

ROUTE-M



**Remote Orbital Utility for
Terrain Exploration**

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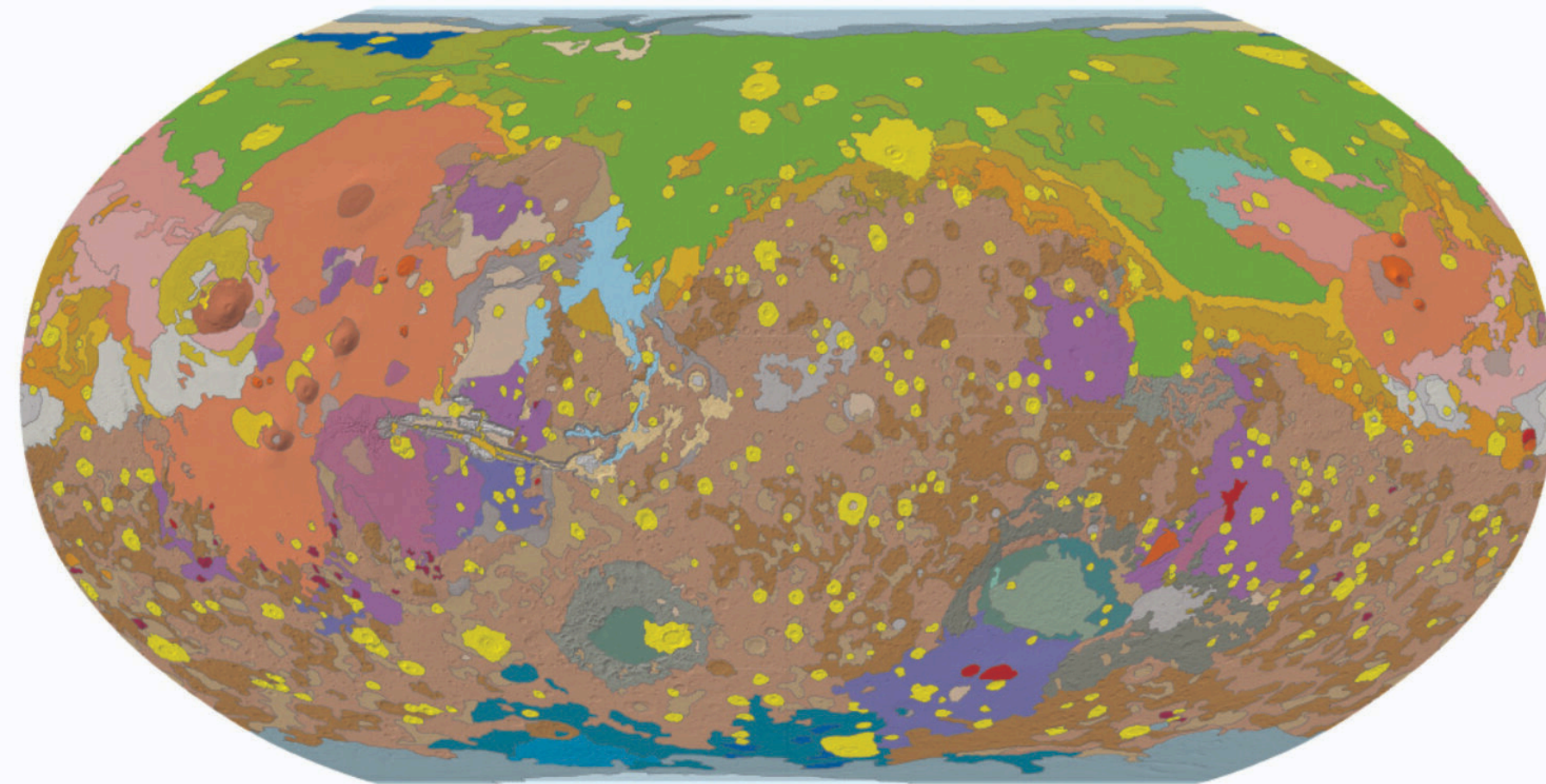
MOTIVATION

Mars was likely once a water-rich planet with a thicker atmosphere

Atmospheric loss led to the cold, dry environment observed today

Understanding Mars helps us study planetary climate evolution

High-resolution mapping is critical for future Mars exploration



Geological Map of Mars

Previous Mars Missions such as the MRO focused primarily on:

01

Targeted Science Campaigns

Previous Mars missions primarily focused on targeted science campaigns, where instruments were directed toward specific regions of interest rather than systematically mapping the entire planet.

02

Landing Site Characterization

Many orbiters were designed to support landing site characterization, collecting detailed imagery and terrain data only in areas being considered for rover or lander missions.

03

Regional Investigations

These missions also conducted regional investigations, studying localized geological features such as valleys, craters, or sediment deposits instead of producing a consistent high-resolution global map.



MISSION NEED AND PROBLEM STATEMENT

**NO MISSIONS EXIST FOR
SYSTEMATIC GLOBAL
HIGH RESOLUTION
MAPPING**

MAJOR RED FLAG

01

Autonomous Rover Navigation

High-resolution terrain maps help rovers plan safe routes without constant commands from Earth.

02

Hazard Avoidance

Detailed imagery allows missions to identify hazards such as large rocks, steep slopes, and rough terrain.

03

Terrain Classification

Surface maps help scientists classify geological features like craters, ridges, and sediment deposits.

04

Orbital maneuver Assurance

Accurate terrain models help spacecraft plan safe orbital maneuvers and improve navigation accuracy.



MISSION NEED AND PROBLEM STATEMENT

PROBLEM STATEMENT

Existing Mars missions focus on targeted observations, but there is no dedicated system designed to efficiently produce a global high-resolution terrain map needed to support future robotic and human exploration.

Space Agencies Organizations such as NASA, ESA, and other international partners responsible for funding, mission planning, and scientific oversight of Mars exploration missions.	Planetary Scientists Researchers studying planetary geology, climate evolution, and astrobiology who rely on high-resolution orbital data to analyze Mars' surface and environmental history.
Scientific Community Scientists and institutions worldwide that use publicly available mission datasets to conduct research and advance knowledge of planetary systems.	Future Exploration Missions Robotic and potential human missions that depend on accurate orbital maps for landing site selection, terrain hazard analysis, and surface navigation planning.

STAKEHOLDERS AND OBJECTIVES

NASA

MARS MISSIONS

ESA

SCIENTISTS



SUBSYSTEMS OVERVIEW



Spacecraft Subsystems

- Payload – HiRISE-derived optical imager
- ADCS – attitude stabilization and antenna pointing
- Communications – X-band + Ka-band deep space communications
- Propulsion – trajectory corrections and MOI
- Power – solar arrays and batteries
- Thermal Control – heaters, radiators, and MLI insulation
- Avionics and data handling



SYSTEM REQUIREMENTS SUMMARY



MISSION REQUIREMENTS

Mission Requirements (Structural and Payload)	
Requirements Identifier	Description
MS-PAYL-001	The mission shall acquire high resolution imagery of the Martian surface at approximately 1m/pixel from an average altitude of 300 km around Mars
MS-PAYL-002	The mission shall acquire imagery in the visible spectral range to support mapping, colour reconstruction and surface feature identification
MS-PAYL-003	The payload shall support off-nadir imaging up to 15 degrees from nadir.
MS-PAYL-004	The mission shall support geolocation accuracy that allows for autonomous navigation and scientific analysis
MS-PAYL-005	The mission shall generate imagery at a rate sufficient to support global surface mapping (at least 90%) over the mission lifetime
MS-PAYL-006	The mission shall manage science data generation such that acquired imagery remains compatible with the available data handling and communication limits.
MS-PAYL-007	The mission shall maintain payload operating conditions within allowable thermal limits during operations
MS-STRUC-001	The structure shall survive launch, ascent and separation environments without structural failure or loss of mission function
MS-STRUC-002	The structure shall maintain payload alignment and structural stability to preserve imaging performance during operations
MS-STRUC-003	The structure shall package the spacecraft within the launch vehicle fairing envelope
MS-STRUC-004	The structure shall support the dual spacecraft launch architecture
MS-STRUC-005	the structure shall support both stowed and deployed configurations

PAYLOAD REQUIREMENTS

Payload Requirements				
Requirements Identifier	Description	Derived From	Verification Method	Notes
PAYL-001	The Payload shall achieve a ground sampling distance of less than or equal to 1 meter +/- 25cm per pixel from a 300km altitude	Mission objective, variance derived from the current accuracy levels of HiRise	Analysis (optical modeling, geometry) + Inspection (design parameters)	Mission Objective
PAYL-002	The Payload shall point at 15 degrees in the forward direction relative to the spacecraft's movement with an accuracy of +/- 1 degrees	Derived from Off Nadir Camera Calculations	Analysis (coverage modeling, STK) + Test (ADCS pointing validation)	ADCS Requirement
PAYL-003	The Payload shall operate in the spectral range of 400-900 nm	Allows for imaging in the Visible and the VIR Bands allowing for full colour reconstruction	Analysis (mission simulation) + Test (operational validation)	Science Objective
PAYL-004	The payload shall support image acquisition of 400 images per Martian Day with an exposure of 15 seconds per image	Derived from data rate calculations that require at least 363 Images during peak image acquisition window	Analysis (mission simulation) + Test (operational validation)	Operations Requirement
PAYL-005	The payload shall produce images with a resolution of 40000x20000 pixels per acquisition	Derived from Camera Resolution Calculations	Analysis (optical geometry) + Inspection (detector design)	Mission Objective

STRUCTURAL REQUIREMENTS

Structural Requirements				
Requirements Identifier	Description	Derived From	Verification Method	Notes
STRUC-001	The Structural subsystem shall maintain payload boresight alignment within limits to achieve the ground resolution of less than or equal to 1 meter	Mission Objective	Analysis (structural deformation modeling) + Test (alignment verification)	PAYL-001
STRUC-002	The structural subsystem shall limit structural pointing disturbances to maintain payload under 5 micro rads	Derived from Jitter Calculations	Analysis (vibration modeling) + Test (modal and vibration testing)	PAYL-008
STRUC-003	The structural subsystem shall withstand launch loads and vibration environments with a positive margin of safety	Operational Requirement. Need to withstand all vibrations to ensure no cracks form during launch and operations	Analysis (FEA) + Test (vibration, acoustic testing)	Launch Requirements
STRUC-004	The structural subsystem shall house both orbiters until separation procedures are initiated	Mission Requirement. A single rocket is being used for launch and thus the structure should house both orbiters	Analysis (load distribution) + Test (separation testing)	System Requirement

COMMUNICATIONS REQUIREMENTS

- The Data Bottleneck: 1m/pixel global mapping generates over 46 Terabytes of raw data over the mission lifetime.
- Onboard Processing: 10:1 JPEG2000 compression reduces final image sizes to 104 MB.
- Downlink Architecture: High-speed Ka-band (32 GHz) utilizing a shared 14-hour daily Deep Space Network (DSN) allocation.
- Adaptive Scheduling: Image capture scales dynamically from 57 to 363 images per day based on Earth-Mars distance to prevent the 256 GB storage buffer from overflowing.

C&DH REQUIREMENTS

Command and Data Handling Requirements				
Requirement Identifier	Description	Derived From	Verification	Method Notes
CDH-001	The subsystem shall include a solid-state recorder with a usable storage capacity of >1TB	Data Volume Analysis; DSN Contact Constraints	Analysis	Storage sizing based on peak data generation (37.8 GB/day) and buffering requirements with margin.
CDH-002	The subsystem shall support storage of at least 3 days of peak science data generation without data loss.	Mission Operations Concept; Data Volume Analysis	Analysis	Verification using worst-case data accumulation during DSN blackout periods.
CDH-003	The subsystem shall acquire, store, and route science and housekeeping data between payload, onboard storage, and communication subsystems.	System Architecture Definition	Inspection	Review of onboard data handling architecture and interface control documents.

CDH-004	The subsystem shall support onboard data throughput greater than or equal to the peak instrument data generation rate without data loss.	Payload Data Rate Requirements	Analysis	End-to-end data flow simulation from payload to transmitter.
CDH-005	The subsystem shall ensure no loss or corruption of science data during storage, transfer, and transmission.	Science Data Integrity Requirements	Test / Analysis	End-to-end validation using error detection and correction schemes.
CDH-006	The subsystem shall support continuous science data acquisition and storage during communication blackout periods.	DSN Contact Constraints	Analysis	Simulation of data accumulation and buffering during no-contact intervals.

ADCS REQUIREMENTS

ADCS Requirements Summary			
Requirements Identifier	Description	Verification Method	Notes
ADCS-P1	The ADCS shall provide continuous and accurate attitude knowledge to support imaging and mission operations.	Analysis (error budget) + Test (sensor validation)	Imaging performance
ADCS-P2	The ADCS shall maintain precise and stable spacecraft pointing during imaging operations within required limits.	Analysis (jitter) + Test	Prevents image blur
ADCS-P3	The ADCS shall support off-nadir pointing and efficient reorientation between imaging targets.	Analysis (geometry, slew) + Simulation	Coverage & efficiency
ADCS-P4	The ADCS shall maintain accurate antenna pointing toward Earth during communication operations.	Analysis (link budget) + Test	Communication reliability
ADCS-P5	The ADCS shall maintain stable and reliable operation by managing disturbances, preventing actuator saturation, and supporting safe mode over the mission lifetime.	Analysis + Simulation + Test	Reliability & lifetime

PROPULSION REQUIREMENTS

- Base Maneuvers: 520 kg allocated for Mars Orbit Insertion (MOI) and major trajectory corrections.
- Unique Challenge: 300 km low-altitude orbit induces constant aerodynamic drag and momentum buildup over the 7-year science phase.
- Targeted Solution: Deterministic allocation of 15 kg of bipropellant exclusively for Angular Momentum Desaturation (AMD), based on MRO heritage data.
- Total Wet Mass: 1,500.5 kg per spacecraft (includes strict 10% safety margin on the 535 kg total base propellant).

THERMAL REQUIREMENTS

Thermal Subsystem Requirements Summary			
Requirements Identifier	Description	Verification Method	Notes
THERM-001	The thermal subsystem shall maintain spacecraft bus and avionics temperatures between 0°C and +40°C during nominal operations	Thermal Analysis + TVAC Testing	Operational temperature limits
THERM-002	The payload shall survive temperatures between -20°C and +50°C during eclipse	Thermal Analysis + TVAC Testing	Survival temperature limits
THERM-003	The thermal subsystem shall provide sufficient active heating power (approximately 200 W) to maintain spacecraft components within allowable temperature limits during eclipse	Thermal Model/Simulation (NX)	Eclipse heating requirement
THERM-004	The thermal subsystem shall reject up to 1500 W of internal heat dissipation during peak sunlit operations	Thermal Model/Simulation (NX)	Peak heat rejection

ELECTRICAL REQUIREMENTS

Electrical (Power) Subsystem Requirements Summary			
Requirements Identifier	Description	Verification Method	Notes
ESP-001	The electrical subsystem shall generate a minimum of 1794 W at end-of-life during sunlit operations	Analysis	End-of-life power requirement
ESP-002	The electrical subsystem shall provide approximately 2250 W at beginning-of-life to account for degradation	Analysis	End-of-life power requirement
ESP-003	The electrical subsystem shall provide sufficient battery capacity to ensure the spacecraft state-of-charge remains $\geq 80\%$ at the end of eclipse	Analysis	80% SOC constraint
ESP-004	The spacecraft battery shall provide a minimum usable capacity of 1750 Wh at end-of-life	Analysis	Eclipse energy requirement
ESP-005	The spacecraft battery shall have a beginning-of-life capacity of approximately 2500 Wh to account for degradation over the mission lifetime	Analysis	Battery degradation sizing

CONCEPTUALISATION AND TRADE STUDIES

Concepts Evaluated

1. Repurposing Mars Reconnaissance Orbiter
 - Rejected due to conflicting mission objectives.
2. Single-Spacecraft Architecture
 - Mapping would require ~14 years → exceeds mission timeline.
3. Relay via MRO
 - Introduces operational dependency and risk.

Selected Concept

- Two-spacecraft constellation with direct-to-Earth communications.





MISSION OVERVIEW

Dual Spacecraft System

- Two orbiters launched together
- Shared interplanetary transfer to Mars
- Separate before Mars orbit insertion
- Improves mapping coverage and revisit time

High-Resolution Imaging Payload

- Orbiter A: Near-polar orbit (~93° inclination)
- Orbiter B: Mid-inclination orbit (~45° inclination)
- Off-Nadir pointing at 15 degrees
- Independent orbit adjustments after separation

Complementary Orbits

- Optical imaging instruments
- Global surface mapping of Mars
- Repeated observations for surface monitoring

Data Processing & Transmission

- Onboard image compression of about 10 times
- Transmission through deep space communication network using KA Band
- Data sent to Earth for analysis



MISSION DURATION AND TIMELINE

Mission Timeline					
Project Stage	Starting Date	Ending Date	Allocated Time (Days)	Description	Notes
Phase A	1/1/2026	6/2/2026	36	Finalize Mission objectives, Develop STM and RTM, Draft MRD, Preliminary link and thermal analysis	
	6/2/2026	16/02/2026	10	MRD Finalization and submission	
	16/02/2026	20/02/2026	4	SRR Preparation	
Phase B	15/01/2026	30/03/2026	74	Subsystem block Diagrams, preliminary mass and power closure, ConOps Validation, Cost refinement, Risk mitigation planning	
	30/03/2026	15/04/2026	16	PDR Preparation	
Phase C	15/04/2026	17/10/2027	550	Detailed Subsystem definition, updated mass and power budgets, updated thermal modelling, ICD preparation	
	17/10/2027	15/12/2027	59	CDR Preparation	
Phase D	15/12/2027	22/04/2031	1224	Structural integration, payload integration, software validation	
	22/04/2031	1/6/2031	40	FRR Preparation	
	1/6/2031	1/7/2031	30	Launch Window	
Phase E	1/7/2031	16/04/2032	290	Trajectory Correction Maneuvers, Health Monitoring, Navigation Updates	Cruise Phase
	16/04/2032	17/04/2032	1	Mars Orbit Injection Window	MOI
	17/04/2032	7/10/2032	173	Orbit Trim, Constellation Phasing, Payload calibration, communications Validation	Commissioning Phase
	7/10/2032	17/10/2032	10	ORR Preparation	
	17/10/2032	17/10/2039	2556	Primary Mapping Operations	Main Mission
Phase F	17/10/2039	1/2/2040	107	Final Data Downlink and Decommissioning Procedures	End of Mission

CONCEPT OF OPERATIONS

Launch & Earth Parking Orbit

Spacecraft are launched from Earth and inserted into a ~300 km circular parking orbit before initiating the interplanetary transfer.

Interplanetary Transfer

A Hohmann transfer trajectory is used to travel from Earth to Mars with an approximate time of flight of ~259 days.

Mars Orbit Insertion

The spacecraft separate prior to arrival and each performs a Mars Orbit Insertion burn to enter orbit around Mars.

Orbital Deployment

The two spacecraft are inserted into complementary mapping orbits: one near-polar orbit (~93° inclination) and one ~45° inclination orbit.

Science Mapping Operations

Both spacecraft acquire high-resolution imagery of the Martian surface to support geological analysis and global mapping.

Data Transmission

Collected data is compressed onboard and transmitted to Earth through the deep space communication network.





ORBITAL DESIGN

ORBITAL DESIGN

Two complementary orbital configurations are used to optimize global coverage and temporal observation of the Martian surface.



Polar Mapping Orbit

The first spacecraft operates in a near-polar orbit ($\sim 90^\circ$ inclination) to achieve global coverage of the Martian surface as the planet rotates beneath the spacecraft.



Inclined Revisit Orbit

The second spacecraft operates in a $\sim 45^\circ$ inclination orbit to increase revisit frequency and improve coverage of mid-latitude regions.

SCIENCE INSTRUMENT

Repurposing the HiRise

- The ROUTE-M imaging instrument is derived from the **HiRISE camera architecture used on the Mars Reconnaissance Orbiter**.
- Optimized for a smaller focal length leading to a higher swath width to enable faster global mapping
 - Focal length changed from 12m to 4m
- Allows for 1m/pixel resolution at 40k x 20k per image*
- Images are captured in the visible and Near infrared band
 - from 400-900nm
 - 3 Channels for Full Colour Reconstruction
- Data will be recorded at 14bit images
 - Converted to 8 bit images to retain radiometric detail
 - Colour Reconstruction will take place on board
 - Compressed 10x using JPEG2000 for data transmission

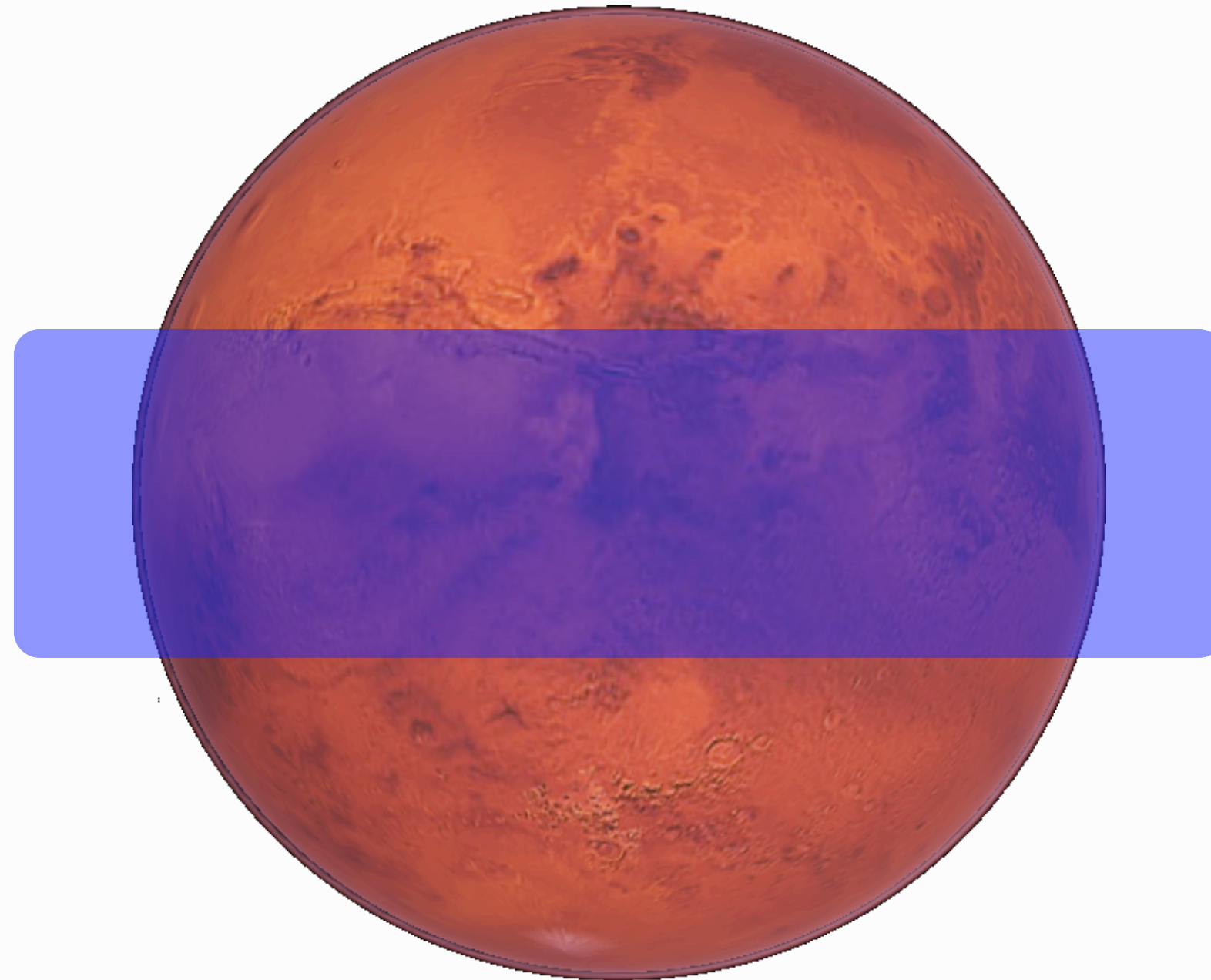


COVERAGE STRATEGY



COVERAGE STRATEGY

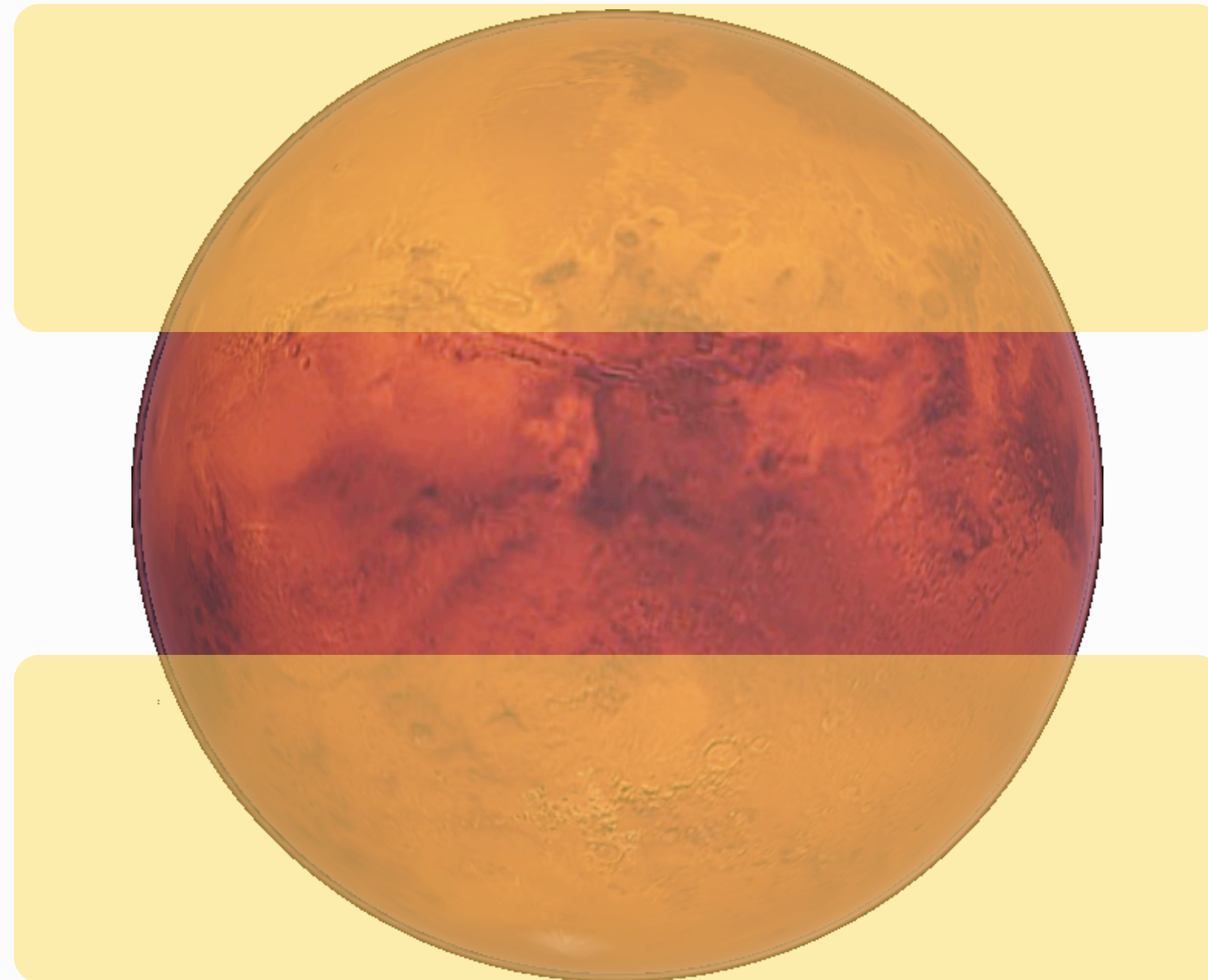
Orbiter 2's primary Coverage Area



**Roughly 50% of Mars' Surface Area
Ranging from ± 30 Degrees Latitude**

COVERAGE STRATEGY

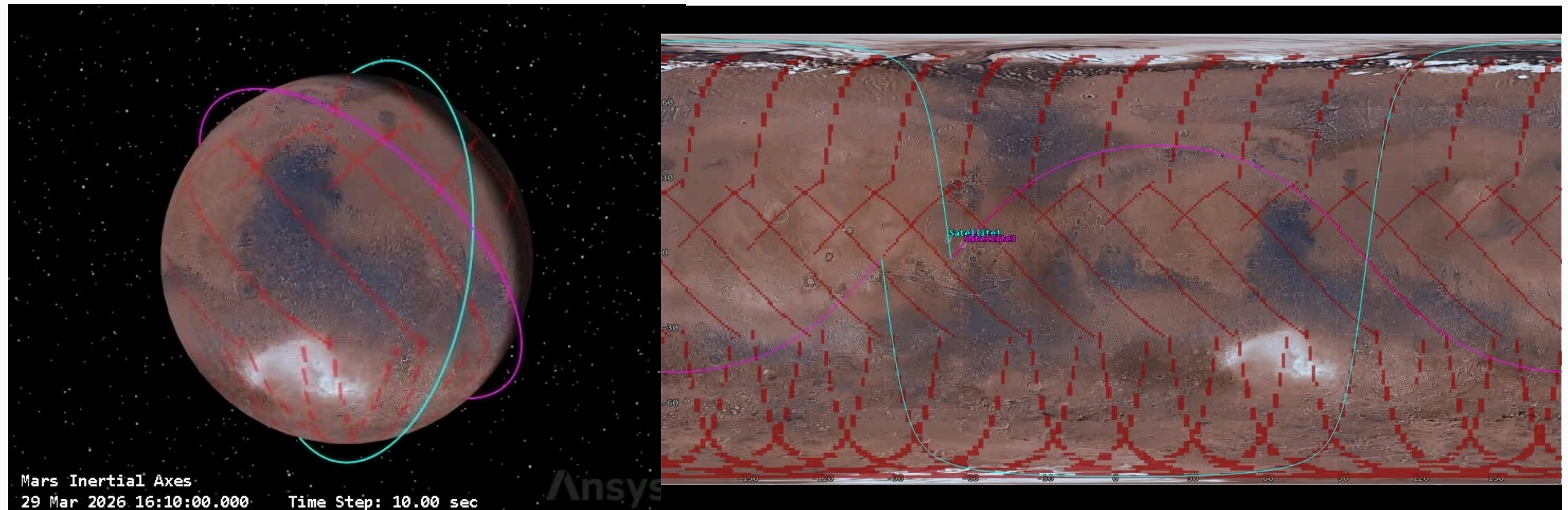
Orbiter 1's primary Coverage Area



Remaining 50% of Mars' Surface Area
Ranging from beyond
+- 30 Degrees Latitude

COVERAGE ANALYSIS

OVER 1 DAY

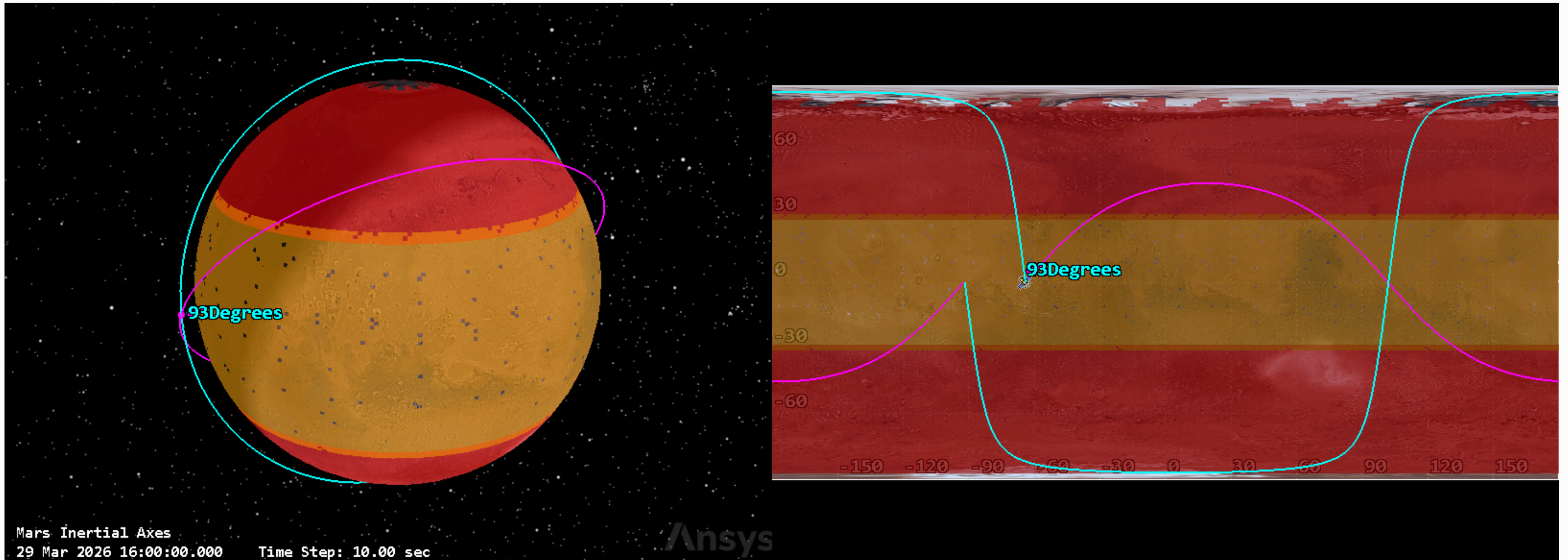


Satellite 1 Covers Roughly 1.53% of Martian Surface

Satellite 2 Covers Roughly 2.6% of Martian Surface

COVERAGE ANALYSIS

OVER 67 DAYS

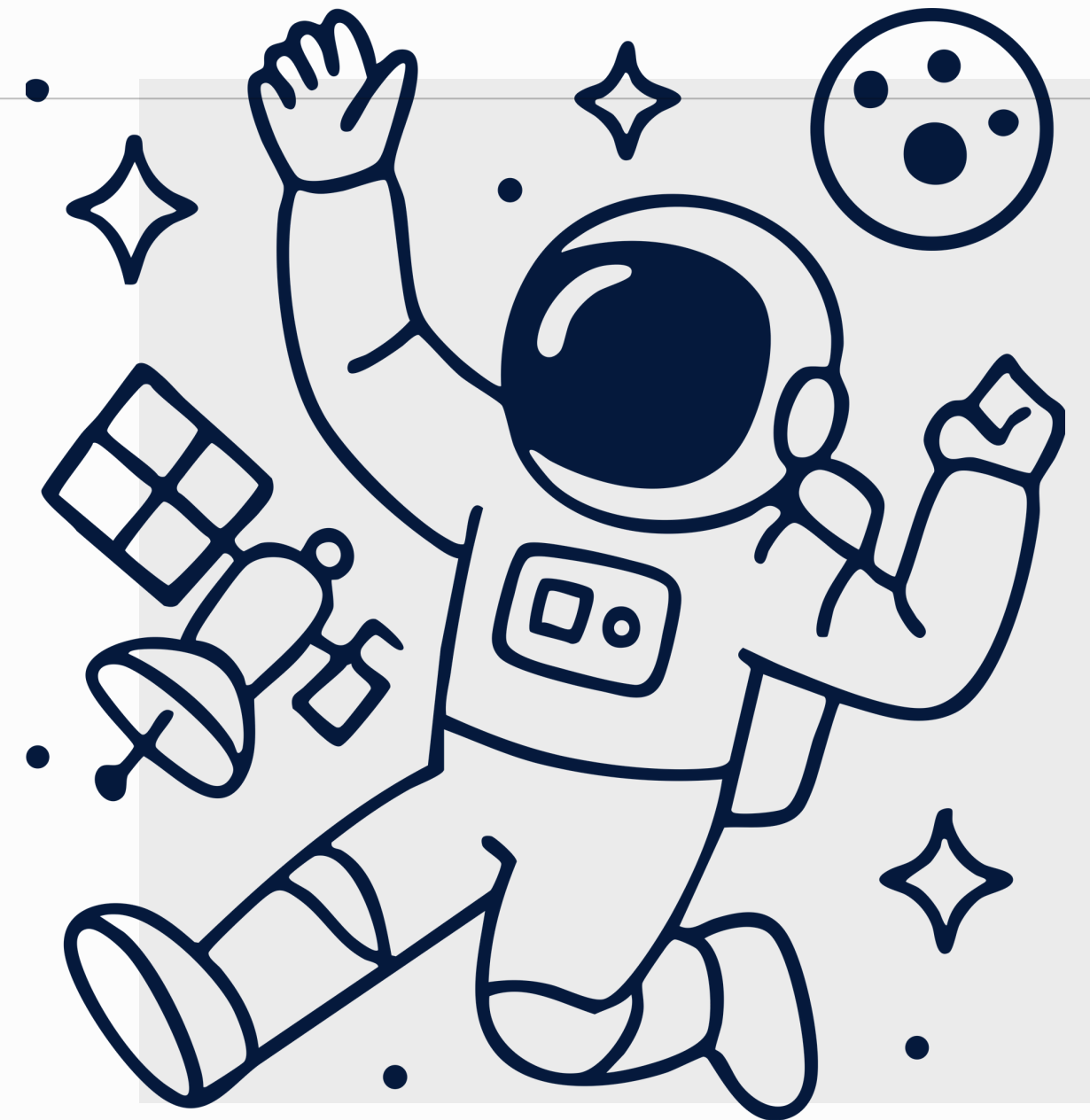


**WE CAN TAKE THE
IMAGES BUT CAN WE
SEND THEM BACK?**

DATA HANDLING AND ACQUISITION

Concepts Evaluated

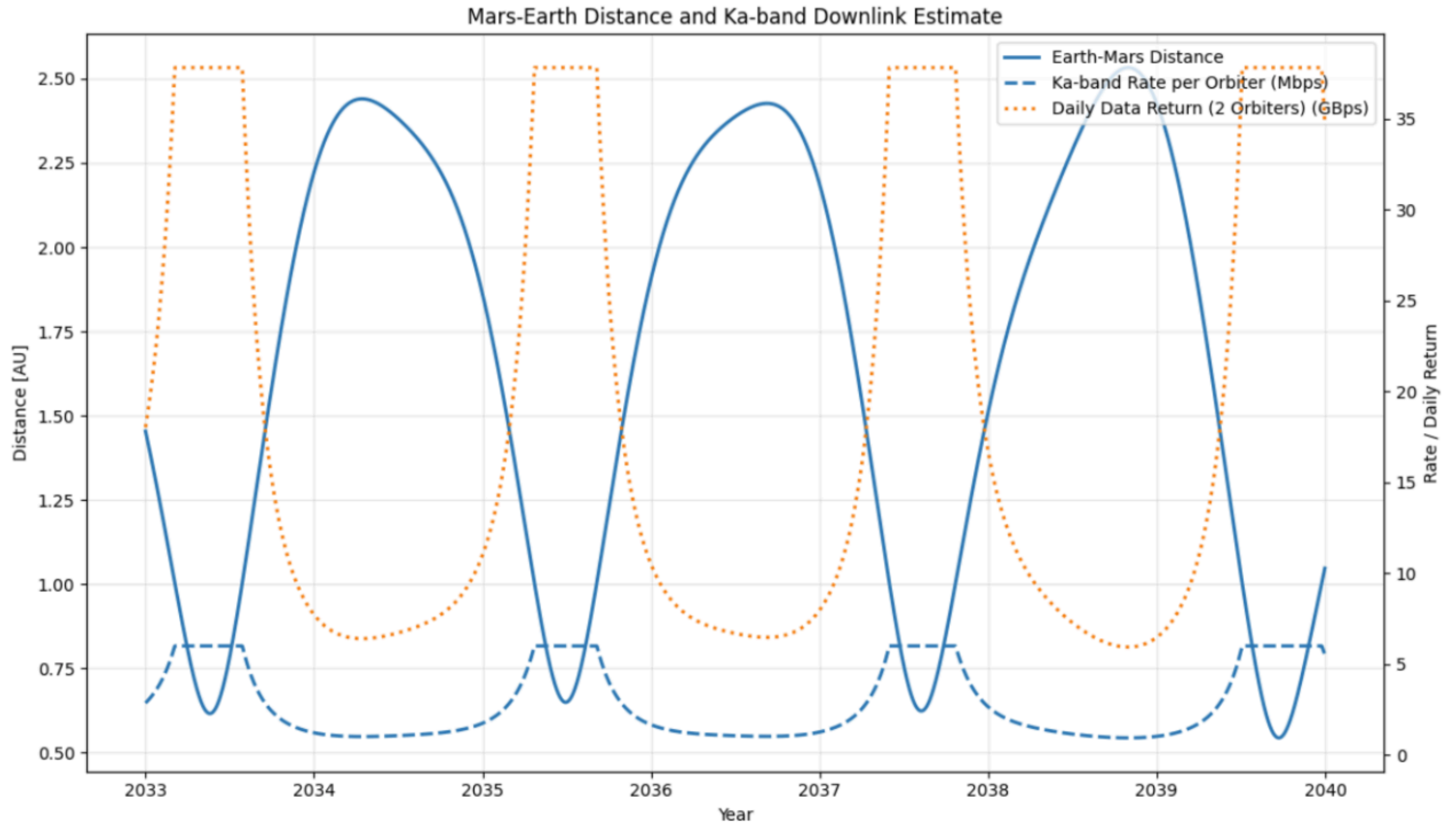
1. Constant Image Acquisition
 - a. Take images at a steady rate throughout the mission lifetime and downlink data depending on available downlink rates
2. Adaptive Image Acquisition
 - a. Create an image acquisition schedule dependent upon available downlink rates
3. High Frequency imaging with large onboard storage
 - a. Capture images continuously and rely on large onboard storage



DATA HANDLING AND ACQUISITION

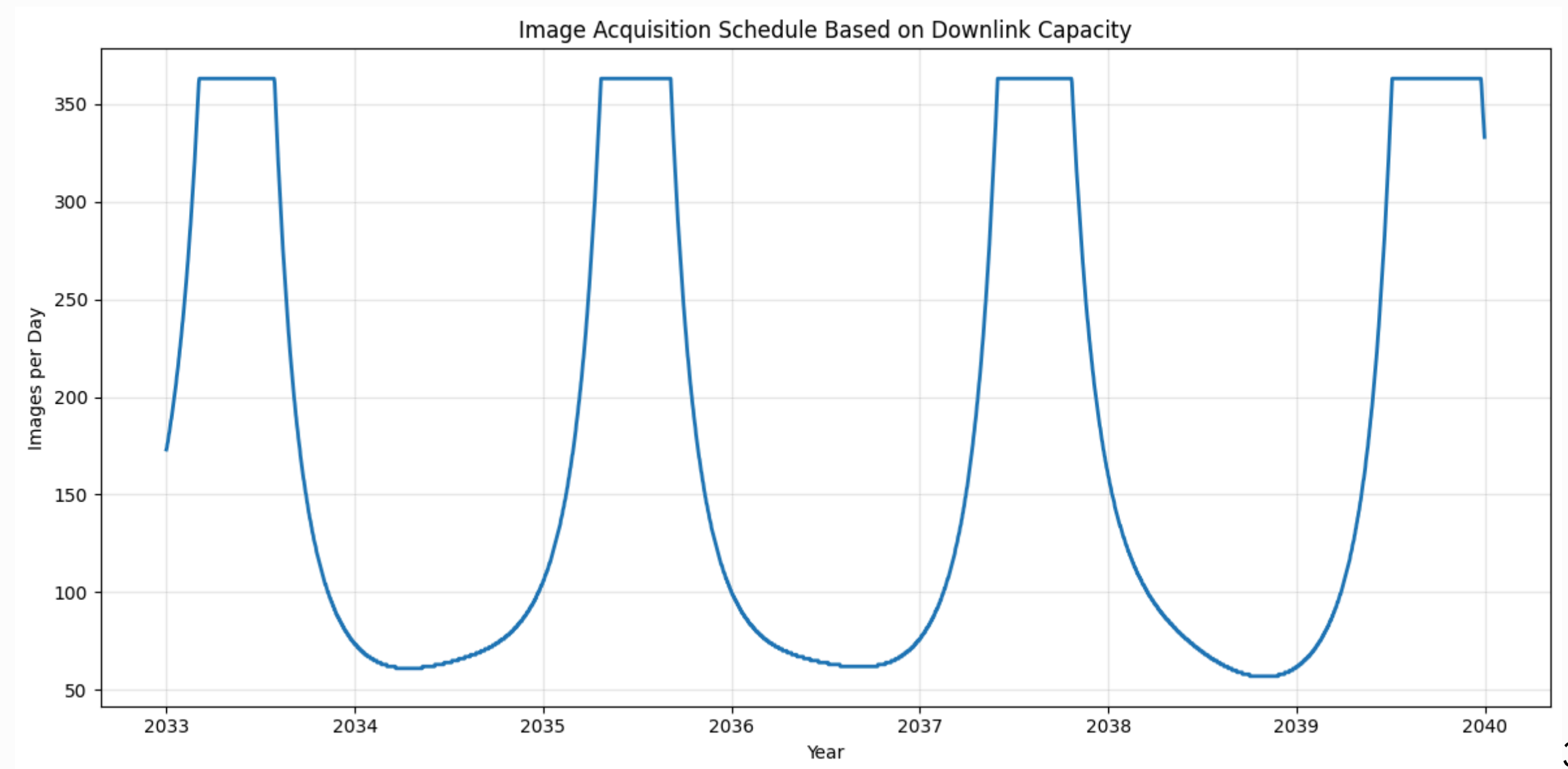
Concept	Description	Advantages	Disadvantages	Score (out of 10)
Constant Imaging Rate	Capture images at a fixed rate throughout the mission regardless of downlink capacity	Simple operations and predictable imaging schedule	Risk of exceeding onboard storage when downlink rates are low	6
Adaptive Imaging Schedule (Selected)	Adjust the number of images captured based on available downlink bandwidth	Maximizes usable data return and prevents storage overflow	Requires scheduling logic and mission planning	9
Continuous Imaging with Large Buffer Storage	Capture images continuously and store them until transmission opportunities arise	Maximizes raw data collection	Requires large onboard storage and increases risk of data backlog	7
				35

DATA DOWNLINKING



DATA HANDLING AND ACQUISITION

- Pixels per image: 800000000
- Raw image size: 800.0 MB
- Compressed image size: 80.0 MB
- Final data per image: 104.0 MB
- Min images per day: 57
- Max images per day: 363
- Average images per day: 175.3



DOWNLINK ESTIMATES

Min Distance	0.544 AU
Max Distance	2.533 AU
Min rate per orbiter:	0.943 Mbps
Max rate per orbiter	6.0 Mbps
Min total daily return	5.94 GB/day
Max total daily return	37.8 GB/day
Total data transmitted over mission	46746.56 GB

COMMUNICATIONS CONSTRAINTS

- Ka-band (32 GHz) for science data downlink and X-band (8.4 GHz) for telemetry and commanding
- Downlink data rate:
 - ≥ 1 Mbps at maximum Earth-Mars distance
 - ≥ 25 Mbps at minimum distance
- X-band uplink rate of ≥ 2 kbps and a telemetry downlink rate of ≥ 64 kbps
- Both spacecraft allocated 14 hours of DSN contact per day combined
 - onboard buffering of science data between contacts
- Include a solid-state recorder with a usable capacity of ≥ 256 GB

COMMUNICATIONS CONSTRAINTS

- Maintain a minimum link margin of ≥ 3 dB under worst-case Earth-Mars distance and pointing conditions
- The spacecraft attitude control system shall support high-gain antenna pointing and control accuracy of $\leq 0.1^\circ$ during downlink operations
- Weekly science data return capability of ≥ 30 GB
- Communication subsystem peak during X-band downlink shall not exceed 500W





THERMAL SYSTEMS ANALYSIS

HEATER SIZING (COLD CASE)

Survival Heater Sizing

- Worst-case cold condition occurs during orbital eclipse (42 minutes) when the spacecraft receives no solar heating
- For conservative sizing, heaters are assumed to operate for the entire eclipse duration

Heater distribution by subsystem:

Subsystem	Heater Configuration	Power
Battery Thermal Control	2 heaters × 25 W	50 W
Propulsion System	6 heaters × 10 W	60 W
Avionics	4 heaters × 15 W	60 W
Payload instruments	3 heaters × 10 W	30 W

Total heater power:

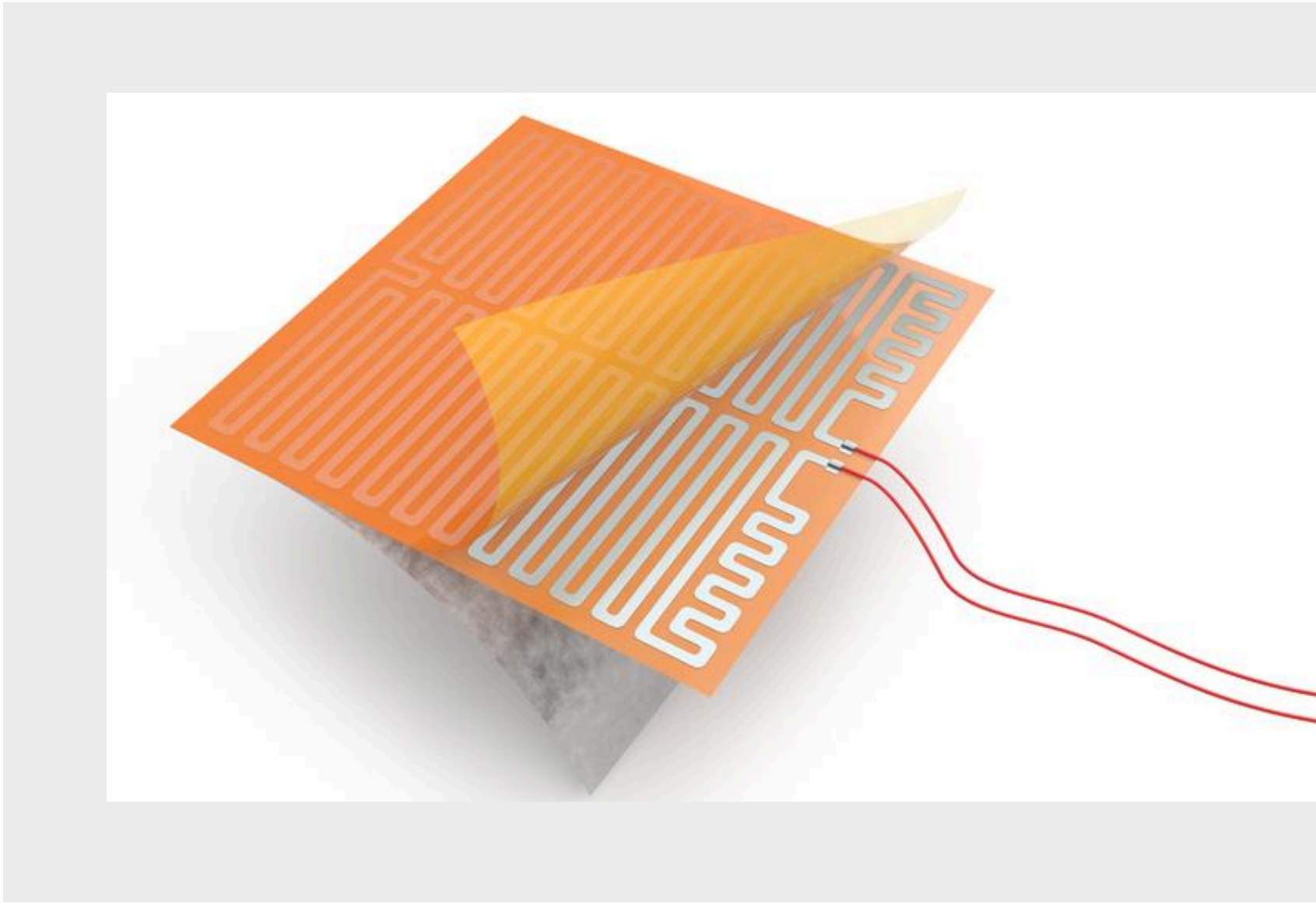
- Total installed heater wattage: 200 W

Heater duty cycle:

- Eclipse fraction of orbit = 37%
- Heater duty cycle = 37%

Orbit-average heater power:

- Average thermal power load = 74W



RADIATOR SIZING (HOT CASE)

Radiator Heat Rejection

- During sunlit operations, spacecraft electronics generate significant waste heat that must be rejected to space in order to prevent overheating
- Total internal heat dissipation during operations:
 - 1500 W
- This heat is produced by:
 - avionics
 - payload electronics
 - communication systems
 - power electronics
- A first-order radiator heat rejection of 300 W/m^2 is assumed
- Total Radiator area required:
 - 5 m^2
- Radiator configuration (two radiator panels):
 - Each panel area = 2.5 m^2
- Radiators are placed on anti-sun spacecraft surfaces to maximize heat rejection



BATTERY SIZING (ECLIPSE ENERGY)

Battery Energy Storage

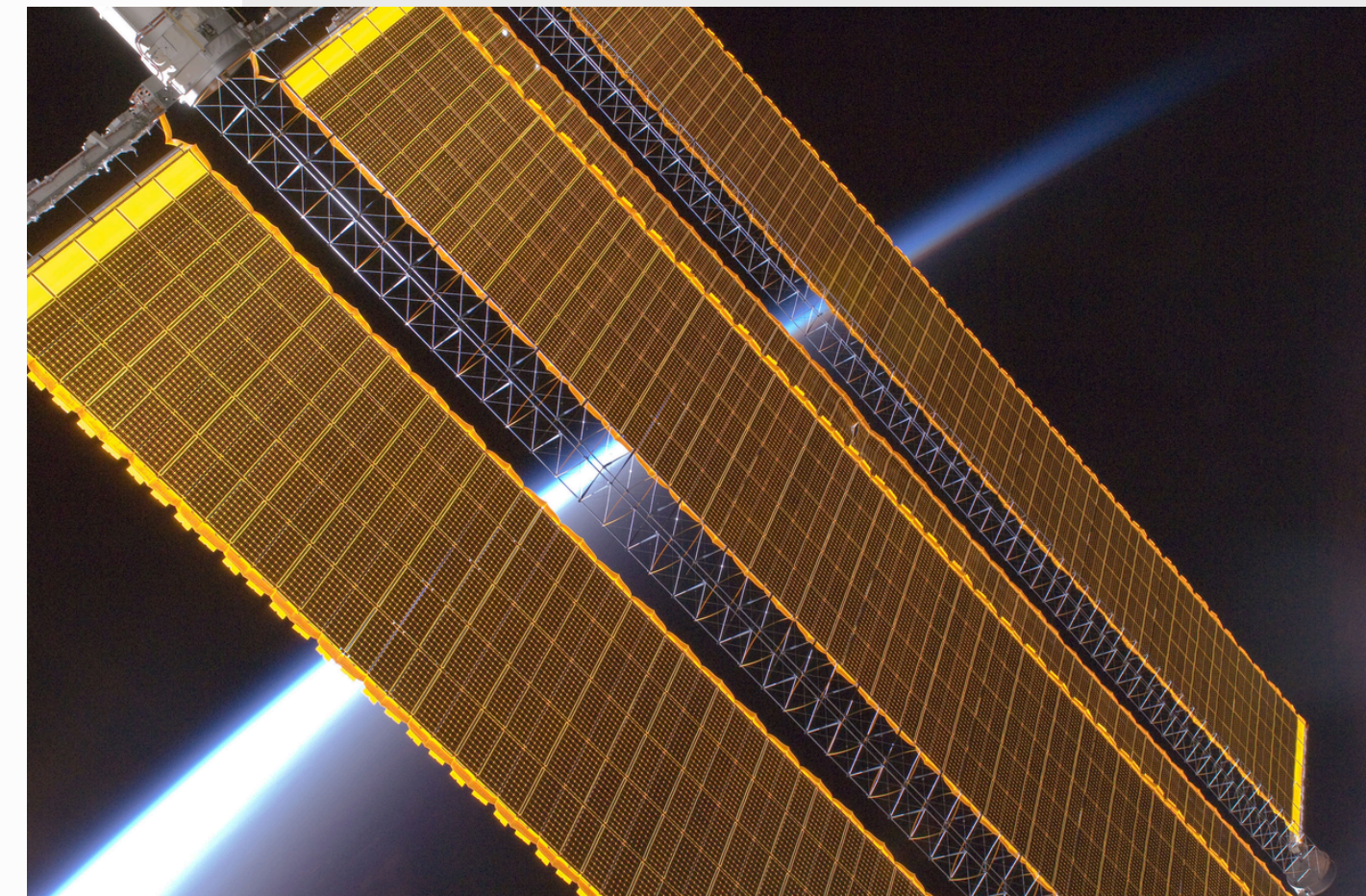
- The spacecraft experiences an orbital eclipse each orbit, during which solar arrays cannot generate power
- During eclipse the spacecraft operates in a reduced-power survival configuration:
 - Essential subsystems = 300 W
 - Survival Heaters = 200 W
- Total eclipse power: 500 W
- Eclipse duration: 42 minutes (0.70 hr)
- Battery energy required per eclipse: 350 Wh
- End-of-Life (EOL) required usable battery capacity: 1750 Wh
 - Based on maintaining $\geq 80\%$ state-of-charge after eclipse (20% of battery capacity discharged per eclipse)
 - ensures sufficient energy margin for contingency scenarios (e.g., attitude loss or delayed recovery)
- Beginning-of-Life (BOL) required battery capacity: 2500 Wh
 - Includes 30% margin for battery degradation over the mission lifetime
 - Ensures sufficient stored energy to support spacecraft survival during eclipse throughout the mission lifetime



SOLAR ARRAY SIZING

Solar Array Power Generation

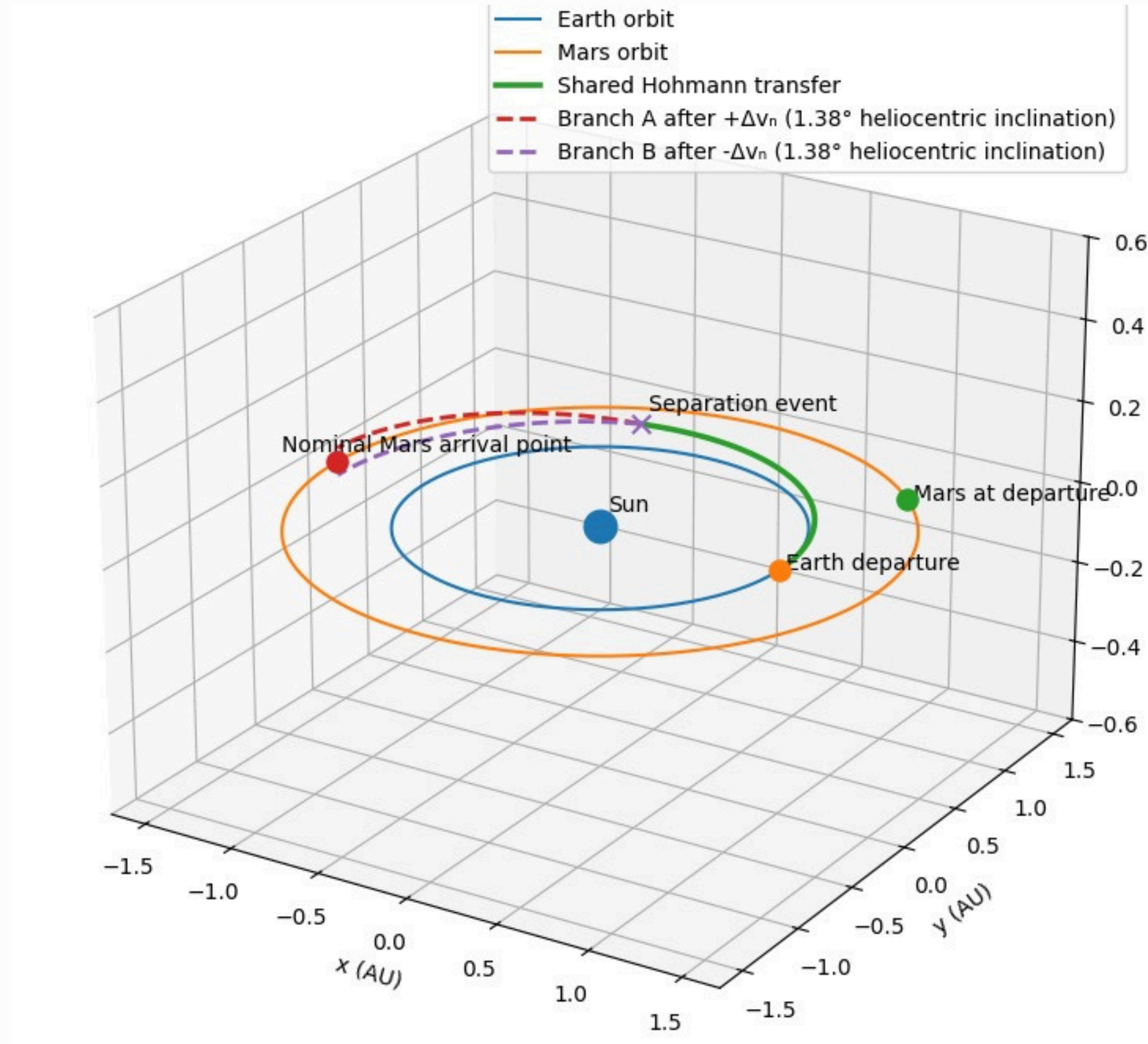
- The spacecraft relies on deployable solar arrays as the primary power source while in Mars orbit
- Power must be generated during sunlit operations (71 minutes per orbit) to support:
 - spacecraft operational power
 - battery charging for eclipse periods
- Total orbital energy demand:
 - 2135 Wh per orbit
- Required solar array power (End-of-Life):
 - 1794 W = 1.8 kW
 - This represents the minimum power the arrays must generate after 9 years of degradation
- Solar array area
 - Assuming solar cell power density of 200 W/m²
 - 9 m²
- Beginning-of-Life solar array power:
 - 2.25 kW
 - To compensate for solar cell degradation (~2.5% per year) over the 9-year mission life
 - This ensures sufficient power generation throughout the full mission lifetime





| **FLIGHT TRAJECTORY**

FLIGHT TRAJECTORY



MODES OF OPERATION

1

Launch & Early Operations

After launch, the spacecraft deploys solar arrays, establishes communication with Earth, and performs system health checks before beginning the transfer to Mars.

2

Cruise / Interplanetary Transfer

During the Earth-Mars Hohmann transfer, the spacecraft operates in a low-power cruise configuration while performing navigation updates and trajectory correction maneuvers.

3

Mars Orbit Insertion

Upon arrival at Mars, the propulsion system performs a Mars Orbit Insertion burn to capture the spacecraft into the planned ~300 km mapping orbit.

4

Orbit Commissioning

After orbit insertion, instruments and subsystems are calibrated and the spacecraft are positioned into their respective near-polar and mid-inclination mapping orbits.

5

Science Operations

The imaging payload captures high-resolution images of the Martian surface during daylight passes with up to **15° off-nadir pointing** to maximize mapping coverage.

6

Data Downlink

Captured images are stored, compressed onboard, and transmitted to Earth using Ka-band communications while telemetry and commands are handled through X-band links.

7 Safe Mode

In case of anomalies, the spacecraft enters safe mode, shutting down non-essential systems while maintaining communication with Earth.



RISKS



RISK	Risk Description	Likelihood	Impact	Risk Level	Mitigation
R1	Launch vehicle anomaly/failure	Low	High	Medium	Use proven launch vehicle and verified integration procedures
R2	Interplanetary trajectory error	Medium	High	High	Perform trajectory correction maneuvers and continuous navigation tracking
R3	Mars orbit insertion failure	Low	High	Medium	Redundant propulsion systems and autonomous burn monitoring
R4	Eclipse power limitations	Medium	Medium	Medium	Battery sizing and power-saving eclipse mode
R5	Communication / DSN constraints	Medium	Medium	Medium	Onboard data storage and flexible downlink scheduling

		Severity of Harm (Impact)		
		Low (L)	Medium (M)	High (H)
Likelihood	High (H)			
	Medium (M)	R4, R5	R2	
	Low (L)		R1, R3	

COST AND BUDGET OVERVIEW



Subsystem / Required By	Cost (USD\$M)	Additional Notes / Basis
Available Budget	750	Mission constraint
Project Management & Systems Engineering	55	Streamlined management structure, Includes Personnel
Spacecraft Bus – Orbiter 1	115	Analogy-based estimate, adjusted for heritage reuse
Spacecraft Bus – Orbiter 2	100	13% second-unit discount due to duplicated design
Propulsion Subsystem ×2	60	Cruise corrections + MOI + phasing
Communications (X/Ka + Antennas) ×2	45	Direct-to-Earth architecture
Payload (HiRISE-derived) ×2	120	HiRISE heritage basis: \$40M in 2006 → \$63.7M in 2026 using NASA inflation factor 1.593; reduced for scope simplification + second-unit savings
Onboard Data Handling + Compression ×2	25	Compression + storage
Integration & Test (I&T) + QA	60	Shared testing across identical spacecraft
Ground Segment + Data Processing Pipeline	20	Reduced processing scope
Mission Operations (Cruise + 7-year mapping)	30	Automation + efficient scheduling
Contingency / Margin Reserve	120	NASA-style reserve expectation at this phase
TOTAL	750	Meets budget cap

MASS BUDGET OVERVIEW



Subsystem / Required By	Cost (Kg)	Additional Notes
Structures and Mechanism	180	
Thermal Control	45	Radiators, Heaters, MLI Blanket
Power	160	
ADCS	70	
Avionics	55	
Comminucations	60	
Propulsion Hardware	85	
Harness and Cabling	35	
Payload: HiRISE -derived imager	70	
Dry Mass (CBE)	760	
Dry Mass with Growth (20%)	152	
Dry Mass with Growth	912	
Propellant (MOI + TCM + Phasing +Margins)	520	
Propellant Margin (10%)	52	
Wet Mass (per spacecraft)	1,484	
Total Mass	2968	Accounts for both Spacecrafts

POWER BUDGET OVERVIEW



Hot Operational Power Budget (Sunlit)		
Subsystem / Required By	Cost (W)	Additional Notes
Payload (Stereo Imager + LiDAR)	600	Payload operates only during sunlit portion of the orbit
Communications (TX + modem + data handling)	250	Downlink and communications active during operations
Avionics	250	Core spacecraft electronics
ADCS (sensors, controls)	200	N/A
Power subsystems (PDU, converters, losses)	100	Power conditioning and distribution losses
Margin	100	N/A
Total Available Power Budget	1500	Constraint (set by hot operational internal dissipation used for radiator sizing)
Cold Survival Power Budget (Eclipse)		
Subsystem / Required By	Cost (W)	Additional Notes
Cold Survival Internal Power (P_int)	300	First-order conservative assumption (payload OFF), with internal power being consumed by only essential subsystems
Survival Heaters (P_Heater)	200	Installed heater wattage capacity, and is assumed ON through the entire duration of the eclipse (conservative)
Total Eclipse Power Draw	500	Used to determine battery sizing and battery energy required per eclipse

COMMUNICATIONS BUDGET OVERVIEW



Subsystem / Required By	Cost (KB per sol)	Additional Notes
Total Available	3500000	
Payload (High-res imaging)	-3125000	Calculated as 400 images (40000 x 20000 pixels) at 8-bit depth with 10x compression.
Spacecraft Health (Telemetry)	-51200	Housekeeping data (battery, thermal, status) sampled at 1 Hz (50MB total per day)
ADCS (Navigation/Tracking)	-25600	High precision orbital data needed for 50-150m geolocation accuracy requirement
Command Overhead (Error Correction)	-156250	Space for Turbo Coding and packet headers to ensure >99% successful file delivery
Total Remaining	141950	3.36GB - Under the 3.5GB limit with 4% margin remaining.



PROJECT MANAGEMENT AND TEAM CONTRIBUTIONS

Sarthak Sahai

- Mission background and assumptions
- Stakeholder analysis
- ConOps and risk assessment
- Data Downlink Calculations
- image Resolution Calculations
- STK Simulations

Prajakta Lal

- Interplanetary transfer analysis
- Mars Orbit Insertion calculations
- Propulsion mass budgeting
- Mission cost breakdown

Hishaam Hassan

- Volumetric constraints
- Launch vehicle selection
- Mass budget

Sufyan Parvez

- Power and thermal constraints
- Thermal system analysis
- Mass Budget (Thermal)

Meryl Almeida

- Communications architecture
- Data rate analysis

THANK YOU

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OTHER RESOURCES

- [1] “General Environmental Verification Standard (GEVS) for GSFC Flight Programs and projects,” NASA,
<https://standards.nasa.gov/standard/GSFC/GSFC-STD-7000> (accessed Feb. 16, 2026).
- [2] “Camera technical specifications,” HiRISE,
<https://www.uahirise.org/specs/> (accessed Feb. 16, 2026).

