY	0	58	0	85
	MRO	22	22	130	332
	MAVEN	38	126	26	98
	Total	***60***	***206***	***156***	***515***

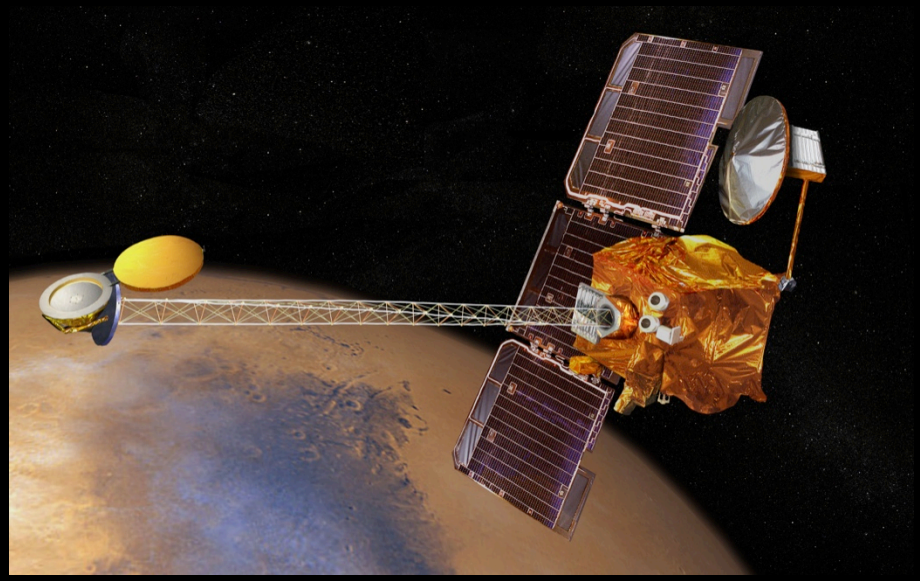
MAVEN

- Key elements:
  - Competitively selected, PI-led Mars Scout mission
  - Science focus on Mars aeronomy
  - Highly elliptic orbit
  - Launch: Nov 18, 2013
  - MOI: Sep 22, 2014
  - One Earth year primary mission, followed by extended science/relay mission
  - Single string MEP-provided Electra UHF relay payload
    - Implements new LDPC forward error correction code

	MAVEN
Agency:	NASA
Launch:	Nov 18, 2013
Orbit:	• 150 x 6,200 km elliptical • 75 deg inclination • Non-sun-synchronous
Deep Space Link:	
- Band	• X-band
- Power Amplifier	• 100 W TWTA
- High Gain Antenna	• 2 m HGA (body fixed)
Proximity Link:	
- Transceiver	• Electra (single string)
- Protocol	• CCSDS Proximity-1
- Antenna	• Quadrifilar Helix
- ***Forward Link***	
- Frequency	• 435-450 MHz
- Data Rate	• 8, 32, 128 kbps
- Coding	• (7,½) Convolutional
- Return Link	
- Frequency	• 390-405 MHz
- Data Rate	• 1, 2, 4, …, 2048 kbps
- Coding	• (7,½) Convolutional, LDPC
- Other	• 8-bit I/8-bit Q open loop recording • Suppressed Carrier Modulation • Adaptive Data Rates

Odyssey

	Mars Odyssey
Agency:	NASA
Launch:	Apr 7, 2001
Orbit:	• 400 km circular • 93 deg inclination • Sun-synchronous
Deep Space Link:	
- Band	• X-band
- Power Amplifier	• 15 W SSPA
- High Gain Antenna	• 1.3 m HGA
Proximity Link:	
- Transceiver	• CE-505
- Protocol	• CCSDS Proximity-1
- Antenna	• Quadrifilar Helix
- Forward Link	
- Frequency	• 437.1 Mhz
- Data Rate	• 8, 32 kbps
- Coding	• Uncoded
- Return Link	
- Frequency	• 401.585625 MHz
- Data Rate	• 8, 32, 128, 256 kbps
- Coding	• (7,½) Convolutional
- Other	• 1 bit-per-sample open loop recording

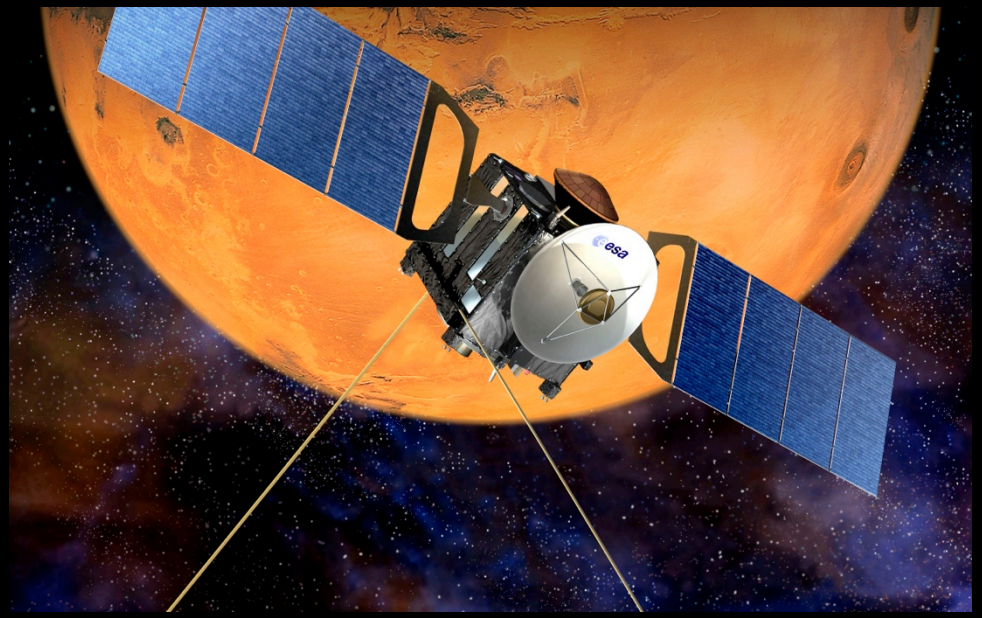


Orbiter health status:

- Reaction Wheel failure
- Limited propellant lifetime

Mars Express

	Mars Express
Agency:	ESA
Launch:	June 2, 2003
Orbit:	• 330 x 10,530 km elliptical • 86.9 deg inclination • Non sun-synchronous
Deep Space Link:	
- Band	• X-band
- Power Amplifier	• 65 W TWTA
- High Gain Antenna	• 1.65 m HGA
Proximity Link:	
- Transceiver	• Melacom
- Protocol	• CCSDS Proximity-1
- Antenna	• Patch Antennas (2)
- Forward Link	
- Frequency	• 437.1 Mhz
- Data Rate	• 8 kbps
- Coding	• Uncoded
- Return Link	
- Frequency	• 401.585625 MHz
- Data Rate	• 2, 4., …, 128 kbps
- Coding	• (7,½) Convolutional
- Other	• 1 bit-per-sample open loop recording



Orbiter health status:

- Solid State Mass Memory anomalies
- Limited propellant lifetime

Mars Reconnaissance Orbiter

	Mars Reconnaissance Orbiter
Agency:	NASA
Launch:	Aug 12, 2005
Orbit:	• 255 x 320 km • 93 deg inclination • Sun-synchronous
Deep Space Link:	
- Band	• X-band
- Power Amplifier	• 100 W TWTA
- High Gain Antenna	• 3 m HGA
Proximity Link:	
- Transceiver	• Electra
- Protocol	• CCSDS Proximity-1
- Antenna	• Quadrifilar Helix
- Forward Link	
- Frequency	• 435-450 MHz
- Data Rate	• 8, 32, 128 kbps
- Coding	• (7,½) Convolutional
- Return Link	
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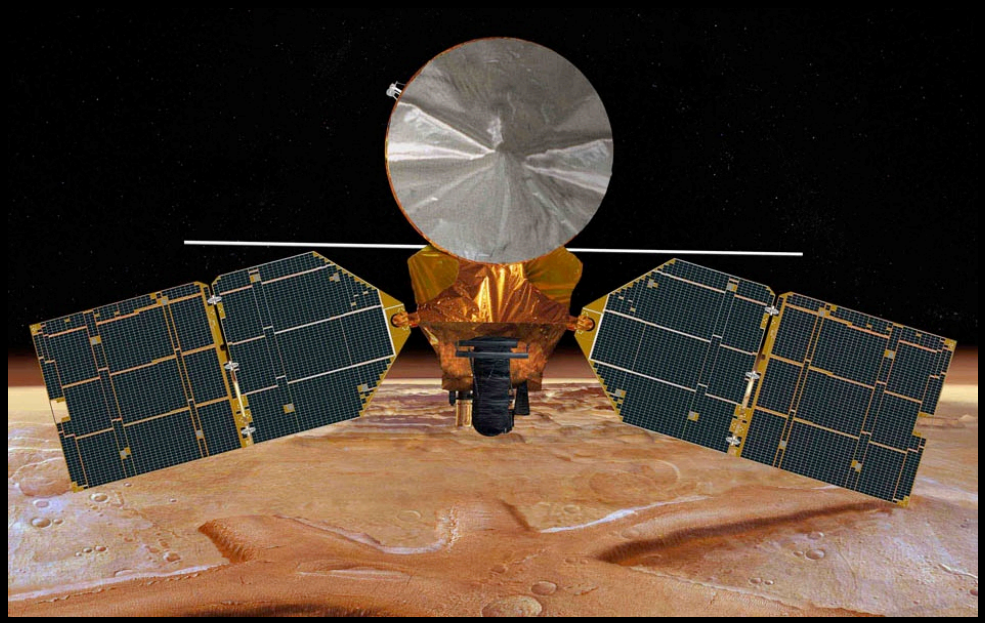

Orbiter health status:

- Waveguide Transfer Switch failure
- IMU lifetime concerns