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Iris at Mars:

First Flight Use of Iris Deep Space Transponder on MarCO

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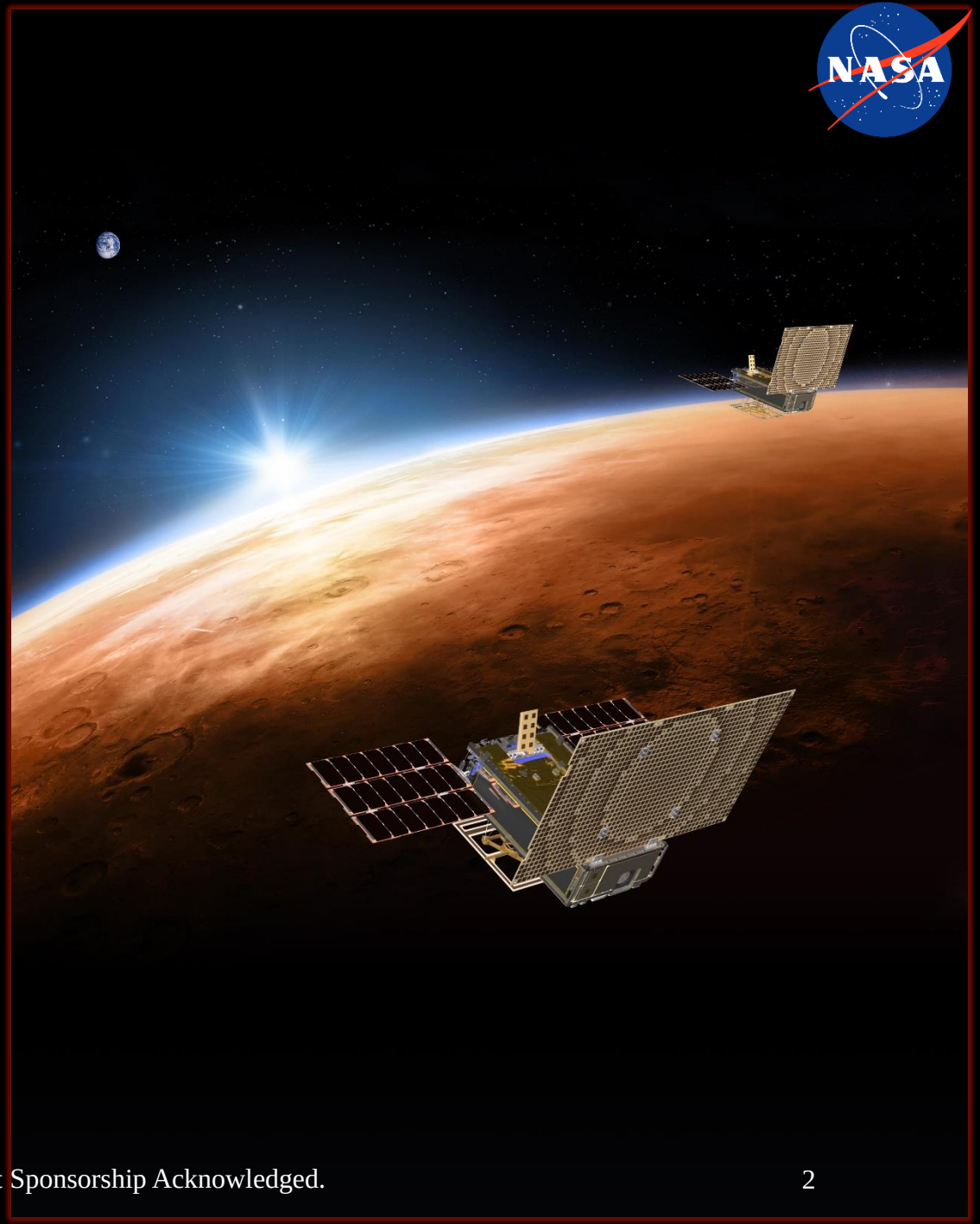

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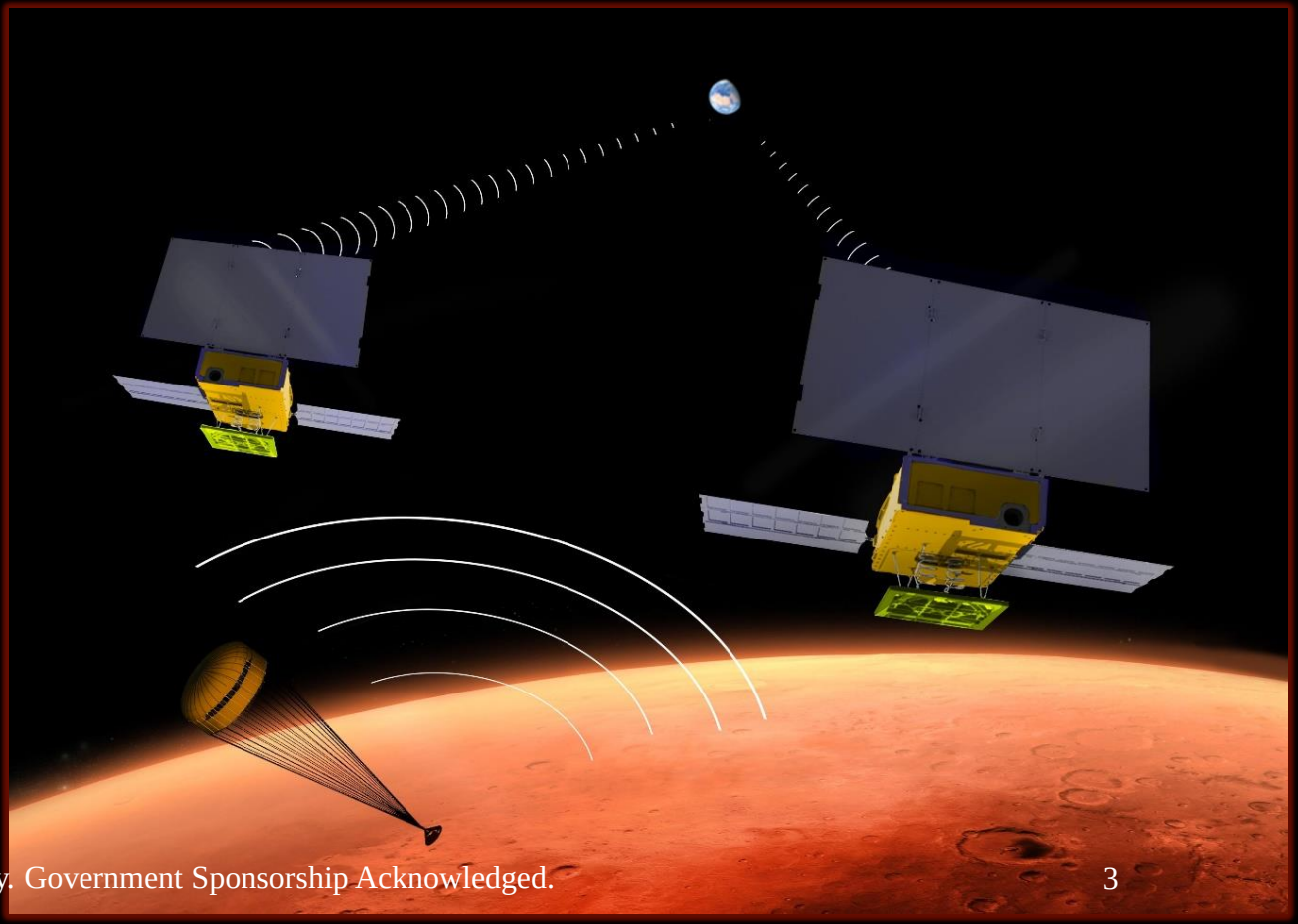
MarCO Mission Overview

- Provide “real-time” data relay during EDL of InSight to Mars
- Bent-pipe:
  - UHF receive of EDL data
  - X-band transmit Direct-to-Earth
- Two for redundancy
- Tech demo – InSight’s success is independent of MarCO’s success
- First deep space CubeSats
- MarCOs launch with InSight but travel independently to Mars



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MarCO Specifications and Subsystems

- 6U (10x20x30cm)
- 13.5kg (30lbs)
- Subsystems:
  - Propulsion (VACCO)
  - Flight Computer (Astronautical Dev. LLC)
  - Electronic Power System (Astronautical Dev. LLC)
  - Solar Panel System (MMA Design LLC)
  - Attitude Control System (Blue Canyon Tech.)
  - Cameras
  - Telecom (JPL)

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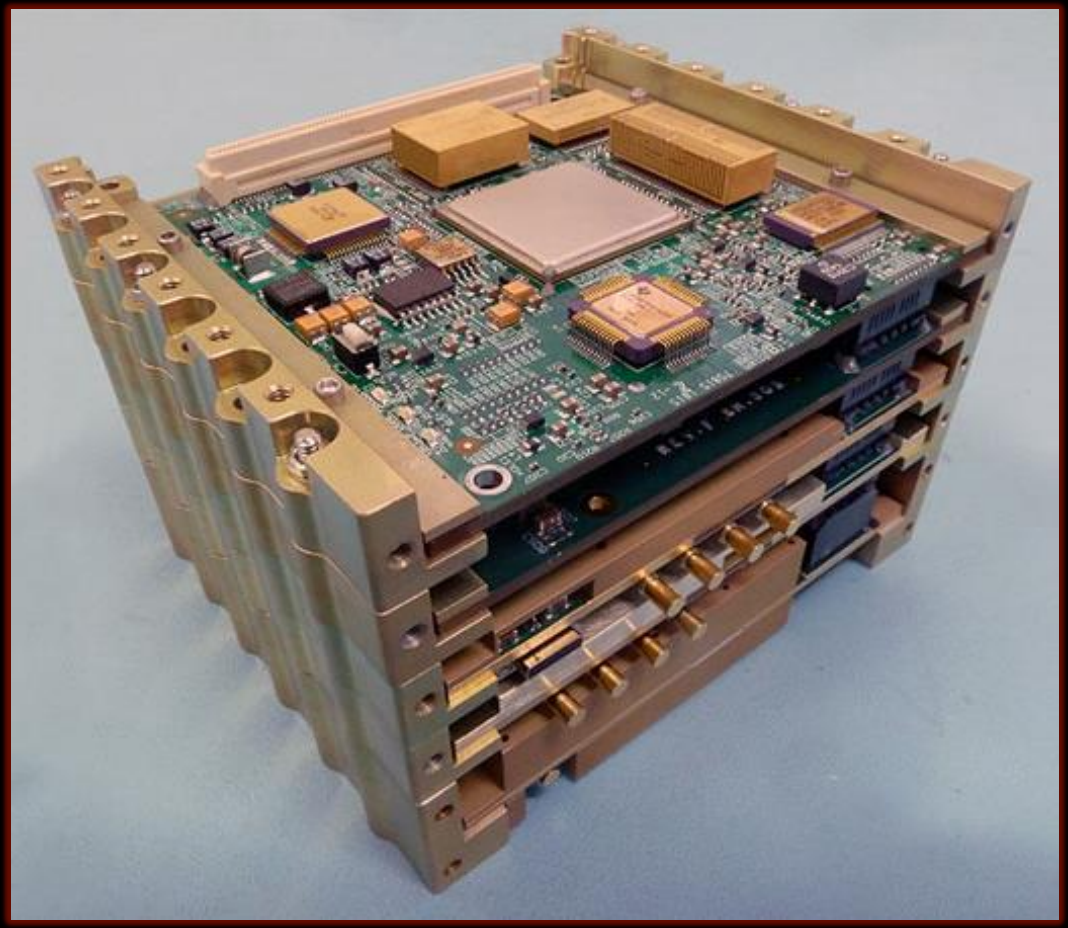
Iris Overview

- Specs: 0.77U, 1.2kg, 35W (Tx/Rx), 4W RF output
- Communicates with DSN at X-Band
  - CCSDS: AOS (down), TC (up)
- V2 design consists of five boards: UHF receiver, X-band receiver, X-band exciter, power, digital
- Virtex 6 with LEON3-FT softcore



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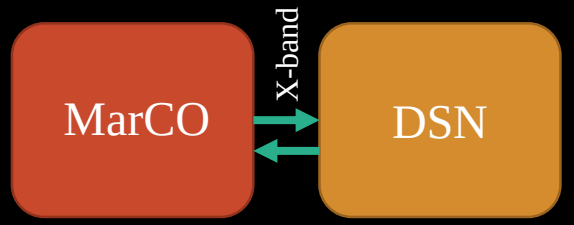
Iris Testing for MarCO

- Ambient and Block V Rx at JPL
  - Downlink with Block V (DSN)

- InSight compatibility at Lockheed Martin
  - Pre-integration with MarCO

- DSN compatibility at DTF-21
  - Post-integration with MarCO



* Cassy: GSE developed with Iris, supports commanding and telemetry (tx/rx)

** Block V: 5th generation DSN receiver currently used at all DSN complexes

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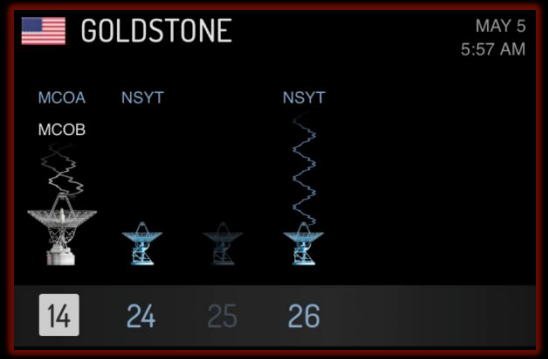
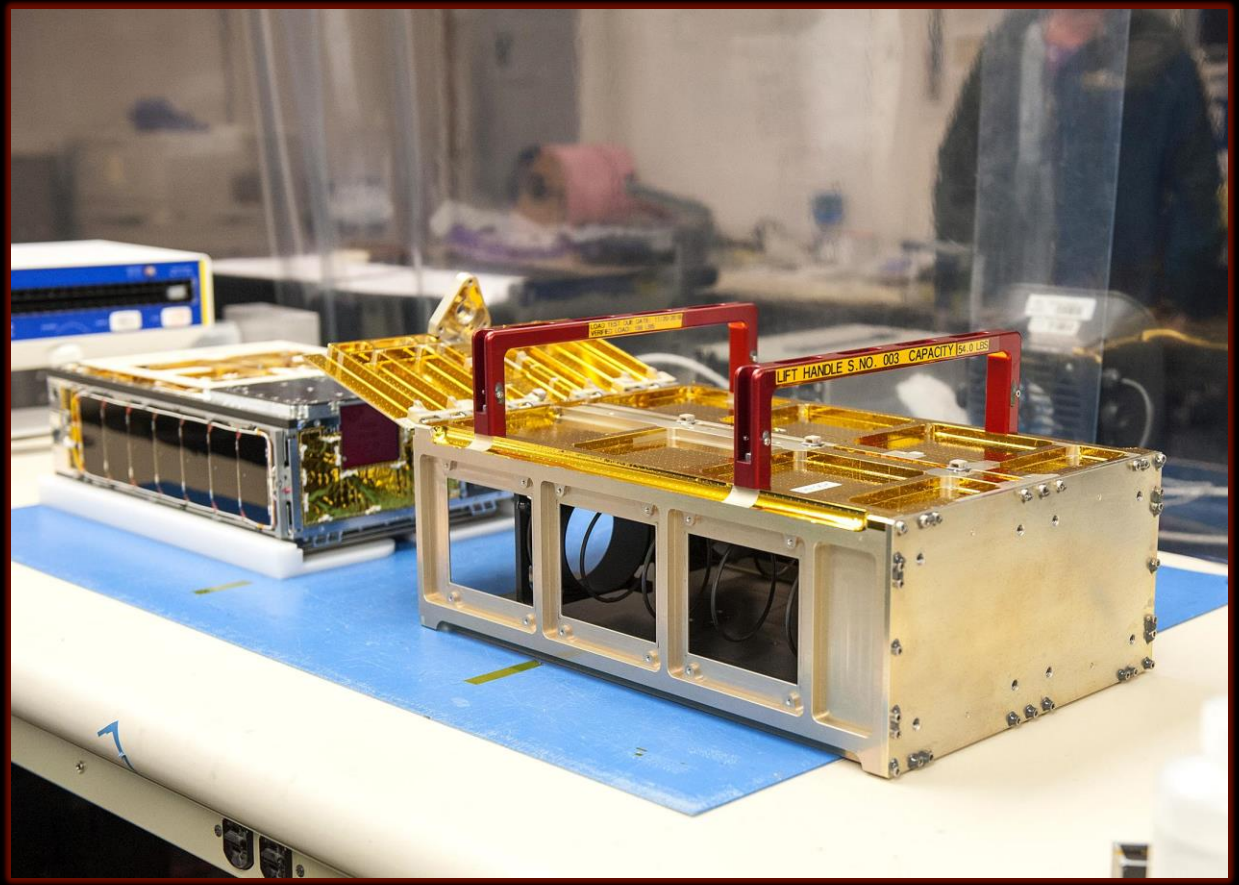
Activities on Launch Day



- May 5, 2018, from Vandenberg Air Force Base near Lompoc, CA
- MarCOs deployed after InSight
- First Contact:
  - Transponder beacons to indicate aliveness
  - Transmits telemetry data
  - MarCO-A: ~5:55am, 5 mins
  - MarCO-B: ~6:05am, 5 mins
  - Nominal telemetry on both SC
- Commanding performed during later pass
- Successful deployment of X-band reflectarray and UHF loop antenna



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Activities During Cruise: Continuous

- Commanding (uplink data)
  - Pre-loaded command sequences in flight computer, allowing for some autonomous functionality
  - Uplinked new command sequences from ground as desired
- Telemetry (downlink data)
  - Downlinked telemetry data containing spacecraft health and status
  - Also downlinked images as available
- Navigation
  - Ranging Mode receives ranging signal (carrier tone) from ground and retransmits ranging signal back to Earth
  - DDOR Mode (delta differential one-way ranging) generates and transmits DDOR tones, which are received by multiple ground stations

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Activities During Cruise: Special Cases

- HGA characterization
  - Verification that HGA in good condition after launch (performed on both SC)
  - Point the antenna to different attitudes and measure how the receive power changes on the ground
    - Nominal boresight, then +/- 2 degrees on different axes
- In-flight test of bent-pipe (EDL) mode
  - Verification that UHF antenna in good condition after launch
  - UHF transmit from Stanford ground station (simulating InSight) to Iris, X-band transmit from Iris to DSN
- Receive tests with Morehead State University ground station

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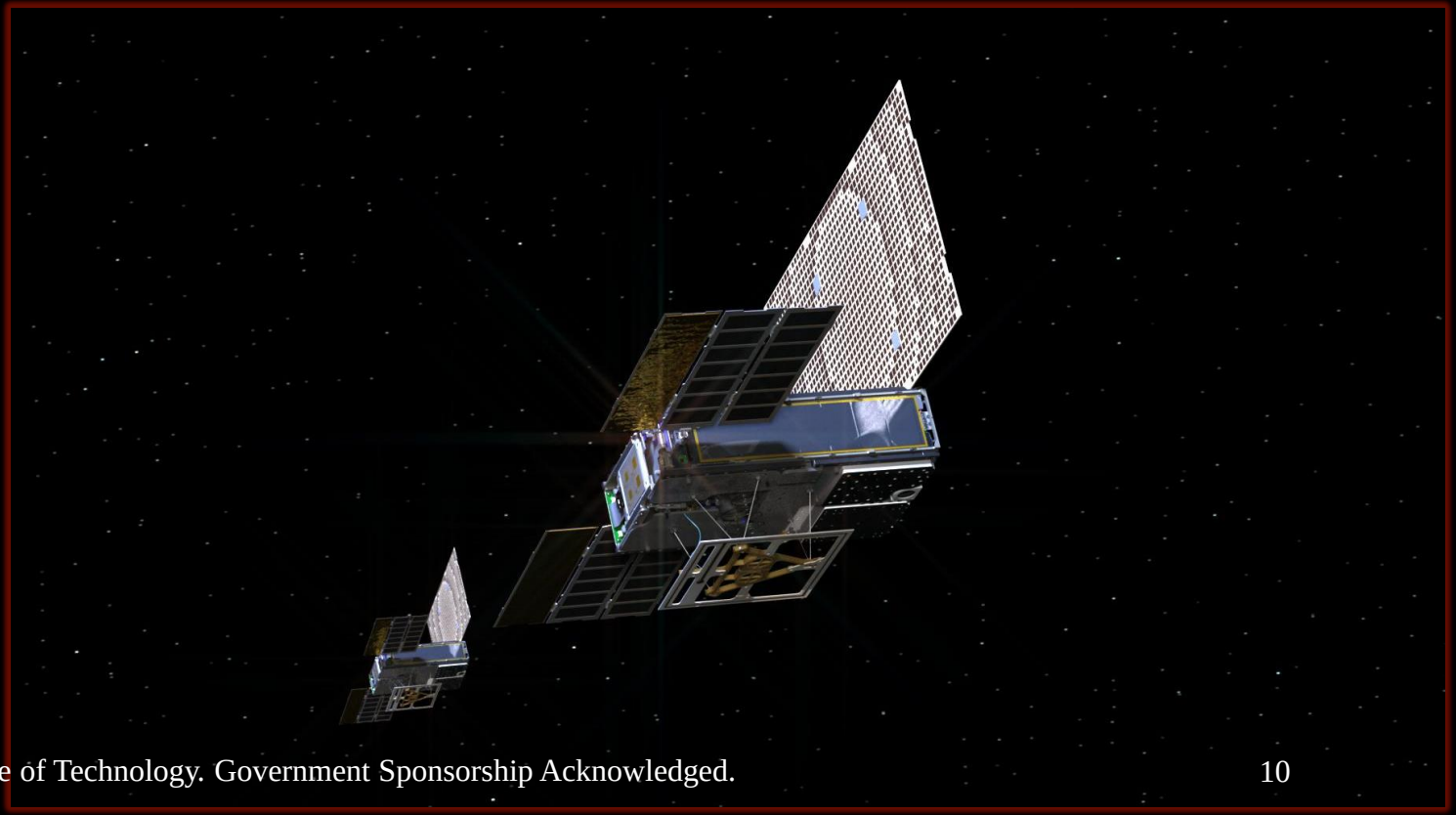
Post-Launch Updates

- Command sequences for a variety of new Iris configurations
- Verified on MarCO Iris spare unit with Cassy GSE, and on MarCO SC testbed
- Examples:
  - Additional Data Rates
  - Tx/Rx with Ranging
  - Carrier-Only Downlink
  - Adjusting Data Arbitration



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Post-Launch Updates in Detail

- Higher data rate required alternate encoding scheme
  - Nominal encoding of Turbo 1/6
  - Requested configuration for downlink data rates including 8 kbps and 16 kbps
  - Turbo 1/6 at 16 kbps (192 kHz) violates MarCO's spectrum allocation license
  - To comply with NTIA license agreement, instead provided:
    - Turbo 1/6 at 8 kbps (96 kHz)
    - Turbo 1/3 at 16 kbps (96 kHz)
- Adjustable data prioritization
  - Data arbitration allows for alternate prioritization of EDL data vs TLM data
  - Not configurable or accessible through pre-defined register
  - Single-threaded software means deterministic locations of variables
  - Disassembled flight software image to find memory location for data arbitration variable

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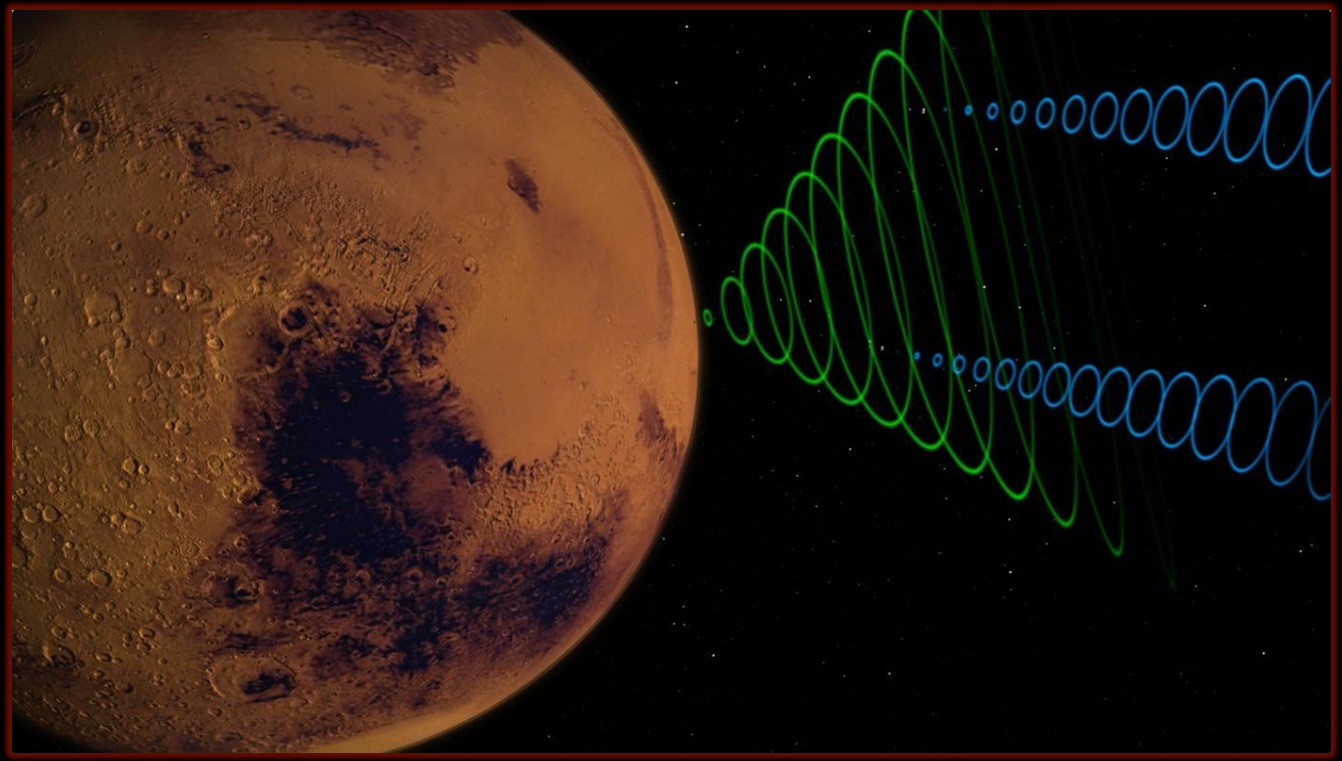
Mission Success at Mars

- Successfully completed EDL with zero data loss
  - Iris transmitted all data that it received
- EDL data recorded:
  - MarCO-A: 694 KB
  - MarCO-B: 712 KB
  - (more than MRO!)
- Performed retransmission post-EDL



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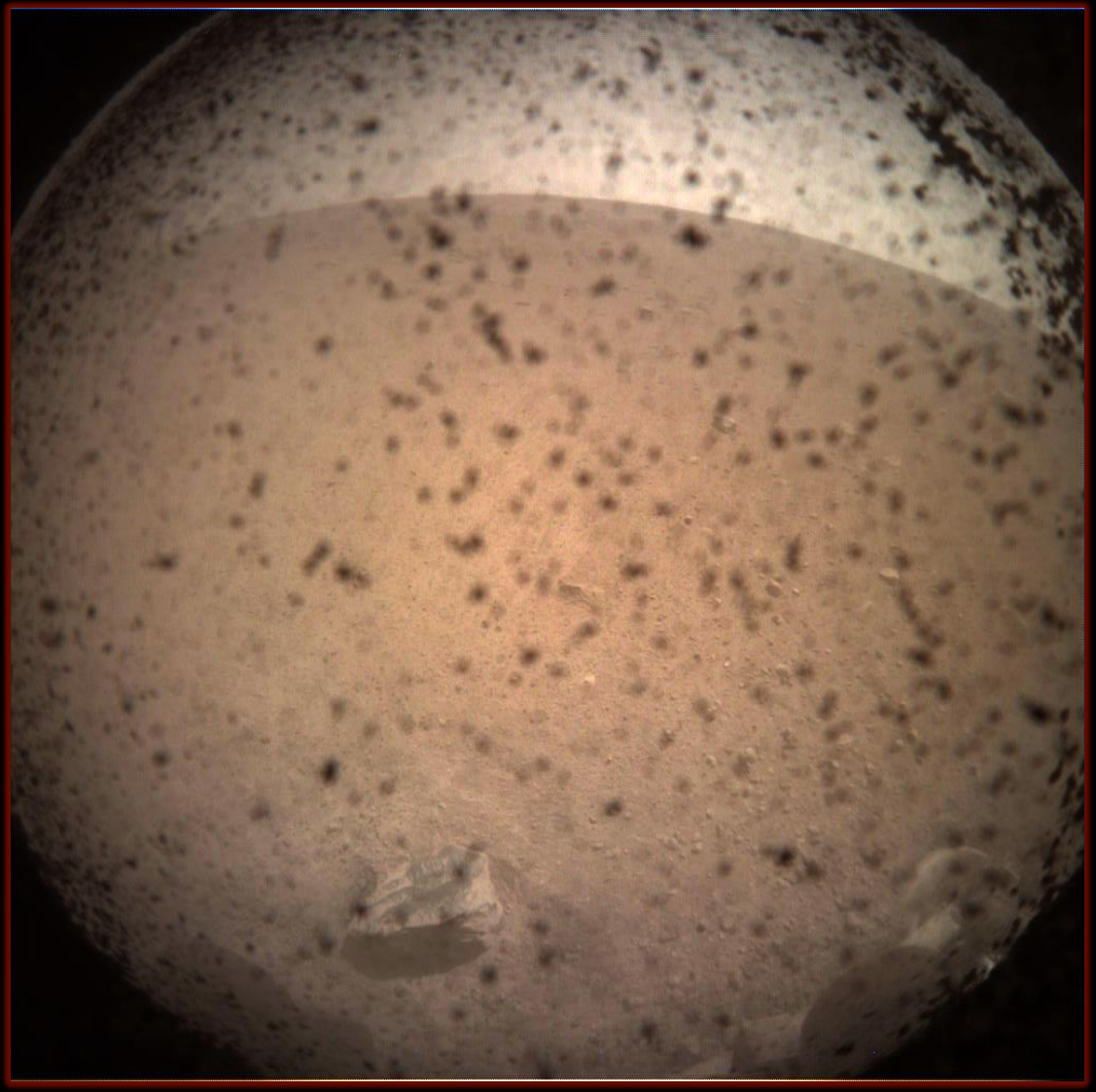
First Image from InSight Lander

- MarCO enabled quick reception of InSight's first image on Mars
- Utilized post-launch updates, including arbitration scheme adjustments and increased data rates



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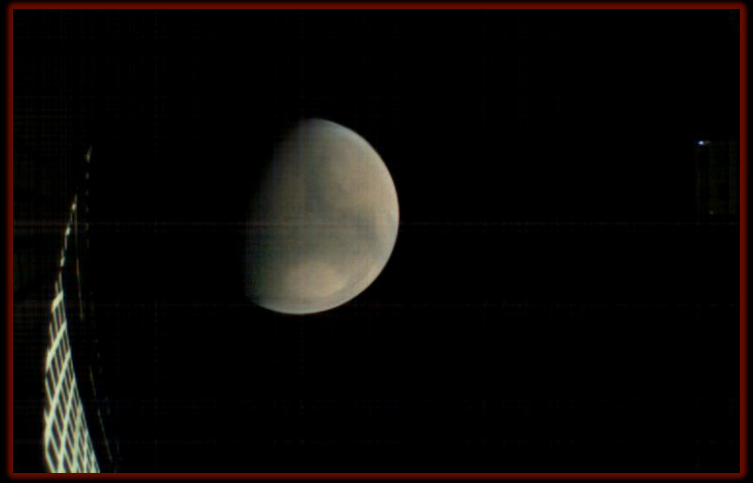
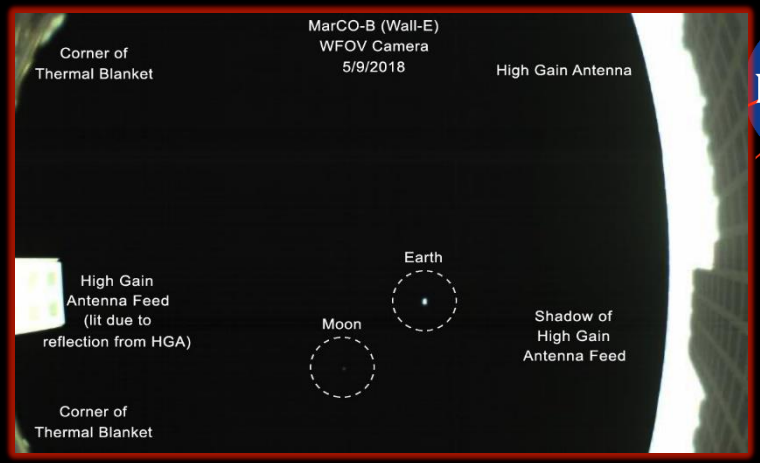
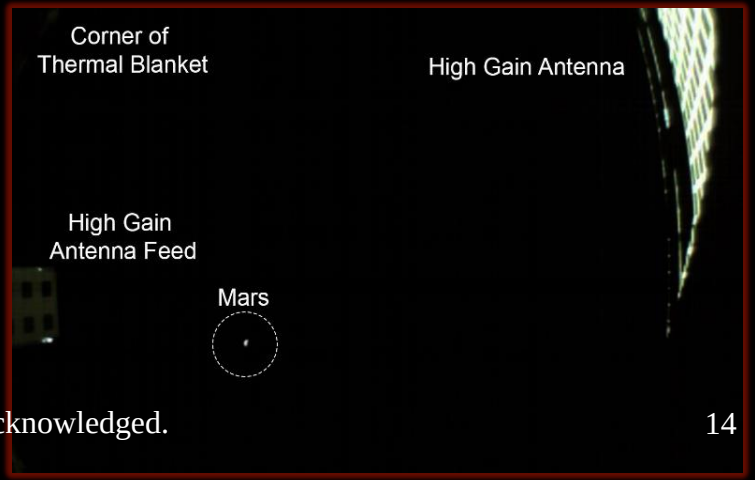
MarCO-B Images







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Approach to Mars

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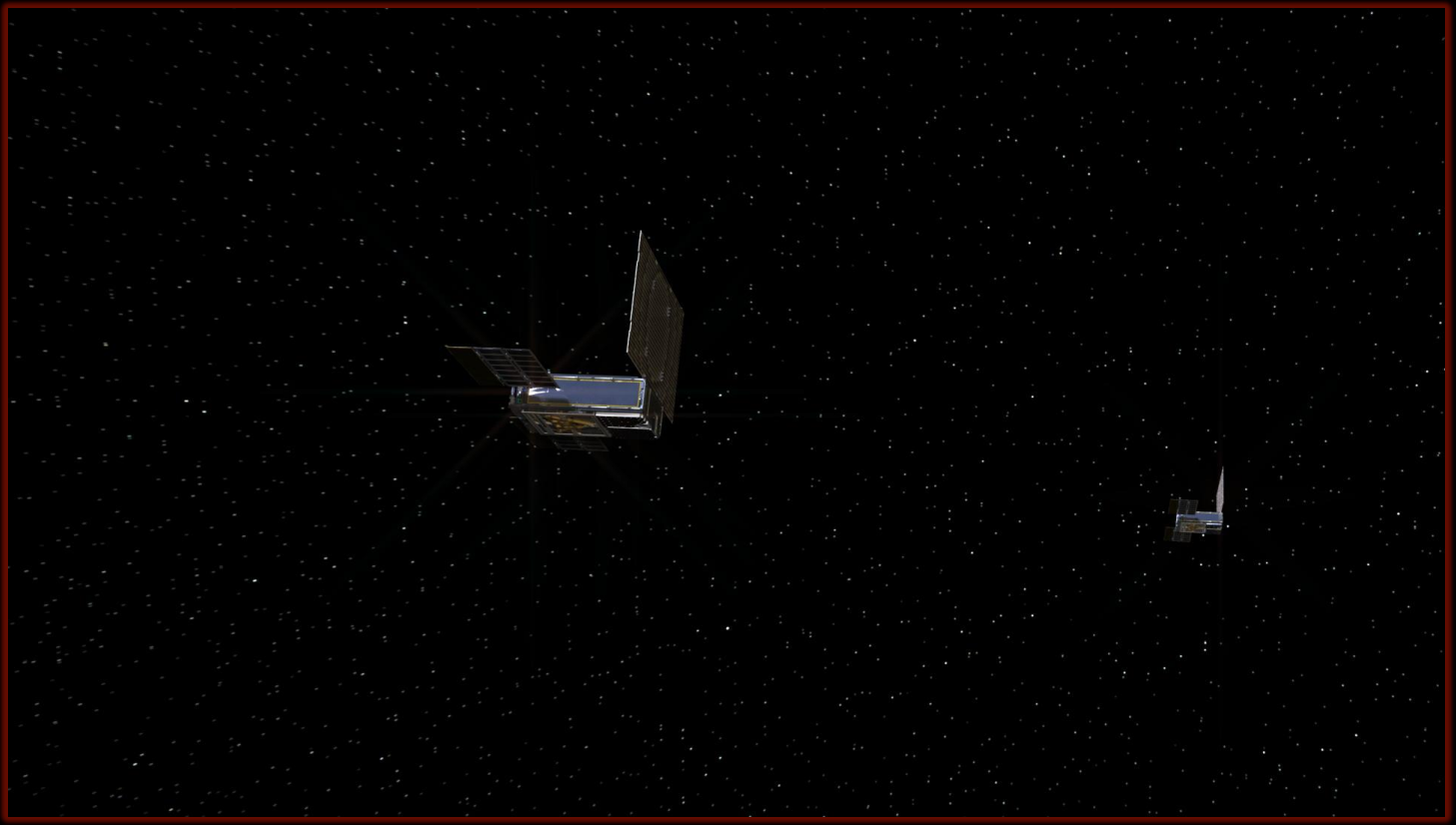
Current State of MarCO and Iris

- Lost contact a few weeks after EDL
  - MarCO-B: Dec. 29 2018; MarCO-A: Jan. 4, 2019
  - Current theory:
    - Issues on brightness sensors leading to attitude control trouble (greater distance requires more precise pointing) and inability to recharge batteries
- Heliocentric orbit; team may attempt to re-engage in early summer 2019
- Next version of Iris has been delivered to several CubeSat missions for EM-1



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MarCO and Iris Teams

And many more not pictured!

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