ICEAA COST CHALLENGE 2026

What Would It Cost to Establish and Sustain a Human Settlement on Mars?

New Jamestown Settlement Concept

Arcadia Planitia, Mars

Prepared by Tecolote Research

THE **CHALLENGE**

- Permanent settlement in an extreme environment
- Long supply chain (Earth -> Mars)
- Limited rescue capability
- High uncertainty in system performance

OUR **OBJECTIVE**

- Estimate the 10 Martian-year Whole Life Cost starting in 2050
- Define the systems required to sustain and grow the settlement
- Build a defensible cost model using real-world data and assumptions

WHY SPEND ALL THIS **MONEY TO GO TO MARS?**

1 PLANETARY BACKUP

Ensures the long-term survival of humanity by establishing a second home beyond Earth.

6 INTERNATIONAL COLLABORATION & PEACE

Unites nations in a shared purpose, fostering cooperation, understanding, and lasting peace on Earth and beyond.

5 ECONOMIC OPPORTUNITIES

Drives innovation, creates new industries, and opens the door to expanding humanity's reach in the solar system.

2 SCIENTIFIC EXPLORATION

Mars holds the key to discovering the history of life, the evolution of planets, and our place in the universe.

3 TECHNOLOGICAL ADVANCEMENT

Pushing the boundaries of science and engineering creates breakthroughs that benefit life on Earth.

4 INSPIRATION & EDUCATION

Inspires future generations to dream bigger, pursue STEM, and solve the world's greatest challenges.

INVESTING IN MARS IS INVESTING IN HUMANITY'S FUTURE.
Exploration. Innovation. Opportunity. For generations to come.

TOTAL PROGRAM COST

$292 BILLION

CY26 Dollars

COST BREAKDOWN BY SYSTEM

1	Transportation System	$14,196.89	4.85%
2	Surface Habitat & Infrastructure System	$56,102.06	19.18%
3	Environmental & Life Support System	$6,331.05	2.16%
4	ISRU System	$13,353.41	4.57%
5	Crew & Human Systems	$15,654.00	5.35%
6	Operations & Sustainment System	$166,330.13	56.85%
7	Science & Technology System	$475.59	0.16%
8	Program & Integration	$19,993.36	6.83%

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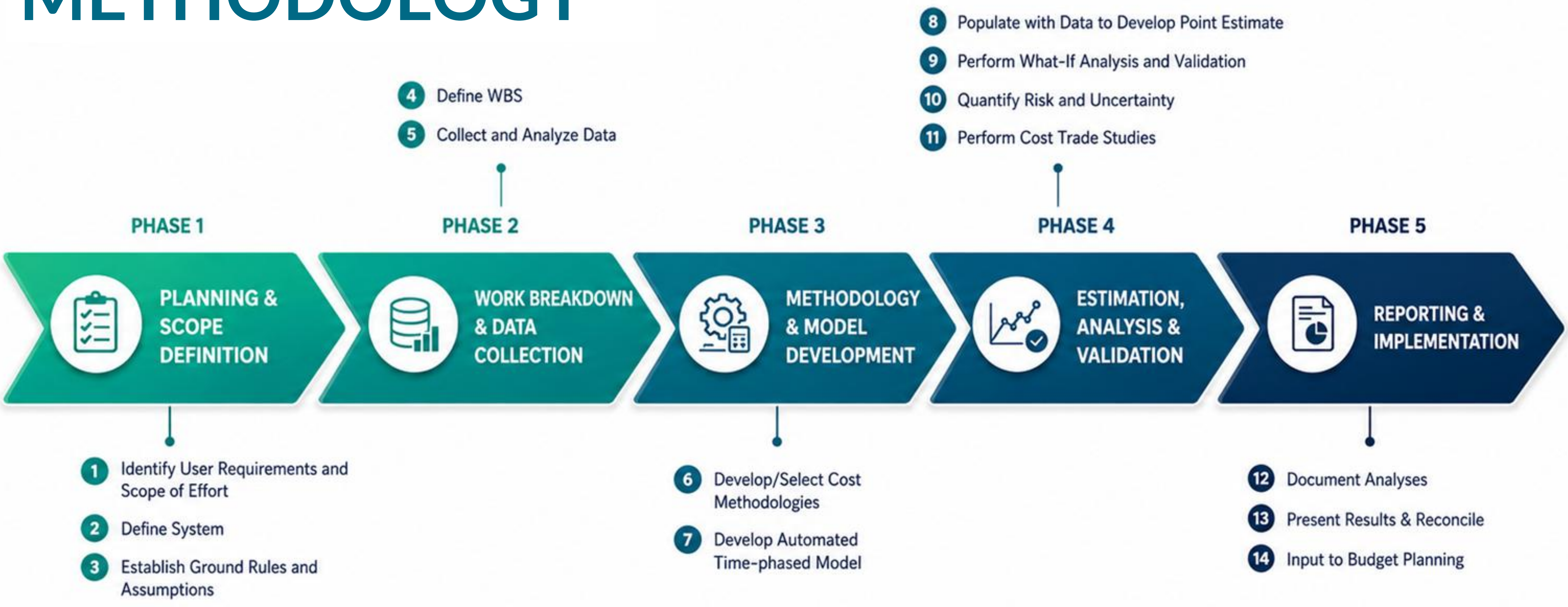
Mentor

Cost estimator with 8 years of experience working on DoD and DHS projects. B.S.E in Mathematics from Mansfield University of PA

Collectively, we have 3.17 Earth years and 1.68 Martian years of cost estimating experience!

THE PROBLEM

METHODOLOGY



The team followed the Tecolote Cost Estimating 14 Steps—an approach that informed the development of the Government Accountability Office (GAO) 12-Step Cost Estimating Process—to produce a high-quality estimate that is comprehensive, well-documented, accurate, and sound.

GROUND RULES & ASSUMPTIONS

Category	Ground Rule or Assumption
Scope	R&D excluded; estimate focuses on Procurement and O&S
Methodology	Parametric model using historical analogies scaled by quantity, mass, and complexity
Inflation	Costs adjusted using NASA's NNSI Index
Risk & Uncertainty	Log-normal and Triangle distribution used, reported at 80% confidence level, as used by NASA
Learning Curve	80% learning curve
Technology	Developing technologies assumed to work as advertised
Darian Calendar	Mission lasts 10 Martian years from 6/15/234-6/15/244; 1 Mars year = 1.88 Earth years
Autonomy	AI/robotics assumed capable of building and maintaining infrastructure; manpower excluded
Habitat & Power	Population grows from 20 to ~480; life support sized for 550; nuclear power assumed
Travel	6-month Mars transit; launches every 26 months using Hohmann transfer windows.

SCHEDULE

LAUNCH	EARTH LAUNCH DATE	MARS LAUNCH DATE	# OF ROCKETS LAUNCHED	PEOPLE FLYING THERE	CUMULATIVE POPULATION ON MARS*
1 Launch 1	1/1/2051	22/14/234	0 HLS, 2 Cargo	astronauts (massive robotic fleet)	-
2 Launch 2	3/1/2053	2/4/236	1 HLS, 0 Cargo	20	20
3 Launch 3	5/1/2055	5/22/237	1 HLS, 2 Cargo	35	55
4 Launch 4	7/1/2057	9/12/238	1 HLS, 2 Cargo	75	130
5 Launch 5	9/1/2059	13/4/239	1 HLS, 2 Cargo	75	205
6 Launch 6	11/1/2061	16/22/240	1 HLS, 2 Cargo	95	300
7 Launch 7	1/1/2064	20/12/241	1 HLS, 2 Cargo	100	400
8 Launch 8	3/1/2066	23/28/242	1 HLS, 3 Cargo	100	500+

*Approximate cumulative population after each crew arrival. It does not account for births or deaths.

Phase 0 *Pre-2050*
Pre-Deployment

Phase 1 *Years 1 - 3*
Industrial & Robotic Deployment

Phase 2 *Years 2 - 6*
Initial Crew & Habitat Activation

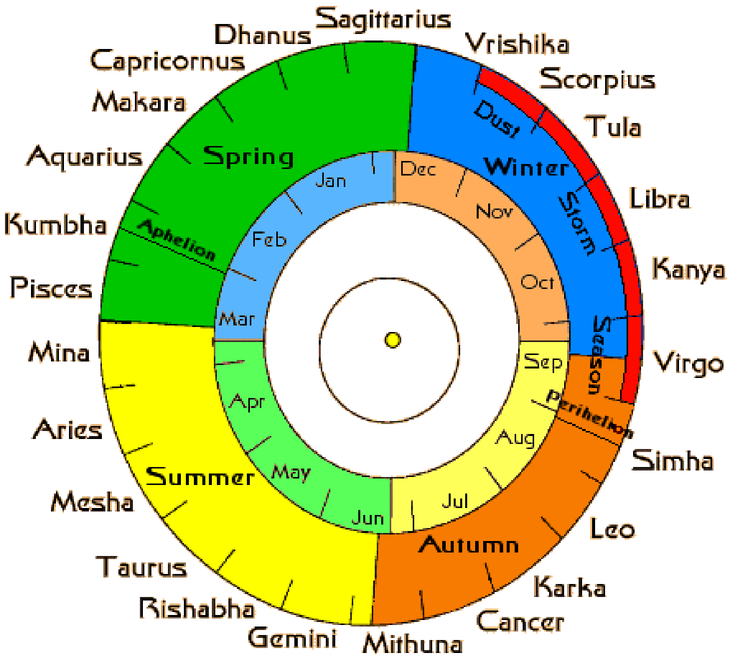
Phase 3 *Years 5 - 12*
Settlement Expansion

Phase 4 *Years 10 - 19*
Self-Sustaining Operations

Phase 5 *Beyond 2069*
Long-Term Stability

DARIEN CALENDAR

MARTIAN YEAR	EARTH START DATE	EARTH END DATE
234	4/26/2049	3/12/2051
235	3/13/2051	1/27/2053
236	1/28/2053	12/15/2054
237	12/16/2054	11/1/2056
238	11/2/2056	9/19/2058
239	9/20/2058	8/6/2060
240	8/7/2060	6/24/2062
241	6/25/2062	5/12/2064
242	5/13/2064	3/29/2066
243	3/30/2066	2/13/2068
244	2/14/2068	1/1/2070



For estimating purposes, our calendar starts at FY2050 and ends exactly 10 Martian years later

Martian Dates:
6/15/234 - 6/15/244

Earth Dates:
10/1/2049 - 7/23/2068

IN THE **SCOPE**

Procurement, Operations, and Maintenance Costs that include:

Transportation & Logistics
- Earth-to-Mars crew and cargo transport systems, propellant production and transfer, launch, refurbishment, and return operations

Surface Infrastructure
- Habitat modules and pressurization systems, power generation and storage, communications and navigation networks

Life Support & ISRU
- Air, water, and food systems, in-situ resource utilization (water extraction, methane production, materials processing), waste management systems

Crew & Operations
- Astronaut training systems, medical and behavioral health systems, EVA systems, maintenance operations, and spare parts logistics

Science & Expansion Systems
- Research infrastructure, robotics and AI systems, and advanced manufacturing capabilities

OUT OF THE **SCOPE**

- R&D and pre-2050 technology development (sunk cost)
- Earth-side industrial base beyond launch operations
- Political, regulatory, and governance costs
- Mission failure costs beyond nominal risk modeling
- End-of-life disposal and decommissioning
- Commercial revenue offsets (no revenue modeled)
- Manpower costs due to the autonomous nature of all systems

WHERE WE ARE BUILDING

NEW JAMESTOWN

ARCADIA PLANITIA, MARS

New Jamestown will be established in Arcadia Planitia, a vast, smooth plain in Mars' northern hemisphere.

STRATEGIC LOCATION

Low elevation, equatorial latitude and proximity to key resources make Arcadia Planitia ideal for long-term sustainability.

ACCESS TO RESOURCES

Evidence of subsurface ice and mineral rich regions to support life support, ISRU, and construction needs.

SAFE & ACCESSIBLE

Relatively flat terrain and fewer extreme elevation changes support safe landing and surface operations.

LOCATION
49.5°N, 183.6°E
Arcadia Planitia

ELEVATION
~ -4.5 km
(Below Mars Mean)

LATITUDE
~ 49.5° North
Near Ideal for Solar Energy & Stability

MEAN TEMPERATURE
~ -55°C
(Annual Average)

ARCADIA PLANITIA OFFERS THE BEST BALANCE OF ACCESS, RESOURCES, AND LONG-TERM POTENTIAL

The ideal place to build humanity's new home on Mars.

THE SOLUTION

DATA **MINING**

We leveraged authoritative sources, normalized all costs to a common dollar year, **and applied proven analogs to estimate Mars settlement costs.**

PRIMARY SOURCES

- NASA Technical Reports Server (NTRS) publications and NASA-published articles
- Publicly available SpaceX Starship pricing
- ISS program data, cost analogies, and CERs
- IDA CERs used for communications systems

DOLLAR YEAR NORMALIZATION

- All source costs normalized to Base Year **FY2026 (BY26)**
- NASA New Start Inflation Indices **(NNSI)** applied
- Conversions applied in both directions

KEY EXTRAPOLATIONS & ANALOGS

- Where no space-specific cost data existed, analogies were drawn from terrestrial industrial sources and scaled for Mars environment
- An **80% learning curve** was applied to all mass-produced hardware

EXAMPLE ANALOG

GTF Velocys Module Plant (Bayou Fuels / Mississppi RNG-to-Fuels) used as industrial analog for propellant and oxygen production. Costs scaled 3x for Mars environment, remote construction, and no existing supply chain.

The estimate combines aerospace, industrial, and terrestrial analog data to model a scalable long-duration Mars settlement architecture.

WBS STRUCTURE

WBS Code	Description
1	Transportation System
1.1	Launch Vehicle
1.2	Life Support
2	Surface Habitat & Infrastructure System
2.1	Habitat Modules
2.2	Nuclear Power System
2.3	Communications Systems
3	Environmental & Life Support System
3.1	Air Management
3.2	Water Systems
3.3	Food Production
3.4	Waste Management
4	ISRU System
4.1	Mining Unit
4.2	Thermal Processing Unit
4.3	Chemical Processing Unit
4.4	Materials Refining Unit
4.5	Maintenance & Repair

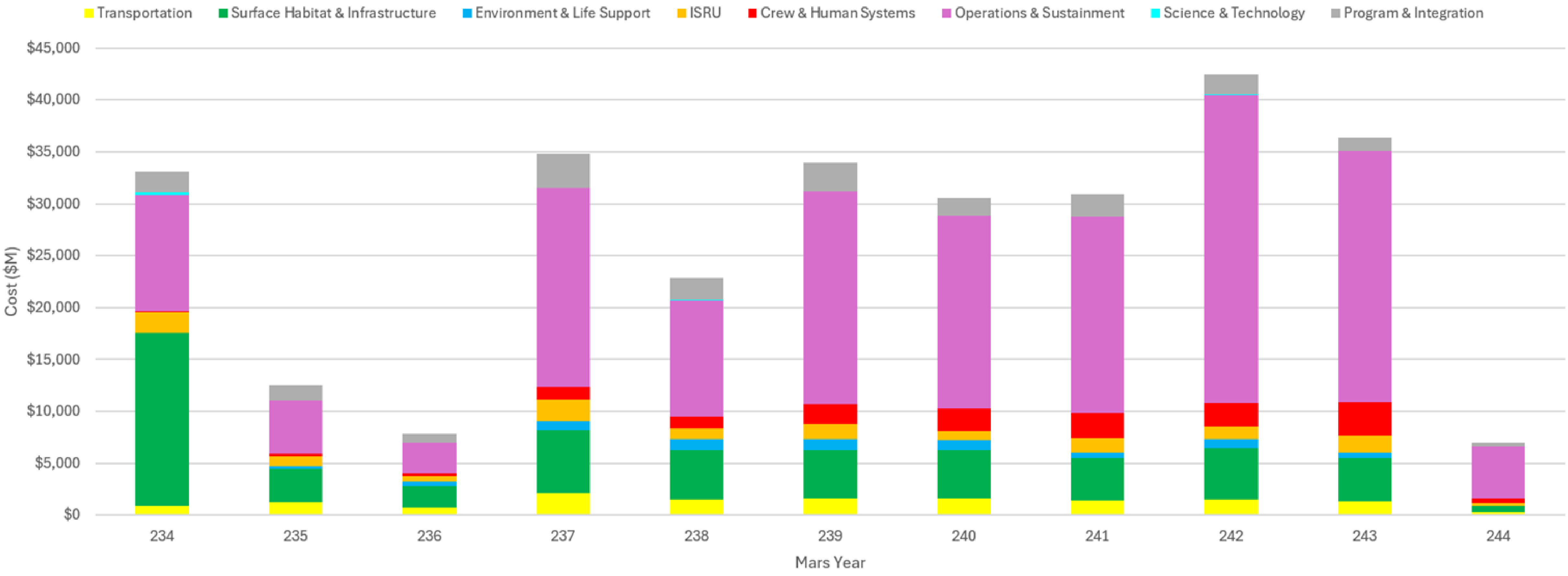
5	Crew & Human Systems
5.1	Crew Training
5.2	Medical & Biomedical Systems
5.3	Behavioral & Psychological Systems
5.4	EVA Systems & Operations
6	Operations & Sustainment System
6.1	Maintenance & Repair
6.2	Supply Chain Integration & Logistics
6.3	Emergency Systems
6.4	System Improvements
7	Science & Technology System
7.1	Research
7.2	Machines
8	Program & Integration
8.1	Safety & Assurance
8.2	Verification & Validation
8.3	Expansion Planning

TOTAL WHOLE LIFE COST
(CY26)

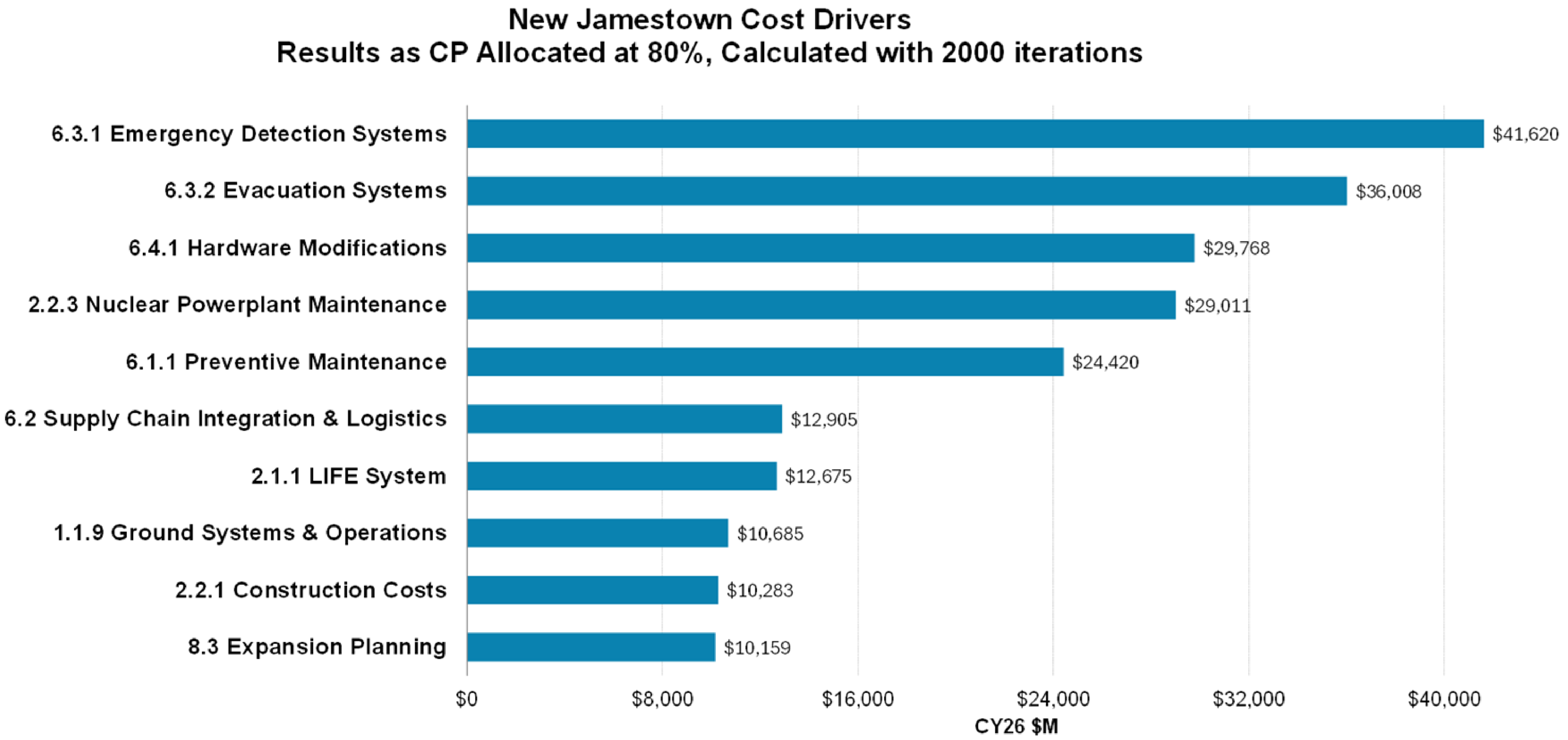
$292.44B
OVER 10 MARTIAN YEARS

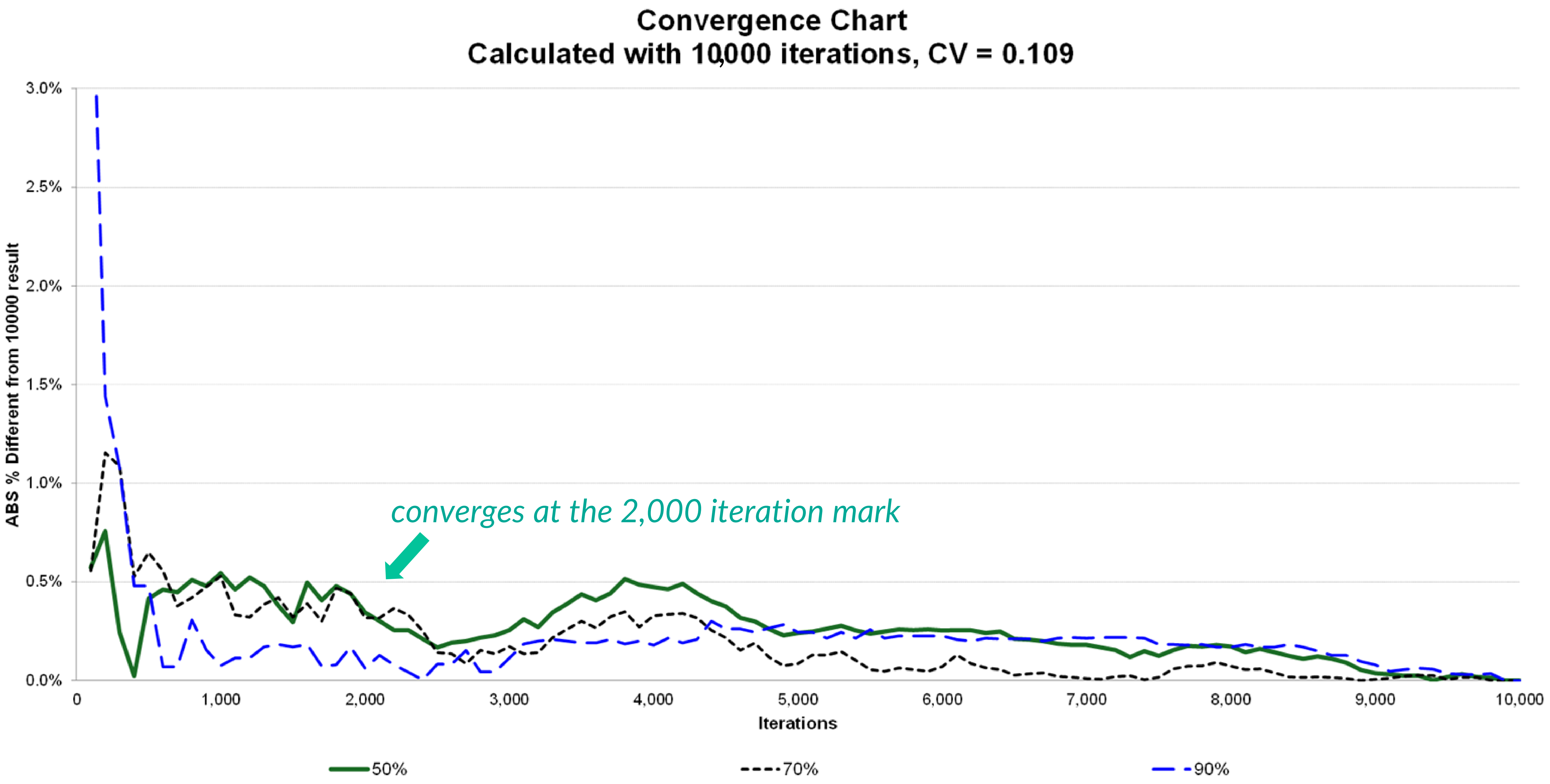
COSTS IN CY2026 $M	TOTAL
Total	**$292,436.49**
Transportation System	$14,196.89
Surface Habitat & Infrastructure System	$56,102.06
Environmental & Life Support System	$6,331.05
ISRU System	$13,353.41
Crew & Human Systems	$15,654.00
Operations & Sustainment System	$166,330.13
Science & Technology System	$475.59
Program & Integration	$19,993.36

10-MARTIAN YEAR **WHOLE LIFE COSTS OVER TIME**



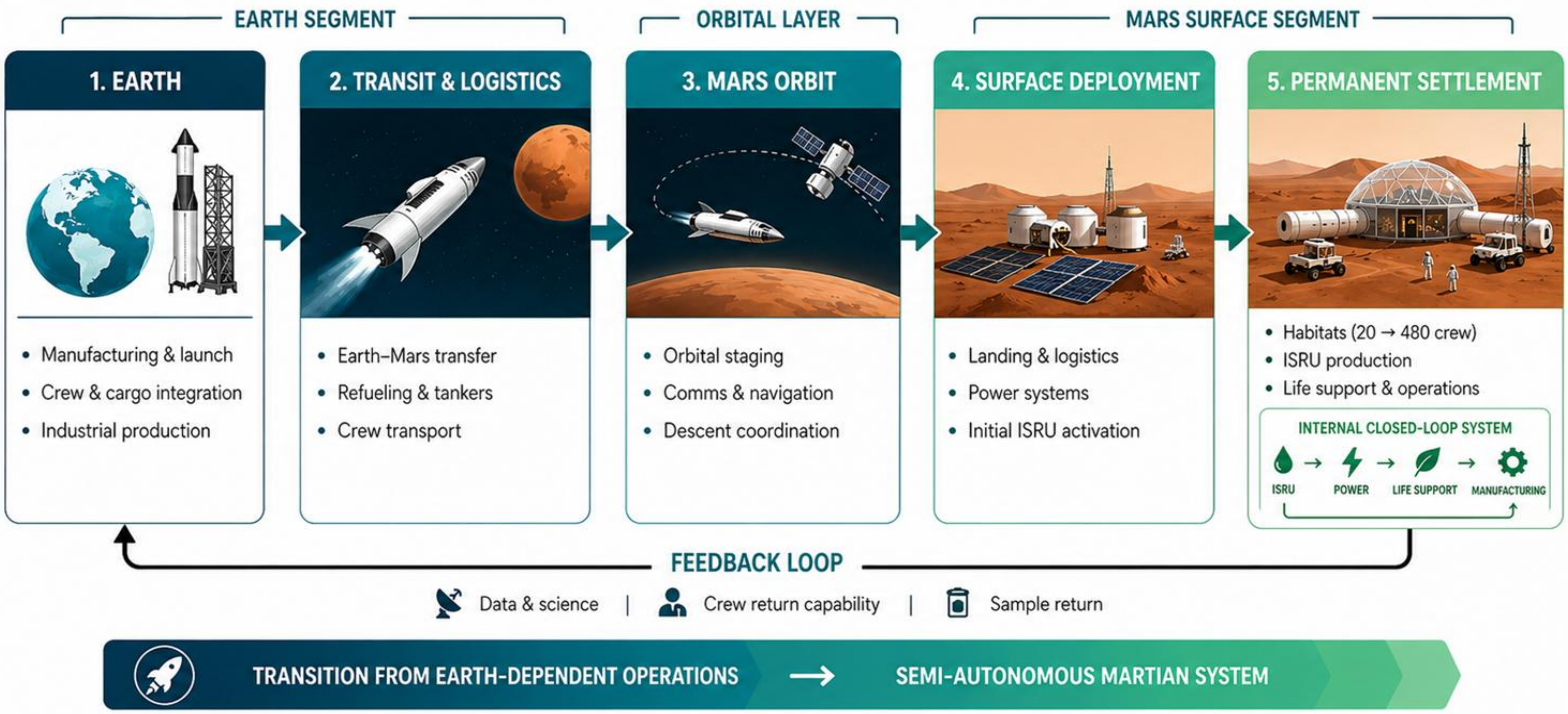
TOP 10 COST DRIVERS




Convergence Chart
Calculated with 10,000 iterations, CV = 0.109
ABS % Different from 10000 result
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Iterations
50%
70%
90%
converges at the 2,000 iteration mark

SYSTEM ARCHITECTURE

END-TO-END **ARCHITECTURE**



TRANSPORTATION

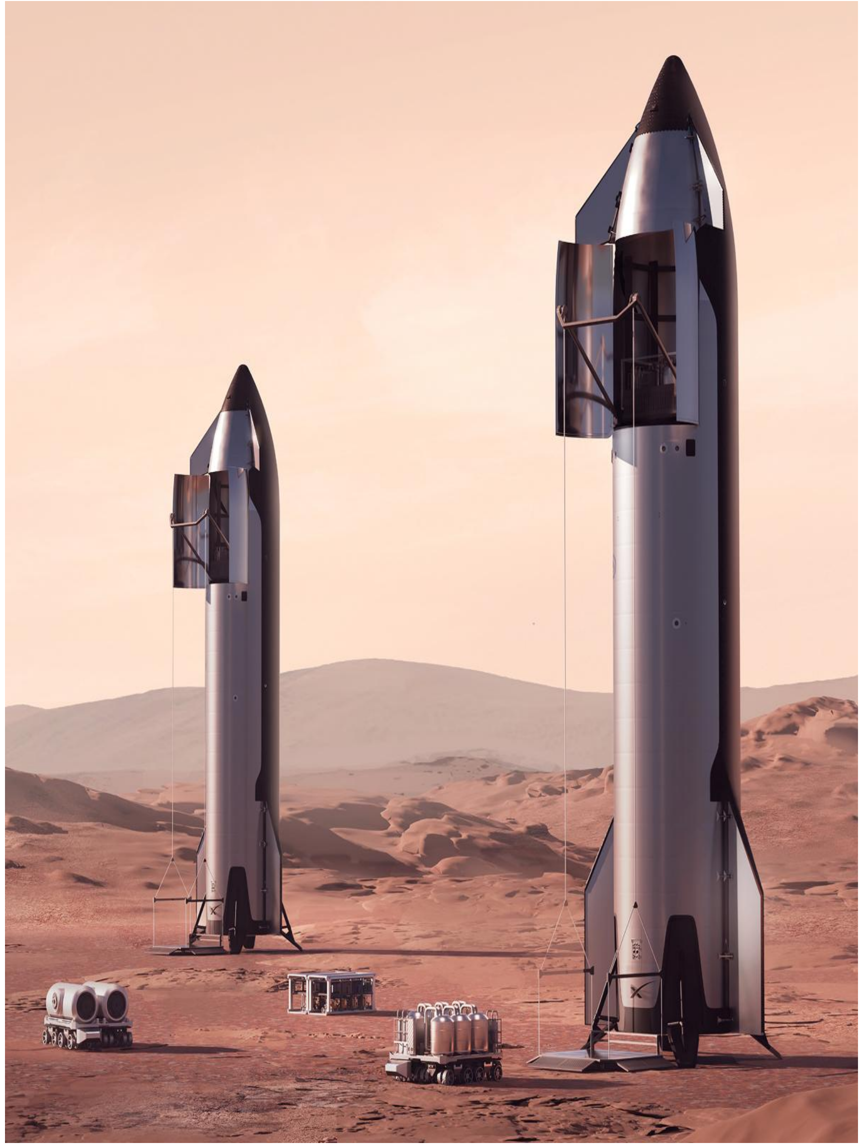
COST SUMMARY — Transportation (CY26 $M)

Launch Vehicle	$12,163M
Transit Life Support	$2,034M
WBS 1 Total	**$14,197M**

4.8% of program total

1.1 Launch Vehicle
Starship is SpaceX's reusable launch system consisting of the Super Heavy booster and Starship upper stage. Three Starship variants will be used, one for crew (Human Landing System), one for cargo, one for refueling, capable of carrying up to 100 crew or 100 tons. in-orbit refueling (10 tanker launches per launch) enables longer-distance missions to Mars. Since detailed SpaceX cost data is not publicly available, the estimate used an analogous approach based on third-party Starship full-stack cost estimates, using approximately $90 million per full stack. Refurbishment was estimated using a scaled Falcon 9 proxy, adjusted for Starship/Super Heavy's greater mass and engine count. Ground Systems & Operations were estimated using Artemis II's reported $568M/year.

1.2 Life Support (Transit)
Life support systems were estimated using an analogous approach based on proven technology currently used on the International Space Station. The estimate accounts for essential crew needs, including food, water, breathable air, and resource recycling through the Environmental Control and Life Support System (ECLSS). $175M/unit scaled by crew size.



SURFACE INFRASTRUCTURE

COST SUMMARY — Surface Infrastructure (CY26 $M)

Habitat Modules	$12,675M
Nuclear Power System	$39,297M
Communications Systems	$4,130M
WBS 2 Total	**$56,102M**

19.2% of program total

2.1 Habitat Modules

Sierra Space LIFE: inflatable 3-story habitat, $280M/unit. Supports 4 crew, including living and working space. Used cost actuals, scaled up for population size. Inputs from Sierra Space.

2.2 Nuclear Power System

Analogous to a terrestrial nuclear plant. 1,000,000 kWh capacity at $7,821/kW. Constructed entirely on Mars using ISRU-produced concrete and steel. Inputs from World Nuclear Association.

2.3 Communications Systems

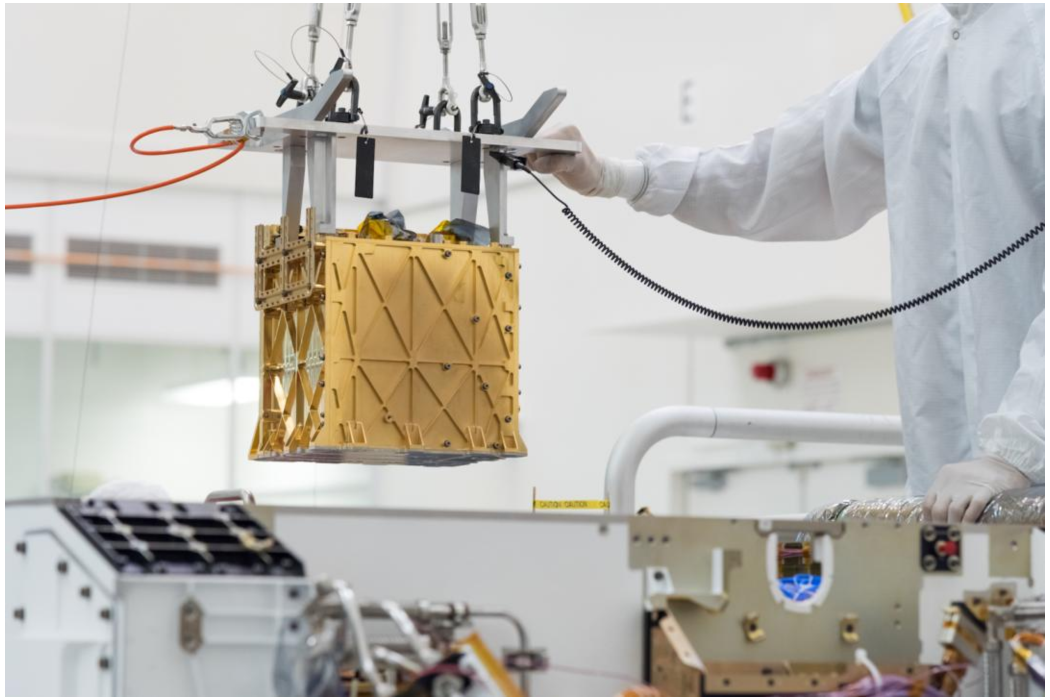
Twin LEO Comm constellations around Earth and Mars, 1 GEO PNT satellite around Mars, Mars ground systems. Satellite CER and technical data from IDA.

LIFE SUPPORT AND ISRU

COST SUMMARY — Life Support & ISRU (CY26 $M)

Air Management (MOXIE)	$2,038M
Water Systems (ECLSS)	$4,278M
Food & Waste	$14M
ISRU System	$13,353M
WBS 3+4 Total	**$19,684M**

6.7% of program total



3.1 Air Management

Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE). \$8.56M/unit, 4 units/person + 1 for redundancy. Cost actuals used and scaled for population size. Inputs from NASA.

3.2 Water Systems

Environmental Control and Life Support System (ECLSS). \$175M/unit, 1 per 10 crew. Cost actuals used and scaled for population size. Inputs from NASA.

3.3 Food Production | 3.4 Waste

Aquaponic farming: \$120K/unit, 1 per 20 people. Composting toilets + trash compactors for waste. Food from Earth during transit. Vendor quotes used from current terrestrial farms and waste management systems.

4.1 Mining / 4.2 Thermal / 4.3 Chemical / 4.4 Materials

RASSOR miner (\$500K/unit) excavates 2,700 kg regolith/day. GTF Velocys industrial plant analog (3x Mars factor) for propellant and O2 production. Enables nuclear plant construction and long-run supply chain independence.

CREW AND HUMAN SYSTEMS

COST SUMMARY — Crew & Human Systems (CY26 $M)	
Crew Training	$2,021M
Medical & Biomedical	$8,888M
Behavioral & Psych	$1,207M
EVA Systems	$3,538M
WBS 5 Total	**$15,644M**
5.3% of program total	

5.1 Crew Training
Includes pre-deployment and refresher training for EVA operations, emergency response, mission systems, and Mars environment adaptation. Initial training is estimated at $1.25M per crew member, with annual refresher training equal to 10% of initial cost. Estimates are based on NASA astronaut training and Mars analog programs.

5.2 Medical & Biomedical Systems
Includes preventative healthcare, emergency medicine, biomedical monitoring systems, pharmaceuticals, and medical facilities for long-duration Mars habitation. Annual recurring costs are estimated at $600K per crew member for preventative care, $200K for emergency medicine, and $150K for monitoring systems. Medical facilities are estimated at approximately $18,000/kg with annual maintenance equal to 10% of facility value.

5.3 Behavioral & Psychological Systems
Includes mental health support, behavioral facilities, recreational systems, and gym facilities to mitigate isolation and reduced-gravity health effects. Behavioral support costs are estimated at $150K per crew member annually, while behavioral and gym facilities are estimated at $7,500/kg and $6,000/kg respectively. Annual maintenance is assumed to equal 10% of facility cost.

5.4 EVA Systems & Operations
Includes spacesuits, life support systems, suit refurbishment, mobility systems, and EVA operational support for Mars surface activities. EVA costs are estimated at approximately $12M per crew member annually due to maintenance, redundancy, and refurbishment requirements. Estimates are based on NASA xEMU development and ISS EVA operational analogs.

OPERATIONS AND SUSTAINMENT

COST SUMMARY — O&S (CY26 $M)

Maintenance & Repair	$40,574M
Supply Chain Integration & Logistics	$12,905M
Emergency Systems	$79,670M
System Improvements	$33,181M
WBS 6 Total	**$166,330M**

56.8% of program total

6.1 Maintenance & Repair

Includes the cost of preventive maintenance, corrective maintenance, and spare parts & consumables. The cost is driven by the cost of maintenance and spare parts & consumables cost on the ISS. It is scaled to the size of the colony.

6.2 Supply Chain Integration & Logistics

Supply chain integration & logistics cost is approximately ~40% of maintenance costs. Maintenance cost is $30,474.9M. Estimates are supported by NASA ISS O&S costs.

6.3 Emergency Systems

Includes emergency detection systems, evacuation systems, and emergency communication systems. Emergency detection cost and evacuation cost on the ISS are scaled to the size of the colony. Antennas will be operating to provide communication 24/7 and personal transceivers will be used on the surface of Mars. Personal Transceivers Cost/Unit : $500 CY26$. Deep Space Network Cost: $1,057/hr and will run continuously.

6.4 System Improvements

Includes hardware modifications and software maintenance & cybersecurity. Hardware cost on the ISS is scaled to the size of the colony. Total cost of software maintenance is 10% of maintenance cost. Maintenance cost is $30,474.9M.

SCIENCE AND TECHNOLOGY SYSTEMS

COST SUMMARY — Science & Technology (CY26 $M)

Research	$71M
Machines	$404M
WBS 7 Total	**$476M**

0.16% of program total

7.1 Scientific Research

Scientific research supports the colony's mission by collecting and analyzing data on Martian geology, atmosphere, climate, seismic activity, and the potential for past or present life. Laboratory equipment was estimated using vendor/catalog pricing, with a total cost of $2.5M. Mars-rated field instruments, including the seismometer at $8.4M/unit and weather station at $26M/unit, were estimated by analogy to monitoring systems used on past Mars missions.

7.2 Machines

Machines provide the physical capability to establish initial habitat infrastructure, explore, build, repair, and operate on Mars with less dependence on Earth. Vehicles, drones, robots, data systems, and manufacturing tools expand the colony's reach, automate dangerous tasks, support infrastructure development, and enable on-site production and repair. Costs were estimated using analogous past space missions, current autonomous technology, and commercial advanced manufacturing systems adjusted for Mars surface operations. Autonomous systems total $355M, while advanced manufacturing totals $47.9M.

PROGRAM AND INTEGRATION

COST SUMMARY — O&S (CY26 $M)	
Safety & Assurance	$3,329M
Verification & Validation	$6,505M
Expansion Planning	$10,159M
WBS 8 Total	**$19,993M**
6.8% of program total	

8.1 Safety & Assurance
The purpose of safety & assurance is to estimate the cost of risk and mission safety of sending humans to Mars and sustaining a human settlement. An analogous contract from NASA worth approximately $494 million was used to estimate this cost.

8.2 Verification & Validation
V&V costs become cheaper as the software matures, largely because maturity allows for the shift from expensive manual testing to automated, standardized processes. Assume 10% of O&S costs to maintain V&V. Estimates are supported by NASA ISS O&S costs.

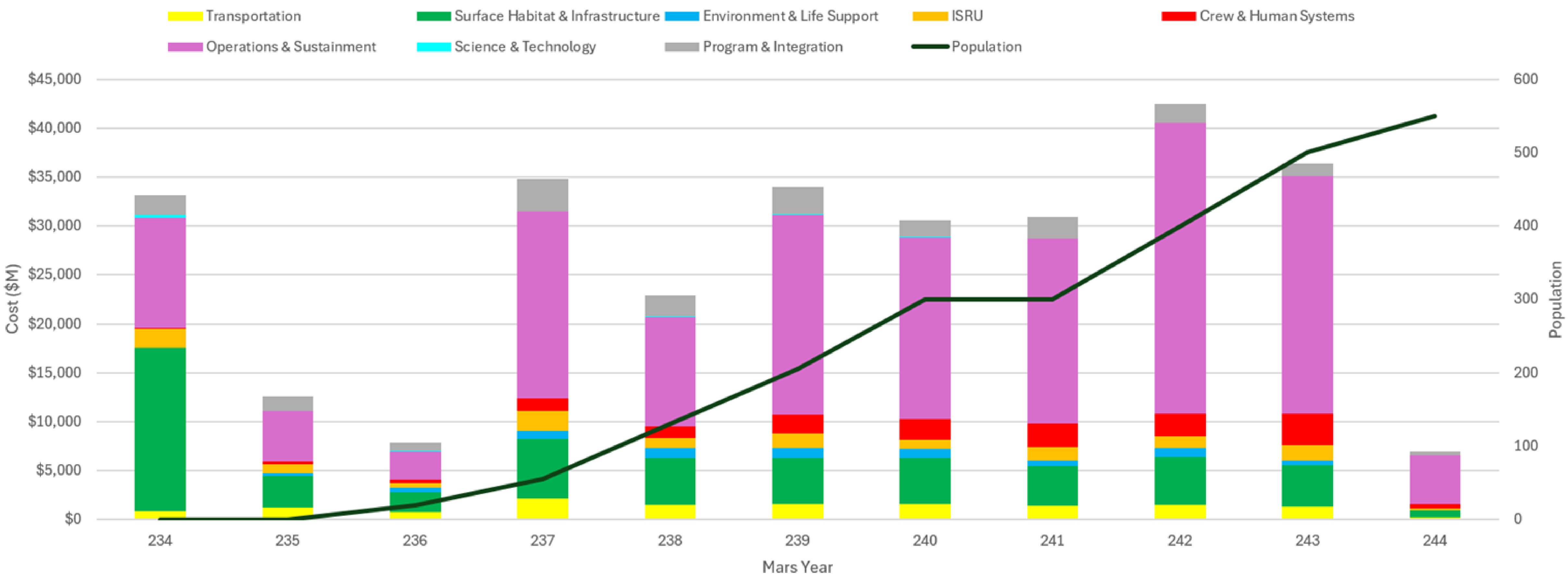
8.3 Expansion Planning
Expansion planning involves complex logistics to deal with the harsh, low-pressure environment. The middle 10 years will be crucial for development as more people start to arrive on Mars
Y1-5: $300M (Foundation), Y6-15: $600M (Growth), Y16-20: $400M (Maturity).

TOTAL COSTS

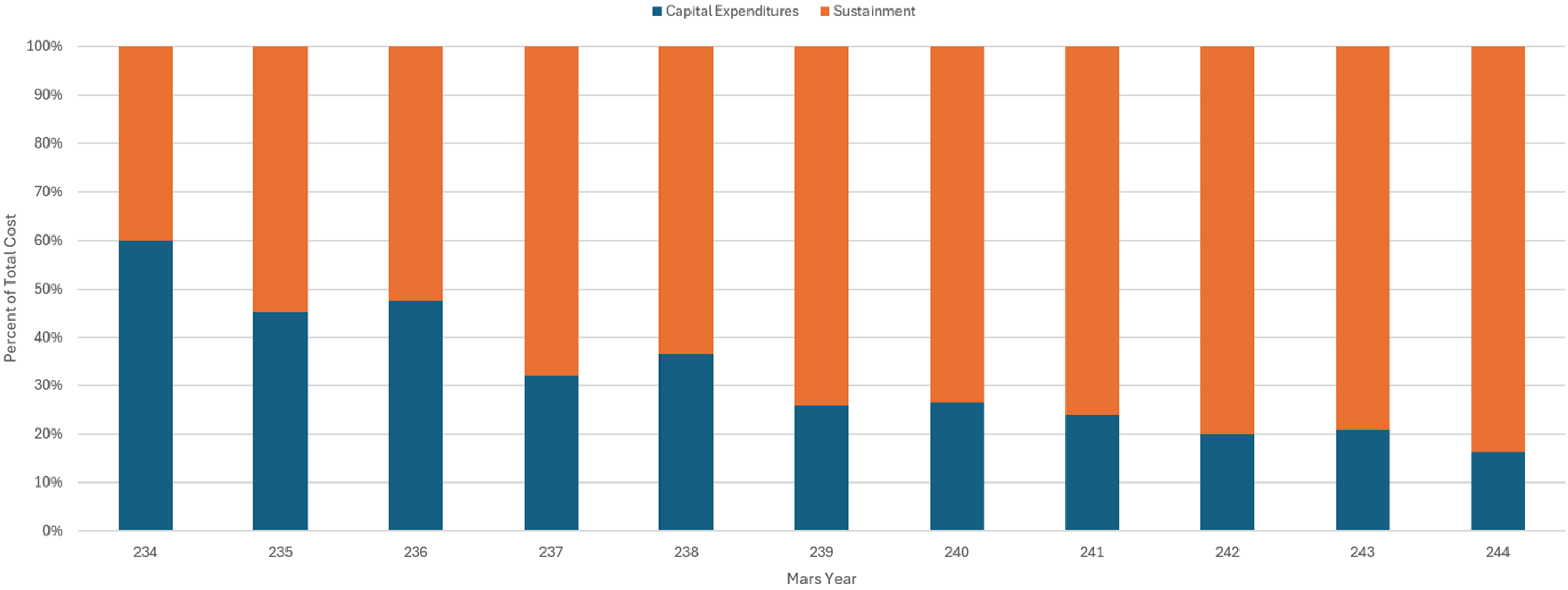
10 MARTIAN-YEAR
WHOLE LIFE COST

Total Costs in CY26 $M	Total	234	235	236	237	238	239	240	241	242	243	244
Total	$292,436	$33,106	$12,565	$7,874	$34,815	$22,864	$33,937	$30,576	$30,935	$42,423	$36,390	$6,951
Transportation System	$14,197	$880	$1,255	$741	$2,156	$1,517	$1,562	$1,570	$1,376	$1,538	$1,354	$249
Surface Habitat & Infrastructure System	$56,102	$16,645	$3,238	$2,044	$6,065	$4,799	$4,723	$4,748	$4,095	$4,889	$4,180	$676
Environmental & Life Support System	$6,331	$0	$236	$480	$822	$974	$1,004	$879	$551	$858	$527	$0
ISRU System	$13,353	$1,993	$925	$459	$2,097	$1,040	$1,517	$926	$1,400	$1,210	$1,573	$213
Crew & Human Systems	$15,654	$93	$264	$334	$1,239	$1,188	$1,909	$2,187	$2,415	$2,330	$3,235	$460
Operations & Sustainment System	$166,330	$11,222	$5,140	$2,932	$19,109	$11,203	$20,436	$18,543	$18,878	$29,664	$24,194	$5,010
Science & Technology System	$476	$295	$21	$15	$24	$21	$24	$25	$15	$23	$13	$0
Program & Integration	$19,993	$1,978	$1,486	$870	$3,302	$2,122	$2,763	$1,698	$2,205	$1,912	$1,315	$343

TOTAL COST vs. POPULATION



CAPITAL EXPENDITURES vs. SUSTAINMENT



RISK & UNCERTAINTY

KEY **UNCERTAINTIES**

BIRTH RATE

- Reproductive viability is a key uncertainty for long-term colonization. Estimated birth rates are expected to range between 5% and 15%.

DEATH RATE

- Mortality rates in early stages are expected to be highly unpredictable. Estimated death rates range between 5% and 25%.

EMERGENCY SYSTEMS ON MARS

- The reliability and performance of emergency systems on Mars are critical for crew safety. Uncertainties include system effectiveness, environmental challenges, and response times.

- Emergency Detection System
- Evacuation Systems
- Emergency Communication Systems

LAUNCH FREQUENCY

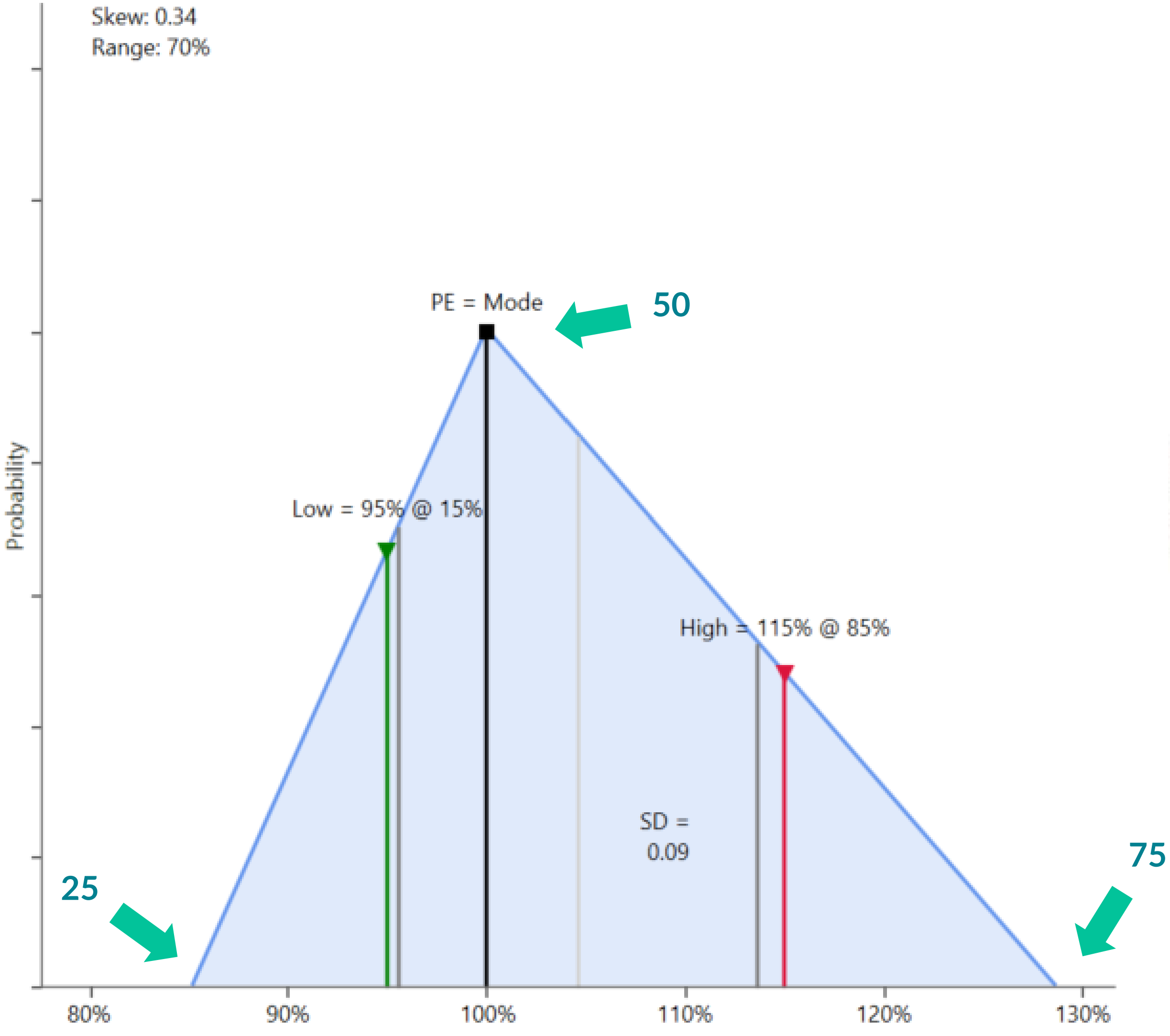
- Launch opportunities occur approximately every 26 months when Earth and Mars are at optimal alignment. However, technical issues or adverse weather conditions may delay launch windows and contribute to schedule overruns.

NUCLEAR POWER SYSTEM RELIABILITY

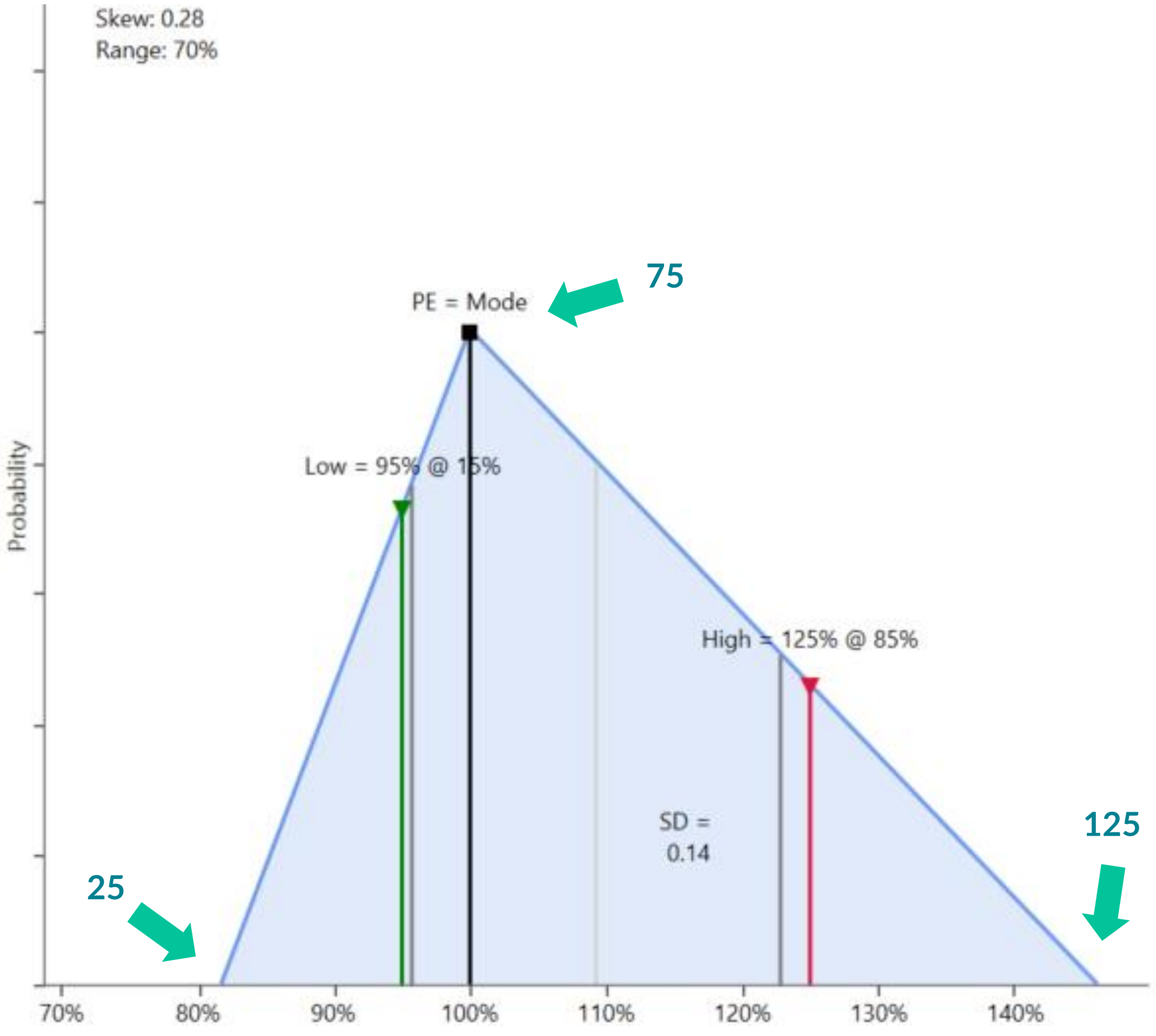
- Nuclear surface power systems introduce uncertainty in long-term settlement operations due to reactor lifespan, maintenance demands, shielding requirements, and potential component failures. Delays in deployment or reduced power output could impact ISRU, habitat operations, and overall settlement growth.

TRIANGLE DISTRIBUTION ON POPULATION

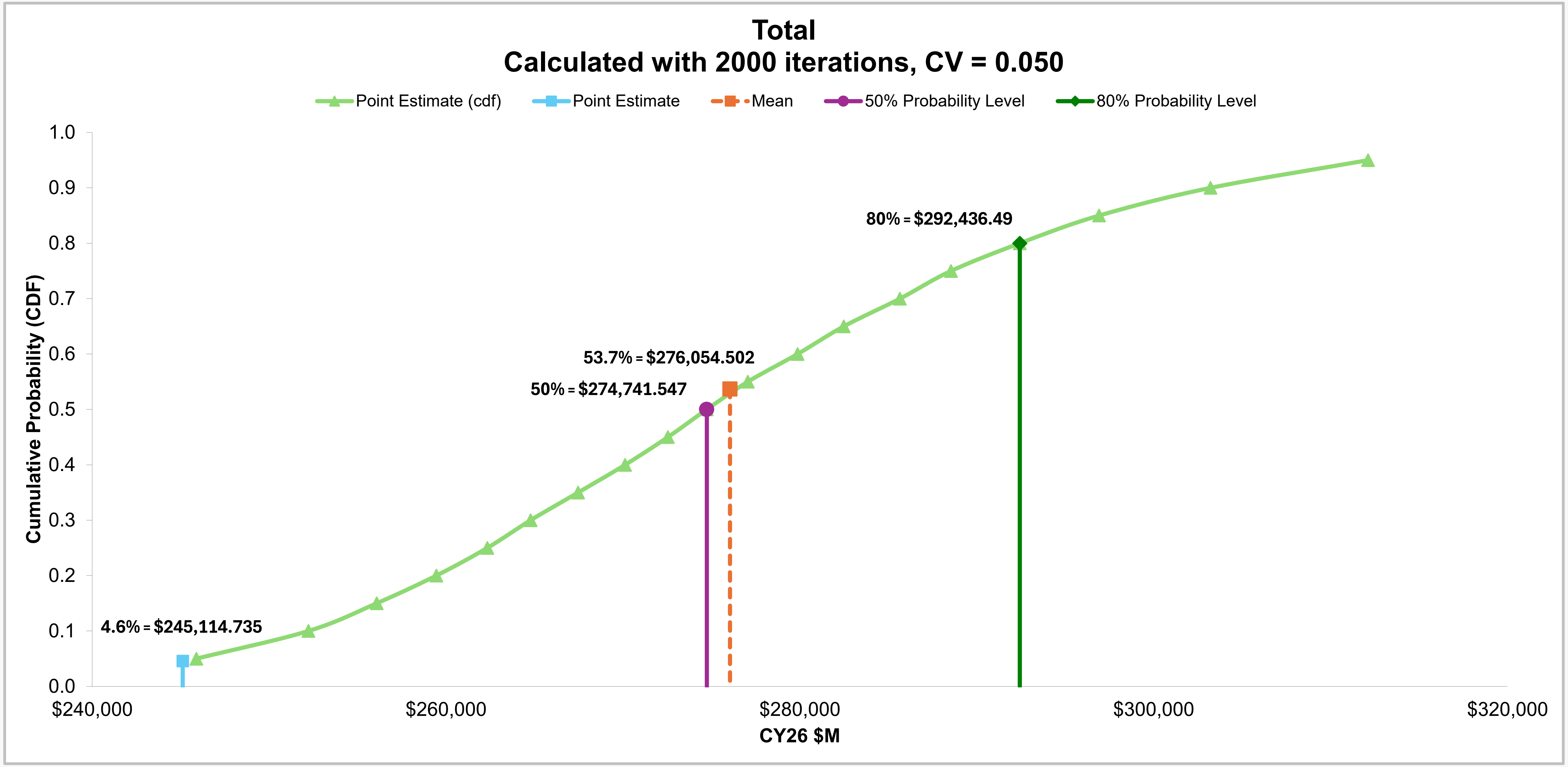
BIRTH RATE



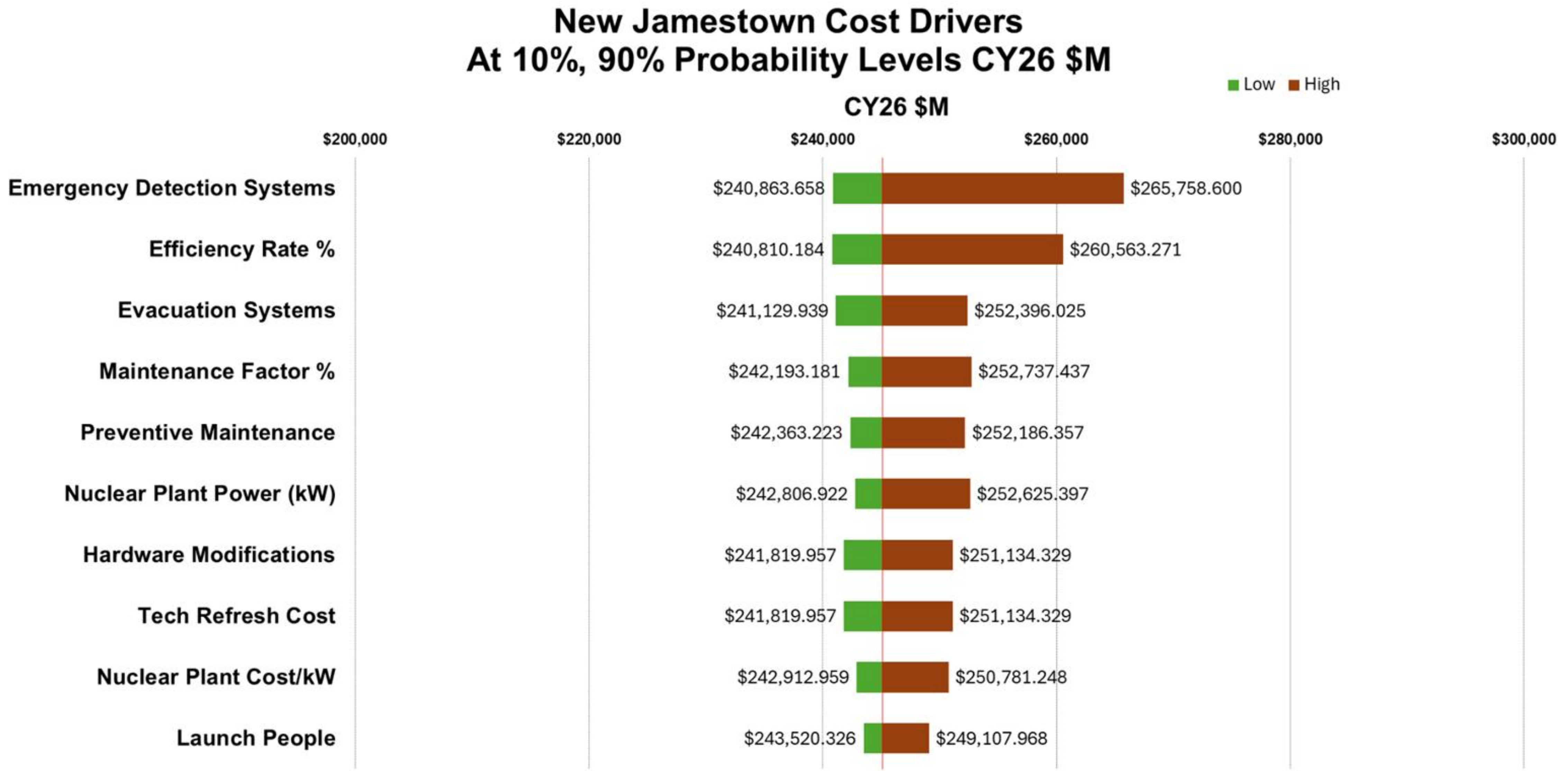
DEATH RATE



SENSITIVITY ANALYSIS



SENSITIVITY **ANALYSIS**



WHERE DO WE GO NEXT?

IF WE COULD **DO THIS AGAIN...**

Time

- The project scope covered a wide range of major systems and cost areas.
- Each major WBS section had enough depth to support its own detailed estimate.
- To manage the workload, team members had to specialize in specific WBS areas.
- With more time, we could have had less isolated specialization and more interaction across sections.

Communication

- The team worked across four different states and multiple time zones; different work schedules and availability made coordination more difficult.
- The separation added challenges when integrating separate sections into one estimate.
- More frequent coordination check-ins or working together in the same location would make collaboration much easier.

Information

- Reliable cost data was limited for many commercial, future, or experimental systems.
- SpaceX cost data is not publicly available, experimental technologies often required rough proxies, and nuclear-related research was difficult due to limited public information.
- This reinforced the importance of source quality and using the strongest available data when building an estimate.

CONTINUED INTEREST / FOLLOW UP RESEARCH

Habitation & Life Support

Refine habitat configurations and life support system costs as new designs and performance data become available.

ISRU & Resource Utilization

Improve cost and performance models for ISRU technologies as field testing and operational data mature.

Nuclear Power Systems

Further evaluate nuclear power options, including safety, logistics, regulatory considerations, and long-term reliability.

Transportation & Launch Systems

Monitor evolving launch vehicle capabilities and costs to update transportation assumptions and cadence.

Economic & Market Conditions

Continuously assess how inflation, commodity prices, and market developments impact long-term settlement costs.

APPLIED AI

AI is expected to play a major role in Mars operations, from autonomous robotics to infrastructure setup and resource management. Likewise, throughout this estimate LLMs were used to support brainstorming, outlining, research, and estimate development. However, outputs were reviewed and verified against referenceable sources before being used in the final estimate.

Outlining & Brainstorming

- Supported early WBS outlining
- Used to brainstorm WBS categories

Research Support

- Used as a subject matter expert for unfamiliar scientific fields
- Recommended equipment that would be needed for the science mission

Rates & Estimate Support

- Helped develop factor and efficiency rates on the O&S section and Program & integration Section

Visuals & Presentation Support

- Used to create diagrams, charts, icons, and other visuals to enhance clarity and communication in this PowerPoint

HOURS **BY ACTIVITY**

Dates	Phase	Tasks	Individual Meeting Hours	Individual Hours Worked	Total Team Hours
4/13-4/14	Planning / Kickoff	Introductions & Discussion	1	0	4
4/15-4/17	Prompt Review	Planning & Task Assignment	1	0	4
4/17-4/27	Cost Estimate Development	Research & WBS Development	2	10	48
4/27-4/30	Cost Estimate Review	WBS Review & Adjustments	2	5	28
5/1-5/5	Brief Development	Slides and ACEIT Model	2	10	48
5/6-5/10	Practice	Practice Briefings & Refinements	2	5	28
		Total:	10	30	160

RESOURCES

Where It Was Found	Title	Link
NASA	Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)	https://www.nasa.gov/space-technology-mission-directorate/tdm/mars-oxygen-in-situ-resource-utilization-experiment-moxie/
NASA	ISS Water Recovery Milestone	https://www.nasa.gov/missions/station/iss-research/nasa-achieves-water-recovery-milestone-on-international-space-station/
NASA	Commercial and Marketing Pricing Policy	https://www.nasa.gov/humans-in-space/commercial-and-marketing-pricing-policy/
NASA	NASA Cost Estimating Handbook	https://www.nasa.gov/ocfo/ppc-corner/nasa-cost-estimating-handbook-ceh/
NASA	NASA Awards Safety & Mission Assurance Contract	https://www.nasa.gov/news-release/nasa-awards-safety-mission-assurance-engineering-contract-2/
NASA Science	Perseverance Rover Science Instruments	https://science.nasa.gov/mission/mars-2020-perseverance/science-instruments/#sensors
NASA JPL	Where Should Future Astronauts Land on Mars?	https://www.nasa.gov/centers-and-facilities/jpl/where-should-future-astronauts-land-on-mars-follow-the-water/
NASA OIG	NASA's Mars 2020 Rover Mission Audit Report (IG-17-009)	https://oig.nasa.gov/wp-content/uploads/2024/02/IG-17-009.pdf
NASA OIG	NASA Management / Oversight Audit (IG-22-005)	https://oig.nasa.gov/wp-content/uploads/2024/02/IG-22-005.pdf
NASA OIG	NASA Inspector General Report (IG-14-031)	https://oig.nasa.gov/office-of-inspector-general-oig/ig-14-031/
NASA NTRS	ECLSS Does Not Exist in a Vacuum	https://ntrs.nasa.gov/api/citations/20205001088/downloads/ECLSS%20Does%20Not%20Exist%20in%20a%20Vacuum%20v9%20(unlinked%20citations).pdf
NASA NTRS	NASA Technical Report (20190027563)	https://ntrs.nasa.gov/api/citations/20190027563/downloads/20190027563.pdf
NASA NTRS	ICES 2023 Knox Paper	https://ntrs.nasa.gov/api/citations/20230003258/downloads/ICES%202023%20116%20Knox%20paper%2006212 3.pdf
NASA NTRS	NASA Technical Report (20200000973)	https://ntrs.nasa.gov/api/citations/20200000973/downloads/20200000973.pdf
NASA NTRS	NASA Technical Report (20080012561)	https://ntrs.nasa.gov/api/citations/20080012561/downloads/20080012561.pdf
NASA Explorers	NASA New Start Inflation Index FY19	https://explorers.larc.nasa.gov/2019APSMEX/MO/pdf_files/2018_nasa_new_start_inflation_index_for_fy19_use_final_dist.pdf
NASA Spinoff	Mission Home	https://spinoff.nasa.gov/Mission_Home
PubMed Central (NIH)	Human Reproduction and Space Colonization Research	https://pmc.ncbi.nlm.nih.gov/articles/PMC10884476/
Texas Tech University	Commercial ECLSS for Deep Space Missions	https://ttu-ir.tdl.org/server/api/core/bitstreams/4da153ec-f412-454e-8e4a-e57f56859cca/content
JSTOR	Space Systems / Cost Analysis Resource	https://www.jstor.org/stable/resrep22888.12?seq=6
World Nuclear Association	Economics of Nuclear Power	https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power#capital-costs
UC Berkeley FHR	Material Input for Nuclear Systems	https://fhr.nuc.berkeley.edu/wp-content/uploads/2014/10/05-001-A_Material_input.pdf
National Museum of the USAF	Space Foods Fact Sheet	https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/197687/space-foods/
Institute for Defense Analyses	Schedule and Cost Estimating Analysis for LEO Satellite Constellations	https://www.ida.org/-/media/feature/publications/s/sc/schedule-and-cost-estimating-analysis-for-leo-satellite-constellations/d-33436.ashx

RESOURCES continued...

Where It Was Found	Title	Link
Defense News	Space Force Targeting More Affordable GPS Satellites	https://www.defensenews.com/space/2024/11/15/space-force-targeting-more-affordable-gps-satellites/
Sierra Space	LIFE Space Habitat	https://www.sierraspace.com/commercial-space-stations/life-space-habitat/
Google Docs	Team Research / Working Document	https://docs.google.com/document/d/1xHdi72ilspbs1B3x6-bAZJsUVgLdUygZ0_ogCa_UcVk/edit?tab=t.0
U.S. Energy Information Administration	Energy Cost / Market Analysis Article	https://www.eia.gov/todayinenergy/detail.php?id=67004
FAA	SpaceX Starship Environmental Impact Statement	https://www.faa.gov/space/stakeholder_engagement/spacex_starship_ksc/SpaceX-SSH-LC-39A-Final-EIS-Volume-II-AppB2-Essential-Fish-Habitat-Assessment-NMFS.pdf
ScienceDirect	Space Systems / Engineering Research Paper	https://www.sciencedirect.com/science/article/abs/pii/S1750583624000136
ScienceDirect	Space Transportation Economics Study	https://www.sciencedirect.com/science/article/abs/pii/S0094576512003761
Eric Shear Space	Life Support for Private Space Stations	https://www.ericshear.space/life-support-for-private-space-stations/
Payload	The Starship Report	https://pro.payloadspace.com/the-starship-report/
Science Interactive	Hidden Costs of On-Campus Labs	https://www.scienceinteractive.com/blog/2025/the-hidden-costs-of-on-campus-labs/
PocketGuard	Artemis II Budget Breakdown	https://pocketguard.com/blog/artemis-ii-budget/
Constellation Response	RM-1 Ruggedized MANET Radio	https://constellationresponse.com/products/rm-1-ruggedized-manet-radio

TECOLOTE
RESEARCH

THANK YOU

for listening

QUESTIONS?

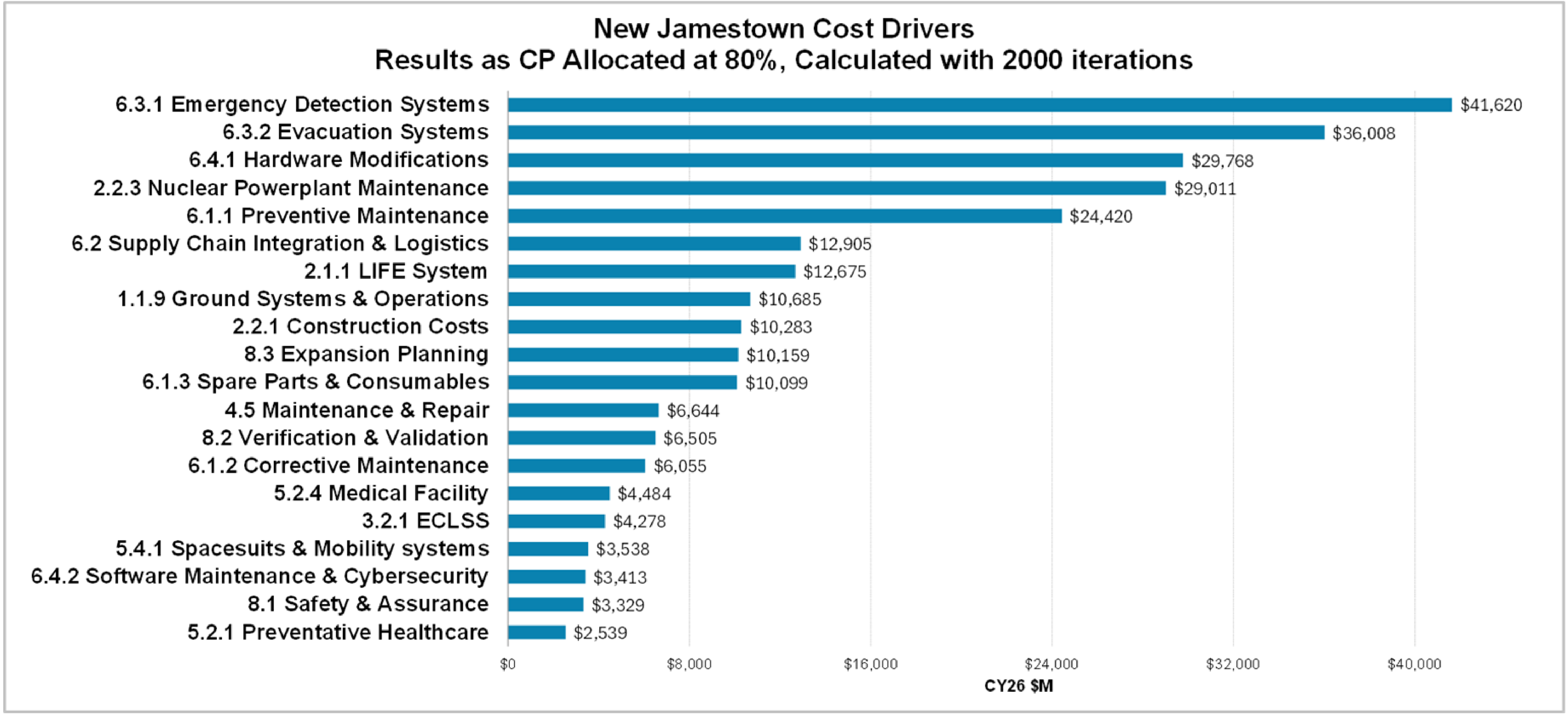
BACKUP

SUPPORTING GRAPHS

WBS

Code	WBS Description
1	Transportation System
1.1	Launch Vehicle
1.1.1	Super Heavy Booster
1.1.2	Super Heavy Booster Propellent
1.1.3	Super Heavy Booster Refurbishment
1.1.4	Cargo Starship
1.1.5	HLS Starship
1.1.6	Tanker Starship
1.1.7	Starship Booster Propellent
1.1.8	Starship Refurbishment
1.1.9	Ground Systems & Operations
1.2	Life Support
1.2.1	Food
1.2.2	ECLSS
1.2.3	Oxygen
1.2.4	Crew Provisions
2	Surface Habitat & Infrastructure System
2.1	Habitat Modules
2.1.1	LIFE System
2.2	Nuclear Power System
2.2.1	Construction Costs
2.2.2	Fuel (Uranium-235)
2.2.3	Nuclear Powerplant Maintenance
2.3	Communications Systems
2.3.1	Comm Satellites
2.3.1.1	Sat around Earth
2.3.1.2	Sat around Mars
2.3.2	PNT Satellite around Mars
2.3.3	Mars Ground Systems
3	Environmental & Life Support System
3.1	Air Management
3.1.1	MOXIE
3.2	Water Systems
3.2.1	ECLSS
3.3	Food Production
3.3.1	Food from Earth
3.3.2	Aquaponic Farm
3.3.2.1	Farm Setup
3.3.2.2	Fish Eggs
3.3.2.3	Grow Lights
3.3.2.4	Seeds
3.3.2.5	Duckweed
3.4	Waste Management
3.4.1	Human Waste
3.4.2	Consumable Trash
4	ISRU System
4.1	Mining Unit
4.1.1	RASSOR 2.0
4.2	Thermal Processing Unit
4.2.1	Water Electrolysis
4.2.2	Filtration & purification
4.2.3	Storage tanks
4.2.4	Distribution piping
4.3	Chemical Processing Unit
4.3.1	Sabatier reactor
4.3.2	Methane liquefaction
4.3.3	LOX/LCH4 storage
4.3.4	Propellant transfer
4.4	Materials Refining Unit
4.4.1	Crushing & grinding
4.4.2	Iron & steel production via MRE
4.4.3	Construction material output
4.5	Maintenance & Repair
5	Crew & Human Systems
5.1	Crew Training
5.1.1	Pre-Deployment Training
5.1.2	Annual Training
5.2	Medical & Biomedical Systems
5.2.1	Preventative Healthcare
5.2.2	Emergency Medicine
5.2.3	Biomedical Monitoring Systems
5.2.4	Medical Facility
5.3	Behavioral & Psychological Systems
5.3.1	Crew Mental Health Support
5.3.2	Behavioral Health facility
5.3.3	Gym/Physical Health facility
5.4	EVA Systems & Operations
5.4.1	Spacesuits & Mobility systems
6	Operations & Sustainment System
6.1	Maintenance & Repair
6.1.1	Preventive Maintenance
6.1.2	Corrective Maintenance
6.1.3	Spare Parts & Consumables
6.2	Supply Chain Integration & Logistics
6.3	Emergency Systems
6.3.1	Emergency Detection Systems
6.3.2	Evacuation Systems
6.3.3	Emergency Communication Systems
6.3.3.1	Surface Comms
6.3.3.2	Earth-to-Mars Comms
6.4	System Improvements
6.4.1	Hardware Modifications
6.4.2	Software Maintenance & Cybersecurity
7	Science & Technology System
7.1	Research
7.1.1	Laboratory Equipment
7.1.2	Seismometer
7.1.3	Weather Station
7.2	Machines
7.2.1	Space Exploration Vehicle
7.2.2	Drones
7.2.3	Robots
7.2.4	Internet/Data/AI
7.2.5	Advanced Manufacturing
7.2.6	Regolith Printer
8	Program & Integration
8.1	Safety & Assurance
8.2	Verification & Validation
8.3	Expansion Planning

TOP 20 COST DRIVERS



10 MARTIAN-YEAR
WHOLE LIFE COST

Total Costs in CY26 $M	Total	234	235	236	237	238	239	240	241	242	243	244
Total	$292,436	$33,106	$12,565	$7,874	$34,815	$22,864	$33,937	$30,576	$30,935	$42,423	$36,390	$6,951
Transportation System	$14,197	$880	$1,255	$741	$2,156	$1,517	$1,562	$1,570	$1,376	$1,538	$1,354	$249
Launch Vehicle	$12,163	$880	$1,167	$562	$1,855	$1,251	$1,269	$1,269	$1,191	$1,271	$1,199	$249
Life Support	$2,034	$0	$88	$180	$301	$266	$292	$301	$185	$267	$155	$0
Surface Habitat & Infrastructure System	$56,102	$16,645	$3,238	$2,044	$6,065	$4,799	$4,723	$4,748	$4,095	$4,889	$4,180	$676
Habitat Modules	$12,675	$0	$338	$686	$1,622	$1,899	$1,823	$1,848	$1,194	$1,989	$1,275	$0
Nuclear Power System	$39,297	$12,515	$2,900	$1,358	$4,443	$2,900	$2,900	$2,900	$2,900	$2,900	$2,905	$676
Communications Systems	$4,130	$4,130	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Environmental & Life Support System	$6,331	$0	$236	$480	$822	$974	$1,004	$879	$551	$858	$527	$0
Air Management	$2,038	$0	$99	$202	$340	$415	$337	$287	$115	$157	$86	$0
Water Systems	$4,278	$0	$137	$277	$481	$557	$666	$589	$434	$699	$439	$0
Food Production	$14	$0	$0	$0	$1	$2	$2	$3	$2	$2	$1	$0
Waste Management	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
ISRU System	$13,353	$1,993	$925	$459	$2,097	$1,040	$1,517	$926	$1,400	$1,210	$1,573	$213
Mining Unit	$38	$10	$2	$3	$5	$4	$4	$4	$2	$1	$3	$0
Thermal Processing Unit	$1,666	$454	$55	$32	$255	$84	$203	$55	$174	$127	$216	$11
Chemical Processing Unit	$3,004	$817	$99	$58	$458	$151	$365	$99	$314	$228	$391	$23
Materials Refining Unit	$2,002	$545	$66	$38	$306	$100	$244	$66	$209	$152	$261	$15
Maintenance & Repair	$6,644	$168	$703	$328	$1,074	$701	$701	$701	$701	$701	$702	$163
Crew & Human Systems	$15,654	$93	$264	$334	$1,239	$1,188	$1,909	$2,187	$2,415	$2,330	$3,235	$460
Crew Training	$2,021	$18	$41	$29	$187	$173	$272	$319	$335	$323	$268	$57
Medical & Biomedical Systems	$8,888	$0	$97	$203	$477	$549	$1,025	$1,217	$1,438	$1,380	$2,247	$254
Behavioral & Psychological Systems	$1,207	$0	$14	$30	$67	$77	$135	$163	$193	$191	$298	$38
EVA Systems & Operations	$3,538	$75	$111	$72	$507	$388	$478	$488	$449	$436	$421	$111
Operations & Sustainment System	$166,330	$11,222	$5,140	$2,932	$19,109	$11,203	$20,436	$18,543	$18,878	$29,664	$24,194	$5,010
Maintenance & Repair	$40,574	$2,353	$3,068	$1,473	$5,027	$3,679	$4,036	$4,465	$4,658	$5,111	$5,455	$1,248
Supply Chain Integration & Logistics	$12,905	$1,004	$1,302	$609	$1,995	$1,302	$1,302	$1,302	$1,302	$1,302	$1,248	$237
Emergency Systems	$79,670	$157	$426	$688	$4,118	$5,878	$8,427	$11,315	$12,573	$15,464	$17,161	$3,462
System Improvements	$33,181	$7,708	$344	$161	$7,970	$344	$6,670	$1,461	$344	$7,786	$330	$63
Science & Technology System	$476	$295	$21	$15	$24	$21	$24	$25	$15	$23	$13	$0
Research	$71	$69	$0	$1	$0	$0	$0	$0	$0	$0	$0	$0
Machines	$404	$226	$21	$14	$24	$21	$23	$24	$15	$23	$13	$0
Program & Integration	$19,993	$1,978	$1,486	$870	$3,302	$2,122	$2,763	$1,698	$2,205	$1,912	$1,315	$343
Safety & Assurance	$3,329	$832	$0	$175	$658	$0	$832	$0	$508	$325	$0	$0
Verification & Validation	$6,505	$655	$849	$397	$1,300	$849	$657	$424	$424	$424	$425	$99
Expansion Planning	$10,159	$491	$637	$298	$1,344	$1,273	$1,273	$1,273	$1,273	$1,163	$890	$244

CAPITAL EXPENDITURES vs. SUSTAINMENT

Capital Expenditure Costs in CY26 $M												
WBS	Total	234	235	236	237	238	239	240	241	242	243	244
Transportation System	$14,197	$880	$1,255	$741	$2,156	$1,517	$1,562	$1,570	$1,376	$1,538	$1,354	$249
Surface Habitat & Infrastructure System	$56,102	$16,645	$3,238	$2,044	$6,065	$4,799	$4,723	$4,748	$4,095	$4,889	$4,180	$676
Environmental & Life Support System	$6,331	$0	$236	$480	$822	$974	$1,004	$879	$551	$858	$527	$0
ISRU System	$13,353	$1,993	$925	$459	$2,097	$1,040	$1,517	$926	$1,400	$1,210	$1,573	$213
Science & Technology System	$476	$295	$21	$15	$24	$21	$24	$25	$15	$23	$13	$0
Sum	$90,459	$19,812	$5,676	$3,739	$11,165	$8,351	$8,829	$8,148	$7,436	$8,517	$7,647	$1,138

Sustainment Costs in CY26 $M												
WBS	Total	234	235	236	237	238	239	240	241	242	243	244
Crew & Human Systems	$15,654	$93	$264	$334	$1,239	$1,188	$1,909	$2,187	$2,415	$2,330	$3,235	$460
Operations & Sustainment System	$166,330	$11,222	$5,140	$2,932	$19,109	$11,203	$20,436	$18,543	$18,878	$29,664	$24,194	$5,010
Program & Integration	$19,993	$1,978	$1,486	$870	$3,302	$2,122	$2,763	$1,698	$2,205	$1,912	$1,315	$343
Sum	$201,977	$13,294	$6,889	$4,136	$23,650	$14,514	$25,107	$22,428	$23,498	$33,906	$28,743	$5,812

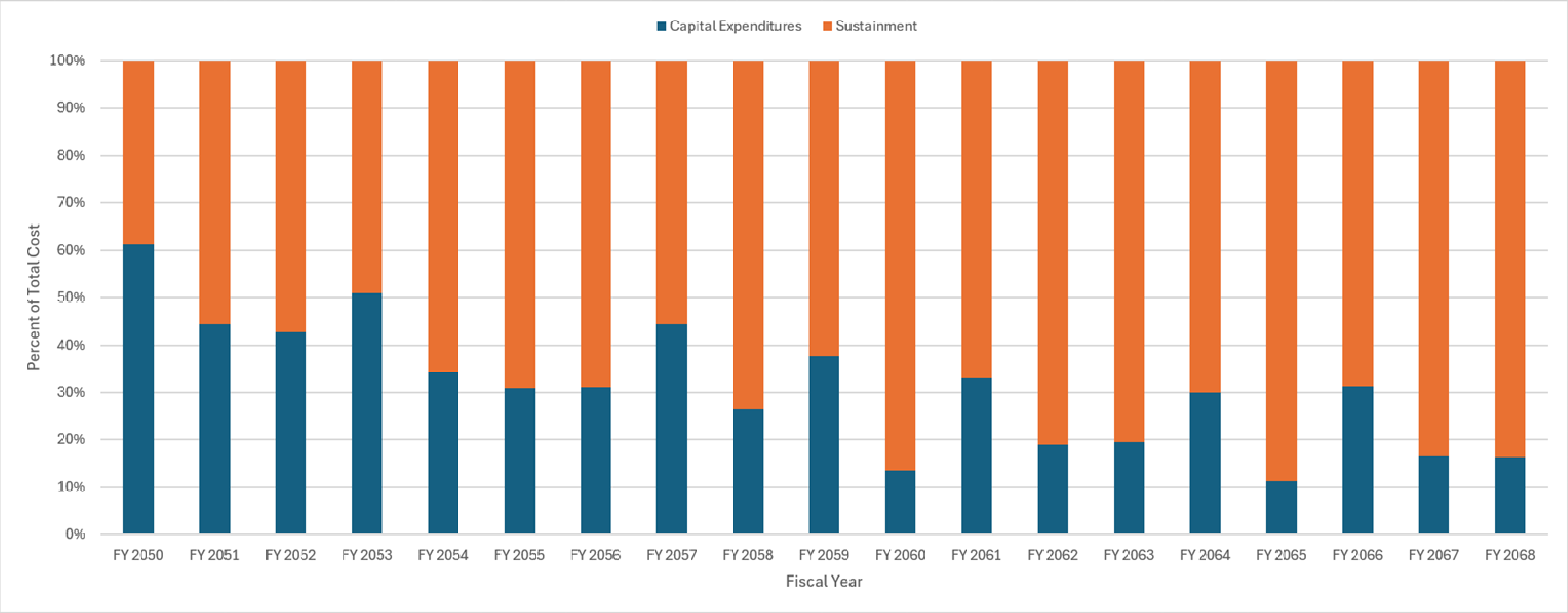
CAPITAL EXPENDITURES vs. SUSTAINMENT

EARTH YEARS

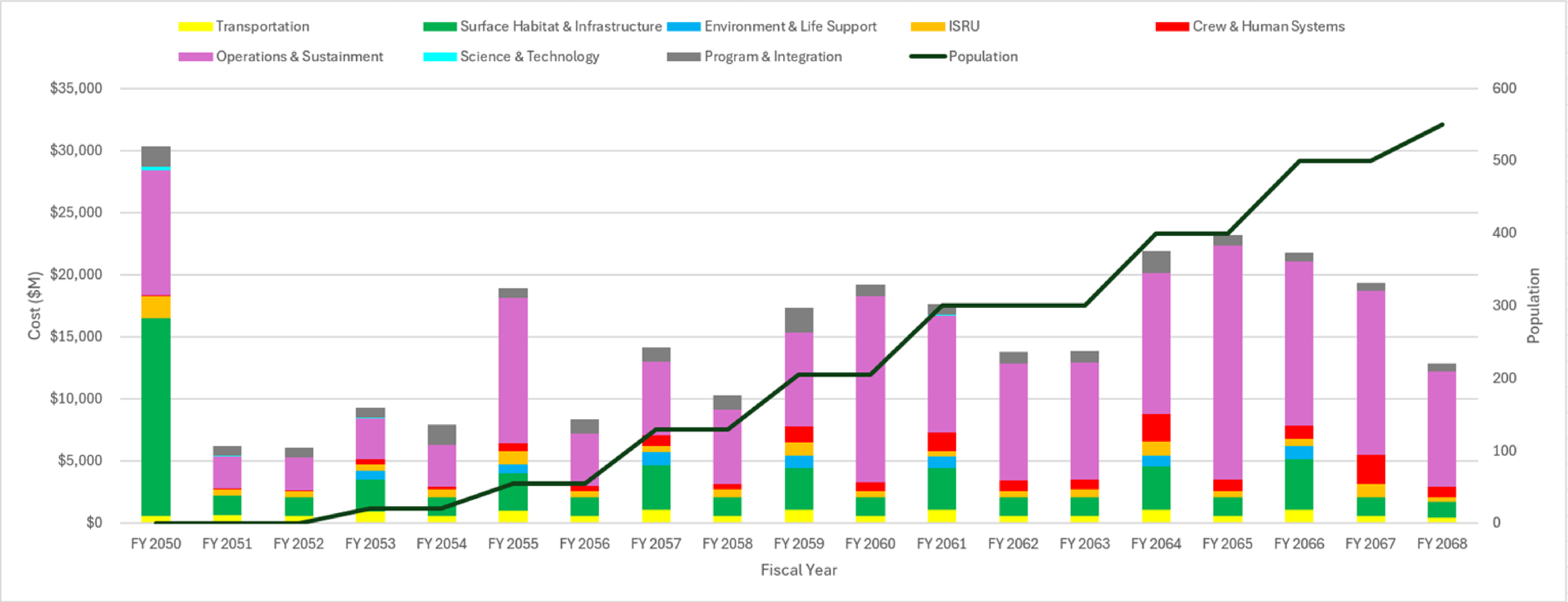
Capital Expenditure Costs in CY26 $M																				
WBS	Total	FY 2050	FY 2051	FY 2052	FY 2053	FY 2054	FY 2055	FY 2056	FY 2057	FY 2058	FY 2059	FY 2060	FY 2061	FY 2062	FY 2063	FY 2064	FY 2065	FY 2066	FY 2067	FY 2068
Transportation System	$14,197	$568	$692	$568	$928	$568	$1,044	$568	$1,062	$568	$1,062	$568	$1,071	$568	$568	$1,073	$568	$1,125	$568	$461
Surface Habitat & Infrastructure System	$56,102	$15,951	$1,542	$1,542	$2,567	$1,543	$2,977	$1,543	$3,630	$1,543	$3,366	$1,543	$3,391	$1,543	$1,543	$3,501	$1,543	$4,043	$1,543	$1,252
Environmental & Life Support System	$6,331	$0	$0	$0	$716	$0	$726	$0	$1,070	$0	$1,004	$0	$879	$0	$0	$903	$0	$1,032	$0	$0
ISRU System	$13,353	$1,772	$492	$492	$495	$608	$1,082	$490	$495	$608	$1,082	$490	$494	$490	$608	$1,081	$490	$608	$1,081	$395
Science & Technology System	$476	$284	$25	$0	$22	$0	$22	$0	$23	$0	$24	$0	$25	$0	$0	$25	$0	$26	$0	$0
Sum	$90,459	$18,574	$2,752	$2,602	$4,728	$2,719	$5,851	$2,601	$6,279	$2,719	$6,537	$2,601	$5,859	$2,601	$2,718	$6,583	$2,601	$6,834	$3,192	$2,108

Sustainment Costs in CY26 $M																				
WBS	Total	FY 2050	FY 2051	FY 2052	FY 2053	FY 2054	FY 2055	FY 2056	FY 2057	FY 2058	FY 2059	FY 2060	FY 2061	FY 2062	FY 2063	FY 2064	FY 2065	FY 2066	FY 2067	FY 2068
Crew & Human Systems	$15,654	$68	$58	$92	$425	$235	$593	$388	$795	$479	$1,289	$713	$1,476	$828	$827	$2,236	$937	$1,065	$2,300	$852
Operations & Sustainment System	$166,330	$10,049	$2,607	$2,607	$3,331	$3,331	$11,692	$4,250	$5,959	$5,959	$7,530	$14,972	$9,420	$9,420	$9,420	$11,335	$18,777	$13,196	$13,196	$9,277
Program & Integration	$19,993	$1,622	$790	$790	$790	$1,622	$790	$1,129	$1,129	$1,129	$1,961	$903	$903	$903	$903	$1,735	$903	$677	$677	$635
Sum	$201,977	$11,739	$3,455	$3,489	$4,546	$5,189	$13,075	$5,767	$7,883	$7,567	$10,780	$16,588	$11,799	$11,152	$11,151	$15,306	$20,616	$14,938	$16,173	$10,764

CAPITAL EXPENDITURES vs. SUSTAINMENT
EARTH YEARS



EARTH-YEARS
WHOLE LIFE COST



EARTH-YEARS
WHOLE LIFE COST

Total Costs in CY26 $M	Total	FY 2050	FY 2051	FY 2052	FY 2053	FY 2054	FY 2055	FY 2056	FY 2057	FY 2058	FY 2059	FY 2060	FY 2061	FY 2062	FY 2063	FY 2064	FY 2065	FY 2066	FY 2067	FY 2068
Total	$292,436	$30,313	$6,206	$6,091	$9,274	$7,908	$18,926	$8,368	$14,162	$10,285	$17,317	$19,189	$17,658	$13,753	$13,869	$21,889	$23,217	$21,773	$19,365	$12,872
Transportation System	$14,197	$568	$692	$568	$928	$568	$1,044	$568	$1,062	$568	$1,062	$568	$1,071	$568	$568	$1,073	$568	$1,125	$568	$461
Launch Vehicle	$12,163	$568	$692	$568	$660	$568	$770	$568	$770	$568	$770	$568	$770	$568	$568	$770	$568	$822	$568	$461
Life Support	$2,034	$0	$0	$0	$268	$0	$275	$0	$292	$0	$292	$0	$301	$0	$0	$303	$0	$303	$0	$0
Surface Habitat & Infrastructure System	$56,102	$15,951	$1,542	$1,542	$2,567	$1,543	$2,977	$1,543	$3,630	$1,543	$3,366	$1,543	$3,391	$1,543	$1,543	$3,501	$1,543	$4,043	$1,543	$1,252
Habitat Modules	$12,675	$0	$0	$0	$1,024	$0	$1,434	$0	$2,087	$0	$1,823	$0	$1,848	$0	$0	$1,958	$0	$2,500	$0	$0
Nuclear Power System	$39,297	$11,821	$1,542	$1,542	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,543	$1,252
Communications Systems	$4,130	$4,130	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Environmental & Life Support System	$6,331	$0	$0	$0	$716	$0	$726	$0	$1,070	$0	$1,004	$0	$879	$0	$0	$903	$0	$1,032	$0	$0
Air Management	$2,038	$0	$0	$0	$301	$0	$299	$0	$456	$0	$337	$0	$287	$0	$0	$189	$0	$169	$0	$0
Water Systems	$4,278	$0	$0	$0	$414	$0	$426	$0	$612	$0	$666	$0	$589	$0	$0	$711	$0	$860	$0	$0
Food Production	$14	$0	$0	$0	$1	$0	$1	$0	$2	$0	$2	$0	$3	$0	$0	$3	$0	$3	$0	$0
Waste Management	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
ISRU System	$13,353	$1,772	$492	$492	$495	$608	$1,082	$490	$495	$608	$1,082	$490	$494	$490	$608	$1,081	$490	$608	$1,081	$395
Mining Unit	$38	$10	$0	$0	$5	$0	$5	$0	$4	$0	$4	$0	$4	$0	$0	$4	$0	$0	$3	$0
Thermal Processing Unit	$1,666	$441	$29	$29	$29	$59	$176	$29	$29	$59	$176	$29	$29	$29	$59	$176	$29	$59	$176	$21
Chemical Processing Unit	$3,004	$793	$53	$53	$53	$106	$317	$53	$53	$106	$317	$53	$53	$53	$106	$317	$53	$106	$317	$43
Materials Refining Unit	$2,002	$529	$35	$35	$35	$70	$211	$35	$35	$70	$211	$35	$35	$35	$70	$211	$35	$70	$211	$29
Maintenance & Repair	$6,644	$0	$374	$374	$373	$373	$373	$373	$373	$373	$373	$373	$373	$373	$373	$373	$373	$373	$373	$303
Crew & Human Systems	$15,654	$68	$58	$92	$425	$235	$593	$388	$795	$479	$1,289	$713	$1,476	$828	$827	$2,236	$937	$1,065	$2,300	$852
Crew Training	$2,021	$12	$13	$25	$27	$52	$56	$83	$89	$95	$136	$156	$166	$177	$187	$164	$171	$179	$128	$106
Medical & Biomedical Systems	$8,888	$0	$0	$0	$295	$24	$353	$66	$440	$154	$818	$238	$924	$352	$352	$1,625	$464	$576	$1,737	$471
Behavioral & Psychological Systems	$1,207	$0	$0	$0	$44	$4	$48	$10	$61	$23	$104	$35	$120	$53	$53	$206	$69	$85	$223	$70
EVA Systems & Operations	$3,538	$55	$44	$67	$59	$156	$136	$230	$206	$207	$231	$284	$265	$247	$236	$241	$232	$224	$212	$206
Operations & Sustainment System	$166,330	$10,049	$2,607	$2,607	$3,331	$3,331	$11,692	$4,250	$5,959	$5,959	$7,530	$14,972	$9,420	$9,420	$9,420	$11,335	$18,777	$13,196	$13,196	$9,277
Maintenance & Repair	$40,574	$1,623	$1,623	$1,623	$1,674	$1,674	$1,764	$1,764	$1,957	$1,957	$2,150	$2,150	$2,394	$2,394	$2,394	$2,652	$2,652	$2,909	$2,909	$2,311
Supply Chain Integration & Logistics	$12,905	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$693	$439
Emergency Systems	$79,670	$109	$109	$109	$782	$782	$1,610	$1,610	$3,126	$3,126	$4,505	$4,504	$6,150	$6,150	$6,150	$7,807	$7,807	$9,412	$9,412	$6,411
System Improvements	$33,181	$7,625	$183	$183	$183	$183	$7,625	$183	$183	$183	$183	$7,625	$183	$183	$183	$183	$7,625	$183	$183	$116
Science & Technology System	$476	$284	$25	$0	$22	$0	$22	$0	$23	$0	$24	$0	$25	$0	$0	$25	$0	$26	$0	$0
Research	$71	$69	$0	$0	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Machines	$404	$215	$25	$0	$21	$0	$22	$0	$23	$0	$23	$0	$24	$0	$0	$25	$0	$26	$0	$0
Program & Integration	$19,993	$1,622	$790	$790	$790	$1,622	$790	$1,129	$1,129	$1,129	$1,961	$903	$903	$903	$903	$1,735	$903	$677	$677	$635
Safety & Assurance	$3,329	$832	$0	$0	$0	$832	$0	$0	$0	$0	$832	$0	$0	$0	$0	$832	$0	$0	$0	$0
Verification & Validation	$6,505	$452	$452	$452	$452	$452	$452	$452	$452	$452	$452	$226	$226	$226	$226	$226	$226	$226	$226	$183
Expansion Planning	$10,159	$339	$339	$339	$339	$339	$339	$677	$677	$677	$677	$677	$677	$677	$677	$677	$677	$452	$452	$452

Weight Available Per Launch Window

Launch	HLS	HLS Weight Avail	Cargo	Cargo Weight Avail
1	0.00	0.00	2.00	67,782.00
2	1.00	21,752.50	0.00	0.00
3	1.00	54,050.00	2.00	5,642.50
4	1.00	24,000.00	2.00	49,342.50
5	1.00	24,000.00	2.00	12,608.50
6	1.00	3,300.00	2.00	31,177.50
7	1.00	0.00	2.00	14.00
8	1.00	0.00	3.00	16,956.00

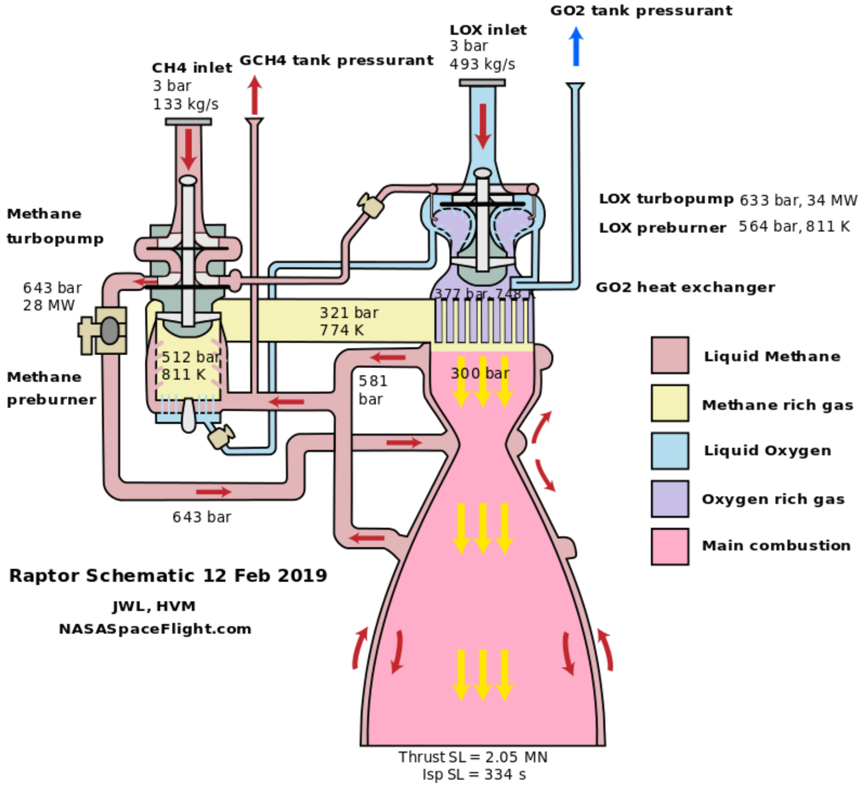
WBS ELEMENTS IN DETAIL

1.1 Engines

The Raptor engine is a methane (CH_4) and liquid oxygen (LOX) rocket engine used to power Starship. It is designed to provide strong performance while being reusable, allowing for frequent launches at lower cost. Compared to kerosene engines, methane offers better efficiency, while hydrogen engines are more efficient overall but much harder to store and handle. Methane was chosen as a practical balance because it produces solid thrust, burns cleaner for reuse, and most importantly it is easier to make on Mars. This allows Starship to refuel on Mars and makes return missions possible without Relying on fuel from Earth.

Cost:

1 Raptor Engine: ~750K



1.1 Super Heavy Booster

Super Heavy is the first-stage booster of the Starship launch system and is responsible for generating the thrust required to lift the fully fueled Starship off the ground. It operates for the initial phase of flight, accelerating the vehicle to near-orbital speeds before separating and returning to Earth for reuse. It is powered by 33 Raptor engines. Designed to be rapidly reusable, reducing overall launch costs.

Purpose

- Lift Starship to near-orbital velocity
- Enable high launch cadence for Mars missions
- Support repeated tanker launches for refueling

Cost

- Booster:
- Fuel:
- Refurbishment:

1.1 Starship Variants

- The Starship upper stage functions as the main mission vehicle and is adapted into multiple specialized variants depending on mission requirements. It is powered by 6 Raptor engines with 3 sea-level and 3 vacuum-optimized engines. Each version is optimized for a specific role, such as transporting crew, delivering cargo, or transferring fuel in orbit.

Variants and Purpose

- HLS: Crew transport
- Cargo: Equipment and supply delivery
- Tanker: Orbital refueling (~10 launches per missic

Cost

- Super Heavy Booster $1033.7M
- HLS/Cargo/Tanker: $443.95M

1.2 Ground Systems & Operations

Ground systems and operations are the Earth-based infrastructure and teams that make launches and missions possible. This includes launch pads, fueling systems, mission control, and all personnel needed to prepare, monitor, and operate the mission from start to finish.

Purpose

- Launch and prepare Starship
- Manage mission operations and communication
- Support refueling and reuse

Cost

- Ground Systems & Operations: $10,684.92M

1.2 Life Support System

The life support system maintains a stable, habitable environment for astronauts during transit to Mars. It is responsible for providing breathable air, clean water, food, and safe living conditions while managing waste and maintaining pressure and temperature. Because Mars missions are long-duration and far from Earth, the system must be highly reliable and capable of recycling resources to minimize resupply, using proven technologies derived from the International Space Station.

Purpose

- Provide oxygen and remove CO_2
- Supply and recycle water
- Store and manage food for long-duration missions
- Maintain cabin pressure, temperature, and habitability

Cost
- Food: $126.62M
- ECLSS: $1814.16M
- Crew Provisions: $95.09M

2.1 Habitat

LIFE - Large Integrated Flexible Environment

The LIFE habitat is a three story inflatable habitat designed by Sierra Space for the Orbital Reef. One LIFE habitat is built to support four people, including space for sleeping quarters, farming, research, exercise, and a medical center.

A large structure built of connecting LIFE habitats will be more than sufficient space for our New Jamestown colony.

Cost/Unit: $280M

People/Unit: 4

Total Cost: $12,675M

2.2 - Power Systems

Nuclear Power Plant

Nuclear power is the most reliable energy source on Mars. Month-long wind storms disrupt solar power too much for it to reliably power a long term facility. A full-size nuclear plant can create 1,000,000 kWh.

Construction of a nuclear plant requires 100,000m^3 of concrete and 12,000 metric tons of steel - much more than is possible to ship from Earth. Our IRSU mining and materials systems will construct the plant entirely on Mars.

Cost/kW: $7821

kWh Produced: 1,000,000

Total Cost: $39,297M

- Construction Costs: $10,283M
- Maintenance Costs: $29,011M
- Uranium (Fuel) Costs: $3.7M

2.3 - Communication Systems

Communication between Mars and Earth is essential. For fast communication, we will have twin LEO communication satellite constellations around Earth and Mars, of 10 space vehicles each. These comm satellite constellations can send signals between space vehicles so that New Jamestown can send and receive communications even when facing away from Earth.

In addition, there will be a GEO Position, Navigation, and Timing (PNT) satellite above Mars to track weather, determine locations on Mars' surface, and monitor our spaceships.

Total Cost: $4,130M

Comm Constellations Cost: $4,072M

PNT Satellite Cost: $55M

Ground Systems Cost: $2M

3.1 Air Systems

MOXIE - Mars Oxygen In-Situ Resource Utilization Experiment

A NASA prototype machine that takes carbon dioxide out of the environment and converts it to oxygen by electrochemically splitting the CO_2 molecules. It also includes filters that ensure O_2 purity. Like a tree!

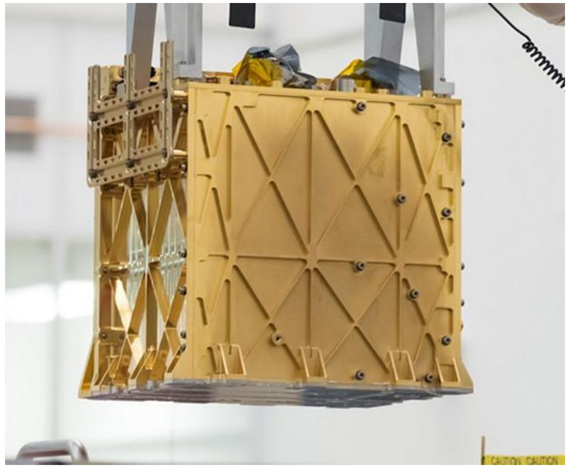
MOXIE currently produces 10g of O_2 per hour, and has a mass of 17.1kg. Based on an estimate made by NASA, a human needs 890g O_2 per day, or 37g/hr. Thus, each person needs 4 MOXIE machines to survive. For redundancy, we will send each person with 5.

As the population increases, the ISRU will begin to provide oxygen to the colony. By 244 the ISRU will provide 75% of all oxygen used by the colony.

Cost/Unit: $8.56M

Units/Person: 5

Total Cost: $2,038M



3.2 - Water Systems

ECLSS - Environmental Control and Life Support Systems

The ECLSS is the current life support system on board the ISS. The ECLSS includes a Water Recovery System (WCS), Water Processor Assembly (WPA), Urine Processor Assembly (UPA) and Brine Processor Assembly (BPA). It has a 98% water retention, and includes water filters so that all water is fresh.

The IRSU Unit will provide all water by mining water from the mars regolith, and the ECLSS will filter and retain the water already in the system.

Cost/Unit: $175M

People/Unit: 10

Total Cost: $4,278M

3.3 - Food

Aquaponic Farming

Producing food on Mars is critical to the survival of New Jamestown. Aquaponic farms are efficient, space saving farm systems that use fish to fertilize plants, creating a small ecosystem. One of these farms can feed 20 people year round, providing a variety of crops as well as fish for a balanced diet.

While traveling, our colonists will eat space food, just like astronauts of today.

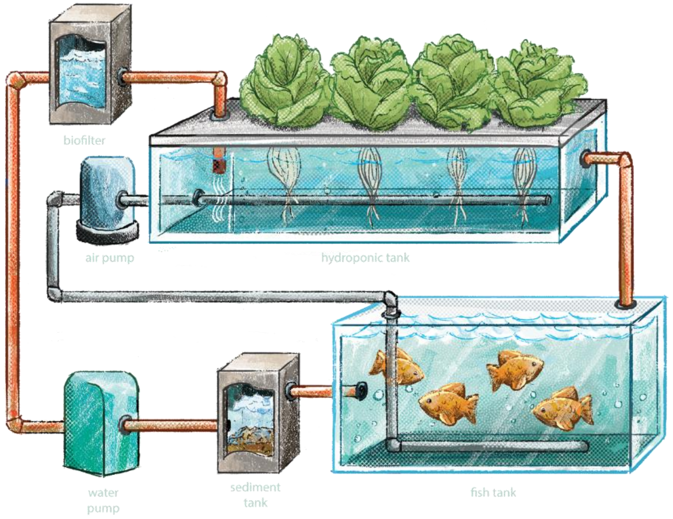
Aquaponic Farm Cost/Unit: $120K

People/Unit: 20

Total Food Cost: $14M

Travel Food Cost: $12M

Farm Cost: $1.7M



3.4 - Waste Disposal

Human and Consumable Waste Disposal

Unlike on the ISS, Mars has gravity. Even with a weaker gravitational pull, a composting toilet system can be used instead of an ISS waste system. A modern composting toilet system can support five regular users.

For consumable waste that cannot be reused, a trash compactor will be used. These trash compactors will serve as a disposal for consumable waste from both the habitat and the scientific systems.

Toilet Cost/Unit: $2970

People/Toilet: 5

Total Waste Cost: $0.35M

Compactor Cost/Unit: $12,300

Compactor Quantity: 50

Communications Satellites

What is a constellation?

A satellite constellation is a collection of space vehicles that perform the job and interact with each other as well as the ground. Each constellation will have 10 space vehicles and orbit in Low Earth Orbit (LEO). The satellites will be launched with a reusable launch vehicle; estimate based on the SpaceX Falcon 9.

Why use constellations?

Unlike the PNT satellite, the comm constellations will be constantly orbiting Earth and Mars. Signals will be able to bounce between satellites, which allows for signals to be sent between Earth and Mars even when the ground systems are not facing each other.

The Comm CER

The satellite cost was estimated using a CER from the Institute for Defense Analyses (IDA). Inputs to the CER are SV quantity, mass, altitude, and development time. All inputs were calculated as averages of 12 real comm constellations.

Aquaponic Farms in Depth

An aquaponic farm is a farm system that uses fish to fertilize its crops. Aquaponic farms grow crops directly in water, and fish live in that same system. The fish waste provides the crops with all necessary nutrients, eliminating the need for fertilizers. In addition, the cyclical design of the tanks retains 95% of water every day, so aquaponic farming has much lower water needs than a dirt farm.

In addition, the dirt on Mars is not suitable to farming. It has many nutrients, just like soil on Earth, but also contains toxic perchlorates that would have to be filtered out. Aquaponic farming eliminates the need for any sort of soil filters or soil shipped from Earth, while providing fish for our colonists to eat!

There are many things that are needed for aquaponic farming. In addition to the machinery, seeds and growing lights must be purchased. To get fish, we will purchase and freeze tilapia eggs, as a live fish would most likely not survive a launch into space. We will also need to purchase duckweed, a plant that will serve as the food source for the tilapia.

Dead due to perchlorates in soil

——————>

4.1 Mining Unit

Regolith Advanced Surface Systems Operations Robot (RASSOR)

Currently on model 2.0; anticipating a larger design for 3.0 by 2050

- teleoperated mobile robotic platform with a unique space regolith excavation capability
- design incorporates net-zero reaction force, thus allowing it to load, haul, and dump space regolith under extremely low gravity conditions with high reliability

Regolith excavation is desired in future space missions for the purpose of In Situ Resource Utilization (ISRU) to make local commodities, such as propellants and breathing air, and to pursue construction operations.

$500,000 per unit
Excavates 2,700 kg of regolith per day
Vehicle mass of 66 kg

4.2-4 ISRU Plant

The ISRU plant enables long-duration Mars settlement by converting local Martian resources into fuel, oxygen, water, and industrial materials. By doing so, this reduces the resupply dependence on Earth.

Regolith/Ice

↓

Water Extraction

↓

Electrolysis $2H_2O \rightarrow 2H_2 + O_2$

↓

Hydrogen + Oxygen

↓

Sabatier Reactor $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

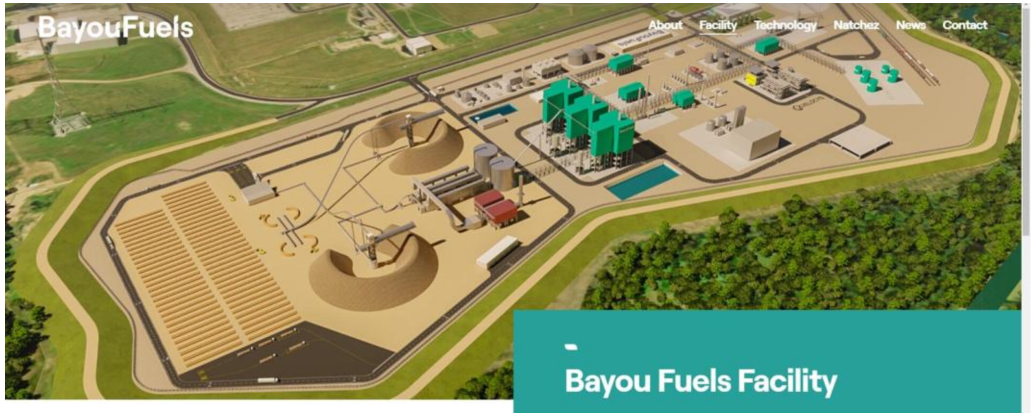
↓

Methane Fuel

ISRU Plant Costs (BY26 $M)

- Mining Systems → $5,500M
- Chemical Processing → $4,200M
- Thermal Processing → $1,800M
- Materials Refinement → $668.9M

Total ISRU System: $12.2B



Production outputs based on Velocys' GTL (gas-to-liquid) facility located in Natchez, Mississippi

5.1 Crew Training

Prepares crews for long-duration Mars transit, surface operations, emergency response, and autonomous settlement management.

Core Training Categories

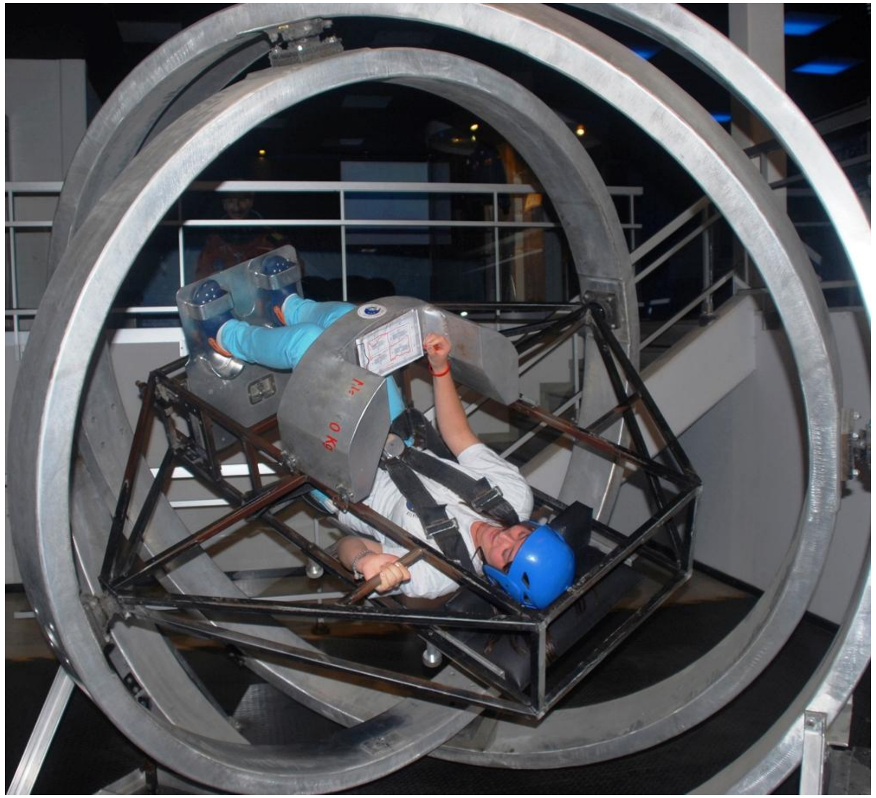
- Surface EVA operations
- Habitat systems operations
- Emergency medical response
- ISRU and maintenance procedures
- Robotics & autonomous systems
- Psychological resilience and isolation adaptation
- Mars gravity adaptation and physical conditioning

Crew Training Costs (BY26 $M)

- Initial training per crew member → $1.25M
- Annual recurring training → 10% refresher
- Simulation facilities & instructors
- EVA certification and emergency drills

Total Crew Training

$1.84B



5.2 Medical & Biomedical Systems

Problems	**Solutions**
Radiation	Advanced shielding and pharmaceutical countermeasures
Bone density loss	Regular weight-bearing exercises, pharmacological interventions, and a diet rich in bone-strengthening nutrients like calcium and vitamin D
Muscle atrophy	Regular resistance training, neuromuscular electrical stimulation, and maintaining a balanced diet rich in proteins and essential nutrients
Cardiovascular changes	Compression garments to aid venous return, engaging in regular cardiovascular exercises to maintain heart health, and effective hydration strategies
Visual impairment	Regular monitoring of eye health, using therapeutic eyewear or corrective lenses, and adjusting the ambient pressure in living quarters
Immune system alterations	Enhancing overall health through nutrition, exercise, stress reduction, and immune support supplements or medications

Point Estimate:
Preventative Healthcare Annual cost (per person): $600k BY$26
Emergency Healthcare Annual cost (per person): $200k BY$26
Health Monitoring Systems cost (per person): $150k BY$26

5.3 Behavioral & Psychological Systems

- Advanced Training: comprehensive training in resilience, stress management, and conflict resolution
- Virtual Reality (VR) Environments: simulating familiar Earth environments can offer mental escapism and relaxation
- Telemedicine and Psychological Support: continuous access to psychological support services from Earth, including regular consultations and emergency interventions
- Habitat Design: habitats with provisions for privacy, communal areas, and green spaces
- Engaging Activities: Organized structured recreational, educational, and creative activities
- Communication Technology: technologies that minimize communication delays and facilitate more natural interactions

Psychological/Behavioral Annual cost (per person) - PE: $150k BY$26

5.4 EVA Systems & Operations

Enables astronauts to safely perform construction, maintenance, science, and logistics operations on the Martian surface.

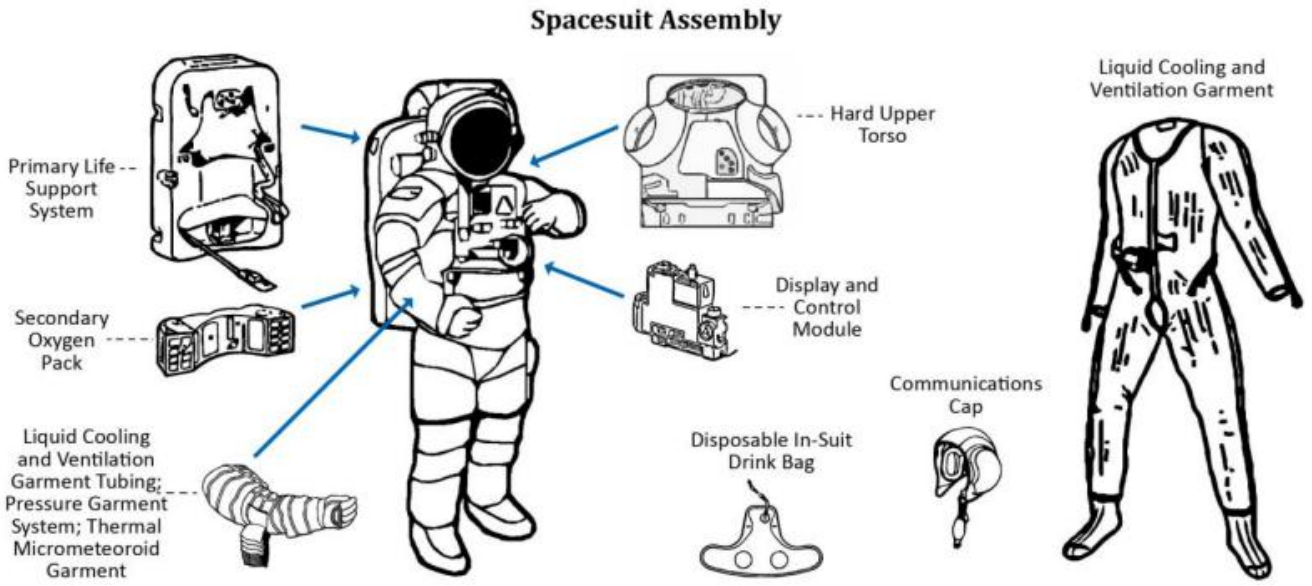
Space suit plan
- Send up crew with 2
- Once 100 people there, 1 per person plus 1 for 2 to share
- Once 300 people there, 1 per person plus 1 for 3 to share

EVA System Costs (BY26 $M)

- Surface EVA suits
- Mobility systems
- Airlock systems
- Suit maintenance & refurbishment
- Spare parts inventory

Total EVA Systems (PE)

$3.14B



6.1 Maintenance & Repair

This includes the cost of preventive maintenance, corrective maintenance, and spare parts & consumables of the colony from 2050 - 2069.

The cost is driven by the cost of maintenance and spare parts & consumables cost on the ISS. It is scaled to the number of humans in the colony. Both become more expensive in the later years as the colony expands and matures.

Total Cost at PE: $37.64 CY26$B

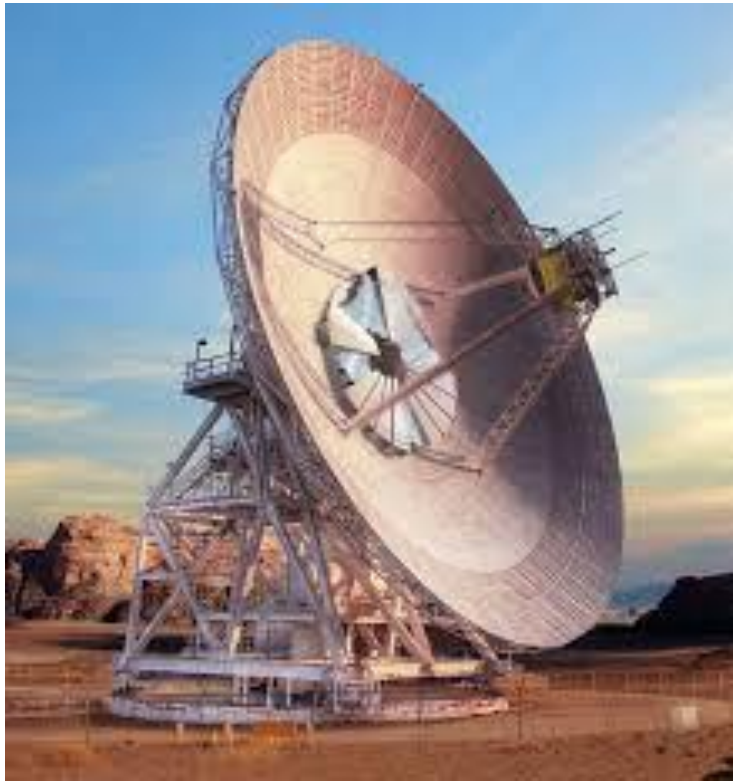
6.2 Supply Chain Integration & Logistics

Assume supply chain integration & logistics cost is 40% of the cost of preventive maintenance and corrective maintenance

Total Cost at PE: $16.072 CY26$B

6.3 Emergency Systems

Communication systems on Mars currently rely twin satellite constellations around Earth and Mars to provide reliable, low-bandwidth communication. In order to communicate during in critical situations, there needs to be a emergency communication system designed to communicate on the surface and between Earth and Mars.



Antennas will be operating to provide communication 24/7 and personal transceivers will be used on the surface of Mars.

Personal Transceivers Cost/Unit : $500 CY26$

Deep Space Network Cost: $1,057/hr

Total Cost at PE: $1.817 CY26$B

6.4 System Improvements

System improvements relating to technology refreshes (hardware) and software updates involve replacing aging hardware and updating software to enhance performance, security, and operational efficiency. By standardizing on a 5 year cycle, it reduces risk, minimizes downtime, and ensures compatibility with modern applications.

Hardware is refreshed every five years and software maintenance is updated annually.

NASA spends $300M on the ISS for hardware modifications. This cost is scaled to the size of the colony.

Assume total cost of software maintenance is 10% of preventive maintenance cost and corrective maintenance cost.

Total Cost at PE: $28.138 CY26$B

7.1 Scientific Research

Scientific research systems are a central component of the Mars mission, enabling the study of the planet's environment, history, and potential for life. The equipment includes both field instruments and laboratory systems designed to analyze samples and collect environmental data.

Purpose:

- Study geology, atmosphere, and climate
- Detect water and subsurface ice
- Search for biosignatures
- Analyze human adaptation to Mars

Costs

- Laboratory Equipment: $2.51M
- Weather/Seismic Activity Monitoring: $68.80M
- Robots/Drones/Rovers: $355.1M
- Internet/Data Infrastructure: $1.45M
- Advanced manufacturing: $27.87M

7.2 Machines

Robotic and autonomous systems provide critical operational support by performing initial tasks that are dangerous, repetitive, or inefficient for human crews as well as preparing the habitat. These systems include ground-based robots, aerial drones, and crew-operated vehicles, each designed for specific operational roles. Their use increases mission efficiency while reducing risk to human life.

Purpose

- Exploration and scouting
- Maintenance and inspection
- Cargo transport
- Scientific data collection

Cost

- Robots
- Drones
- Rovers

7.2 Advanced Manufacturing

Advanced manufacturing systems, particularly 3D printing technologies, allow for the production of tools, parts, and structural components directly on Mars. These systems reduce dependence on Earth by enabling in-situ production and repair. Multiple printing methods including polymer (FDM), resin (SLA), metal printing, and regolith-based construction are used to handle different materials and applications, ranging from small components to large structural elements.

Purpose:

- Produce replacement parts and tools
- Support infrastructure construction
- Enable long-term mission sustainability

Cost:

- Printers
- Materials
- Processing systems

8.1 Safety & Assurance

The purpose of safety & assurance is to estimate the cost of risk and mission safety of sending humans to Mars and sustaining a human settlement starting in 2050.

The Safety and Mission Assurance Engineering Contract III from Science Applications International Corporation will provide safety, reliability, and quality engineering, as well as quality and software assurance support for NASA programs and projects in deep space. The contract is valued at approximately **$494 million**.

Total Cost at PE: $2.964 CY26$B

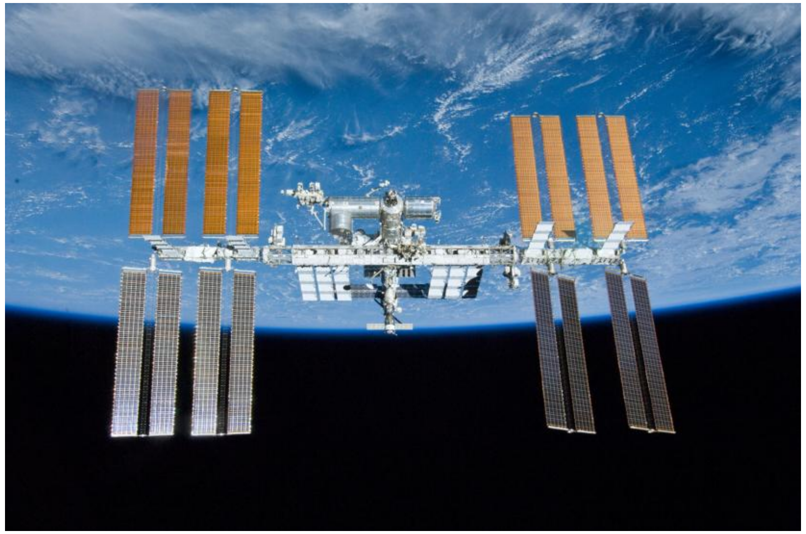
8.2 Verification & Validation (V&V)

V&V assesses whether software associated with science and spaceflight activities will meet program, cost, schedule, and safety requirements.

The international space station (ISS) spends over $1 billion on O&S on the ISS which includes verification & validation of the software. Our system will be more complex.

V&V costs become cheaper as the software matures, largely because maturity allows for the shift from expensive manual testing to automated, standardized processes. While upfront V&V costs can be high, mature systems experience lower failure rates and reduced need for extensive rework.

Total Cost at PE: $5,762 CY26$B



8.3 Expansion Planning

Expansion planning on Mars involves creating a self-sufficient, long-term human presence, moving from initial exploration to establishing a sustainable city.

This involves complex logistics to deal with the harsh, low-pressure environment, with key focus areas including robust habitation, In-Situ Resource Utilization (ISRU), and massive transportation systems.

Y1-5: $300M (Foundation)

Y6-15: $600M (Growth)

Y16-20: $400M (Maturity)

Total Cost at PE: $9.4 CY26$B