National Aeronautics and
Space Administration

Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001

Date 4/15/2024

Reply to Attn of: Science Mission Directorate

TO: NASA Administrator

FROM: Associate Administrator of Science Mission Directorate

SUBJECT: NASA's response to the second Mars Sample Return Independent Review Board (MSR IRB-2) recommendations

Over the last quarter century, NASA has engaged in a systematic effort to determine the early history of Mars and assess its potential as a pathway to understanding the formation and evolution of habitable worlds including Earth. Mars Sample Return (MSR) has been a major long-term goal of international planetary exploration for the past two decades. NASA's Perseverance rover is collecting compelling science samples that will help scientists understand the geological history of Mars, the evolution of its climate, and potential hazards for future human explorers. The return of the samples will also help NASA's search for signs of ancient life.

It is imperative to return these valuable samples to Earth to be studied in state-of-the-art laboratories. This level of work and analysis is impossible to do while on the surface of Mars. A successful MSR campaign enables scientists to address both key questions of today, as well as to inspire future generations to pursue further investigation into questions not yet known.

In an effort to achieve these long-term science objectives, we have been formulating the MSR mission. Given its complexity and the required investment, NASA has been employing lessons learned from our Large Mission Study, which include conducting independent reviews during mission formulation. Two such independent reviews have been conducted on MSR. In September 2023, the second Mars Sample Return Independent Review Board (MSR IRB-2) provided NASA with a comprehensive report and set of recommendations to position NASA to successfully return the high priority science samples currently being collected by the Perseverance Rover on Mars. The Independent Review Board found that the mission remained a top priority, but could not be accomplished within its planned budget. In response, I chartered a team to respond to MSR IRB-2 called the MSR IRB Response Team (MIRT). The MIRT charter was to evaluate and develop a response to the IRB-2 recommendations. Recognizing the importance of an executable program for returning these compelling science samples from Mars, I asked the Science Mission Directorate (SMD) Deputy Associate Administrator (DAA), to lead the MIRT, supported by a highly esteemed team of renowned experts.

In summary, the MIRT has comprehensively responded to the IRB-2 recommendations by proposing a revised MSR mission design with improved mission resiliency and risk posture, reduced overall complexity, improved lines of accountability and authority, descoped content, and improved communications and coordination. The MIRT proposes phasing the content such that the design can be matured, and samples returned, while maintaining NASA's international agreements. The MIRT acknowledges that, in order to be responsive to and in concert with the IRB-2 recommendations and realistic budget constraints, any revised mission design will delay the return of samples to 2040. The MIRT also agrees with the IRB's finding that the overall budget for an MSR mission is likely in the $8.0-$11.0B range. I have made SMD decisions and am providing recommendations to you via the *SMD MIRT Response to MSR Independent Review Board (IRB-2) Recommendations* and *SMD MIRT Response to individual IRB-2 Recommendations* (Enclosed).

My priority is to find a path forward for MSR within a balanced overall Science program. Therefore, in order to further inform an MSR mission design that reduces complexity, schedule and cost, I have directed NASA SMD to explore out-of-the-box architecture and mission element options. To that end, NASA SMD will release a competitive solicitation in the immediate future for funded industry studies to investigate either 1) innovative and alternate MSR architectures or 2) innovative and alternate architecture elements, such as a smaller Mars Ascent Vehicle, that could offer lower life cycle cost, lower annual cost, provide earlier sample return, and/or lower mission complexity and risk. In parallel, NASA SMD will engage NASA centers and JPL to provide their unique expertise and technology capabilities for additional out-of-the-box options.

Given the budgetary constraints across government, NASA will focus the remainder of FY 2024 and FY 2025 to advance formulation of mission components and capabilities that have a high likelihood of being used in any future sample return architecture, as well as evaluate and appropriately incorporate relevant findings from funded industry and Center architecture studies. In November 2023, SMD provided FY 2024 budgetary and programmatic guidance to NASA centers engaged with MSR. For FY 2025, I am recommending an MSR budget request level of $200 million while we assess alternative architectures. While this was a difficult recommendation to make, this FY 2025 MSR funding level also allows other projects within Planetary Science – at the Goddard Space Flight Center, the Jet Propulsion Laboratory, other centers, and with university and industry partners – to continue.

I would like to express gratitude to the MSR IRB-2, the MIRT, and the NASA/ESA MSR team for their dedication and keen advice in moving this transformational mission forward to deliver revolutionary science from Mars that will provide critical new insights into the origins and evolution of Mars, our solar system, and life on Earth.

Nicola J. Fox
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Nicola J. Fox
Associate Administrator, NASA Science Mission Directorate

Enclosed
SMD MIRT Response to MSR Independent Review Board (IRB-2) Recommendations and
SMD MIRT Response to individual IRB-2 Recommendations

cc:
Pam Melroy, DA
Jim Free, AA
Bale Dalton, CoS
Alicia Brown, AA OLIA
Margaret Vo Schaus, CFO
Mary D Kerwin, DCFO
Karen Feldstein, AA OIIR
Marc Etkind, AA Comms
Sandra Connelly, DAA SMD

National Aeronautics and
Space Administration

NASA

SMD MIRT Response to MSR Independent Review Board (IRB-2) Recommendations

April 15, 2024

NASA/ESA
MARS
SAMPLE
RETURN

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Importance of MSR

- For half a century, NASA has engaged in a systematic effort to determine the early history of Mars and to assess its biological potential as a pathway to understanding the formation and evolution of habitable worlds - including Earth.
- This joint campaign with the European Space Agency (ESA) is a pivotal step in a decades-long, carefully developed strategy to understand Mars, provide insight to planetary evolution, and understand the potential for life on other planets
  - MSR has been a top priority of the last two Planetary Science Decadal Surveys
- Perseverance has collected, and will continue to collect, highly valuable science samples that will answer key questions about the geological history of Mars, its climate, and whether life could have developed on Mars
  - Only state-of-the-art laboratories on Earth can fully analyze and detect the faint signatures that unlock the answers to these key questions in planetary evolution and astrobiology
- Samples from Mars are unique because it is the only planet in our solar system once capable of sustaining life which we can also readily explore on the surface through scientific investigations and future human explorers

Summary of Responses

Executive Summary of SMD MIRT's Response

MIRT Background

- SMD AA established the MSR IRB-2 Response Team (MIRT), chaired by the Deputy SMD AA, to evaluate the MSR IRB-2's recommendations
- The MIRT interviewed roughly 70 subject matter experts and evaluated approximately 20 mission design variations prior to presenting recommendations to the SMD AA

SMD MIRT Proposed Responses

- Revise MSR mission design with improved resiliency, risk posture, and reduced complexity
    - Maintain NASA's MSR Memorandum of Understanding with ESA and launch Earth Return Orbiter(ERO)/Capture Containment and Return System(CCRS) in 2030, launch Sample Retrieval Lander(SRL)/Mars Ascent Vehicle (MAV) from Earth in 2035, and return samples to Earth in 2040
    - Returns carefully selected, diverse samples collected by Perseverance
    - Balances programmatic and technical risk, and decouples launch readiness dates
    - Adds Radioisotope Thermoelectric Generators (RTG) to SRL to improve reliability and MAV thermal environment
    - Refreshes telecommunications prior to SRL arrival
    - Provides more time to mature SRL and MAV designs
    - Finalizes Orbiting Sample design early to stabilize overall mission design
    - Parametric Lifecycle Cost estimate of $8-11B; and is consistent with IRB-2

Executive Summary of SMD MIRT's Response

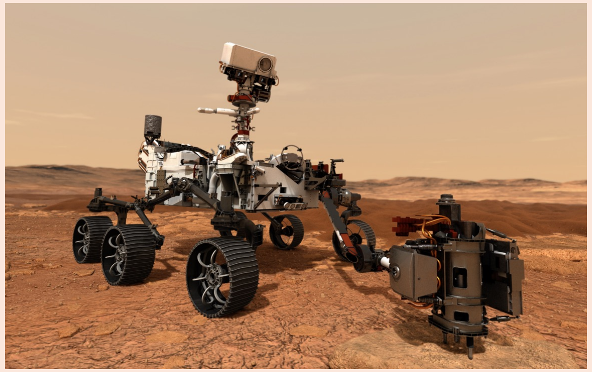
- Improve lines of accountability and authority
  - Keep the Mars Exploration Program (MEP) and Mars Sample Return (MSR) as separate programs
  - Empower the NASA HQ MSR Program Office with all programmatic capabilities including system engineering and PP&C responsibilities
  - Elevate Mars Ascent Vehicle (MAV) and Mars Orbiting Sample system (OS) to Level 2 Projects
  - Establish Standing Review Boards (SRBs) for the MSR Program and MSR Level 2 Projects
- Improve communications and coordination within the Agency and with external stakeholders
  - Expand the frequency of engagement between the MSR Program Director (PD) and NASA Senior Leadership
- Competitively select one world-class Mars Chief Scientist to span MEP and MSR
- Explore out-of-the-box architecture and mission element options by releasing a competitive industry study solicitation as soon as possible.
  - Innovative or alternate architectures could offer lower overall cost, lower annual cost, earlier sample return, and/or less complex/lower risk.
  - Since OS and MAV drive overall mission size, complexity, and cost, studies should include alternative MAV designs.
  - In parallel, engage with NASA Centers and JPL for additional out-of-the-box architecture solutions.
  - The architecture must be capable of returning samples collected by Perseverance from the surface of Mars to Earth

Background

MSR Campaign Elements

MEP

Mars Sample Collector

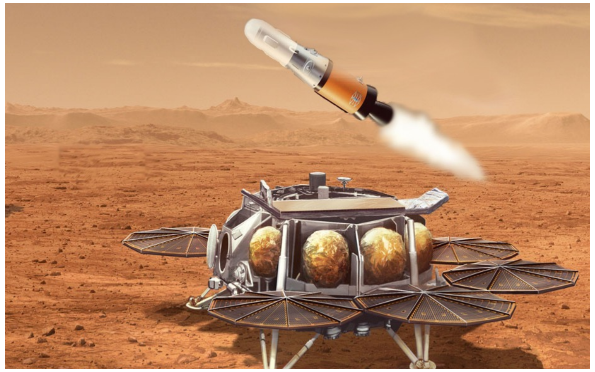


Perseverance Rover

- *Operational on Mars since 2021*
- *Collect samples of rock, regolith, and atmosphere*
- *Cache samples on the surface for retrieval*

MSR PROGRAM

Mars Retrieval Lander & Launch Vehicle



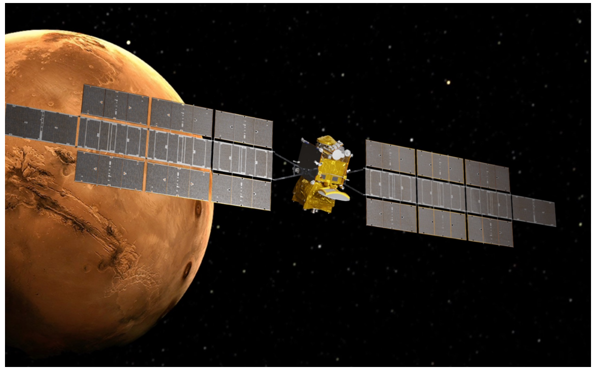
Sample Retrieval Lander (SRL)

Mars Ascent Vehicle (MAV)

Orbiting Sample (OS)

- *Retrieve samples cached onboard Mars 2020 rover*
- *Launch samples into orbit around Mars*

Earth Return Orbiter



Earth Return Orbiter (ERO)

Capture, Containment, and Return System (CCRS)

- *ESA provides the orbiter, GSFC provides the capture system*
- *Capture and contain samples in Mars orbit*
- *Decontamination, Back Planetary Protection (BPP)*
- *Safely return samples to Earth for recovery at landing site*

MEP

Sample Recovery, Transport, & Curation

Sample Receiving Project

- *Recover and transport contained samples to receiving facility*
- *Safety assessment and sample containment*
- *Initial sample science and curation*

MEP – Mars Exploration Program
MSR – Mars Sample Return

MIRT Organization

- SMD organized the MSR IRB-2 Response Team (MIRT) to assess and respond to the IRB-2's recommendations:
  - Core Team for leadership and sub-team integration, chaired by the SMD Deputy AA
    - Independent of existing program personnel
  - Sub teams were comprised of 35 subject matter experts (SMEs)
    - Science Team
    - Technical/Architecture Team
    - Business Team
    - Programmatic/Governance Team
    - Program Director Team
  - Ex-officio members and consultants

MIRT Timeline and SMD Response Process

- MIRT efforts took place between October 2023 and March 2024
  - Conducted roughly 70 interviews with programmatic and science stakeholders
  - Approximately 20 architecture variations were analyzed
    - Conducted three formal Technical Integration Meetings (TIMs) and numerous lower-level studies and analyses
    - ESA and all other MSR organizations participated
  - Developed cost estimates for all architecture variations
- MIRT recommendations were developed for SMD decisions, which were presented for concurrence by the Agency
  - MIRT sub teams prepared final recommendations to the Core Team (CT)
  - MIRT CT deliberated on sub team reports and developed recommendations for the SMD AA
  - The SMD AA made final recommendations to Agency leadership
  - SMD AA briefed NASA Senior Leadership on determinations in response to IRB-2 recommendations

SMD Responses by Theme

Science

Science

Key Takeaways from the IRB-2 Report

- Mars 2020 has been successful in acquiring samples of high scientific value
- The cache of samples deposited at Three Forks is return worthy but is not an optimal sample set because it does not represent the full diversity of geologic environments along the rover's traverse that could preserve signs of life.
- The samples now collected by and carried on Perseverance are of very high scientific value – higher than the cache at Three Forks.
- A clear plan for Mars 2020 to operate with a focus on direct transfer to SRL or placing one or more additional depots is required.
- Driving up and out of Jezero Crater will allow sampling of highly diverse geologic units on the margin, rim, and possibly beyond, enabling the return of an optimized sample suite.
  - Such a traverse requires that there be a certifiable site for landing SRL relatively nearby the samples to be returned.

MIRT Science Evaluation Methodology

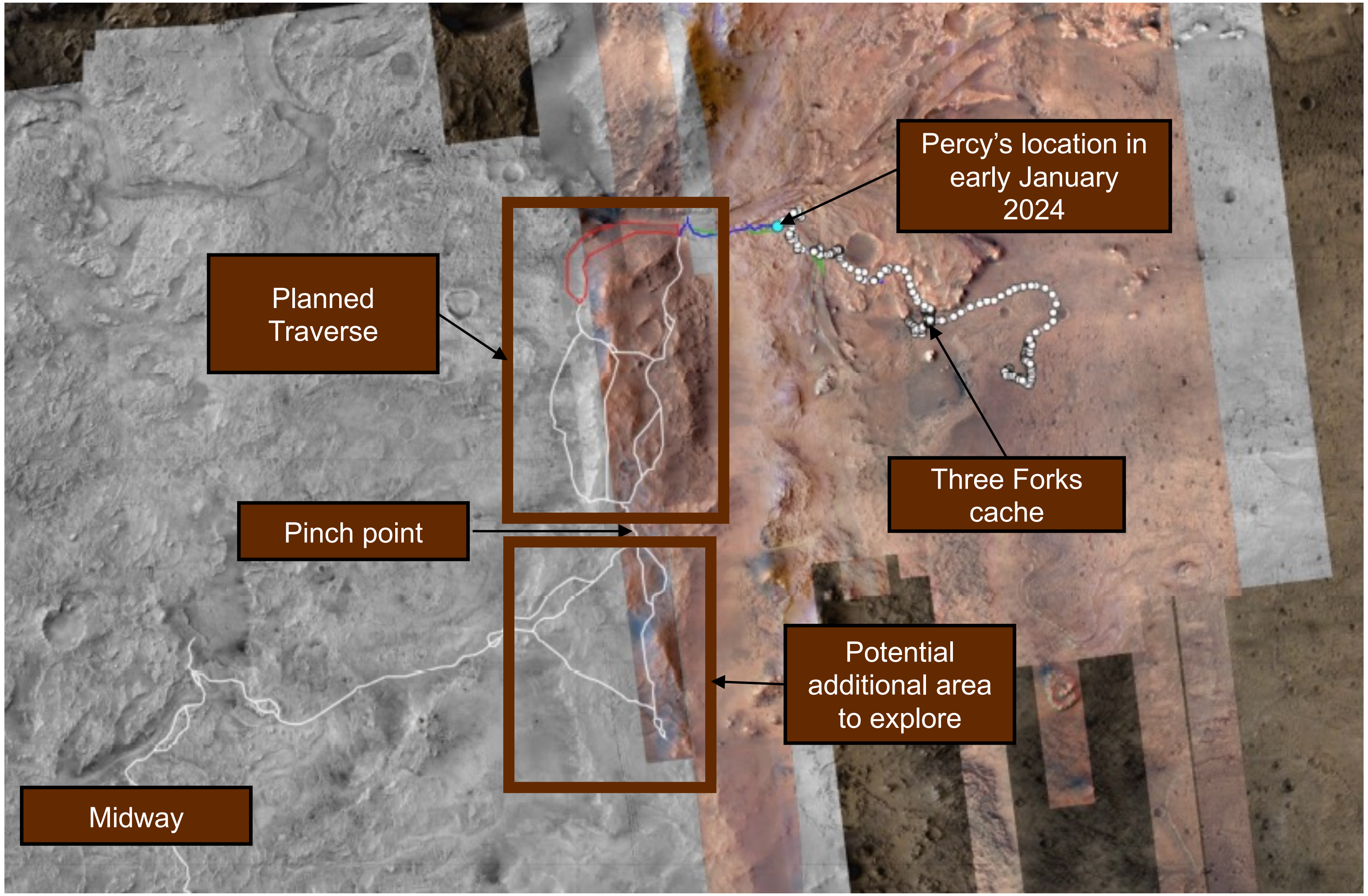
- The MIRT interviewed approximately 20 representatives of the Mars community, including the IRB-2, decadal survey team, Mars 2020, MSR Science Team, Sample Receiving Facility Science Team, Sample Integrity Working Group, MEPAG, etc.
- The MIRT Science team and Technical/Architecture team regularly engaged to ensure science was considered in architecture plans, and architecture options were considered in science plans.
- Key Criteria for MIRT Considerations in making recommendations:
  - The MIRT evaluated 5 options for obtaining a diverse sample set and considered the following for each option: science value, additional driving distance required by Perseverance, and the overall pros and cons
  - It was concluded by the MIRT technical/architecture team that Midway is inaccessible as a landing site

Option	Samples
Use the Three Forks cache	Three Forks Cache (7 rock cores, 1 regolith sample, 1 atmospheric sample + 1 witness tube)
Immediate return to Three Forks	Samples currently on Perseverance (14 samples + 2 witness) as of February 6
Explore & Return (short)	Samples currently on Perseverance; plus, hydrothermal sediments, Noachian basement/sediments, megabreccia, olivine carbonate in stratigraphy (up to 30 tubes: sample + witness)
Explore & Return (long)	Explore & Return (short); plus, fractured rim material, additional megabreccia (up to 30 tubes: sample + witness)
Go to Midway	Explore & Return (long); plus, basement, mineralized fracture (up to 30 tubes: sample + witness)

SMD's Response to Science Recommendations

- SMD concurs with the IRB-2's recommendation to collect geographically and scientifically diverse samples; the greater the diversity of samples from various geographic locations, the greater the science outcome.
- SMD concurs with the IRB-2 that Perserverance should explore outside of Jezero crater, and Perseverance will drive along the crater rim for exploration and sample collection with a dedicated reliability assessment at the "pinch point" (see next chart) to determine risk of continued exploration
    - Exploring the Jezero crater rim area maximizes science by expanding exploration/sampling to ancient Mars and planetary evolution, hydrothermal processes, different habitable environments, and areas of aqueous alteration, none of which exist inside the crater
    - Perseverance returns to the Jezero crater floor in the 2028 timeframe to await MSR arrival, and science could continue after the sample transfer for return to Earth
- Mars 2020 and MSR will develop a joint plan that balances the risk of degradation or failure of Perseverance against obtaining the highest value samples near the crater rim and beyond.
- SMD will ensure the samples selected for return represent the highest value samples to satisfy the Decadal Survey science recommendations
    - MSR will accommodate return of 30 diverse samples collected from geographically diverse locations as the baseline Level 1 requirement.
    - NASA considers the 10 sample tubes deposited at the Three Forks depot to be an available cache for alternatives to the revised architecture and is scientifically worthy of return.
- SMD non-concurs with the IRB-2 recommendation to certify a landing site outside the crater rim due to engineering/mission architecture (landing) constraints at altitudes above the crater floor.

Perseverance Traverse Map



Architecture

MSR Mission Architecture

Key Takeaways from the IRB-2 Report

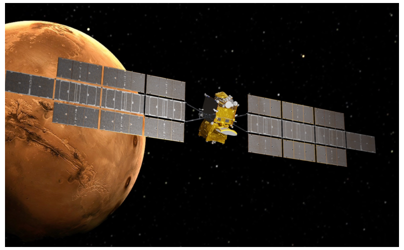
- MSR was established with unrealistic budget and schedule expectations from the beginning.
- There is currently no credible, congruent technical, nor properly margined schedule, cost, and technical baseline that can be accomplished with the likely available funding… The Current MSR architecture is highly constrained and not sufficiently robust...
- Alternate architectures, or variants of the current architecture, should be examined under clear guidelines provided by NASA HQ for yearly budget constraints, while acknowledging that the lifecycle cost will likely be in the $8-11B range regardless of architectural choices.
- Timing of ERO's Mars orbit arrival to support SRL's EDL […] results in intricately linked development and launch schedule dependency… Decouple development schedules…
- The Orbital Sample canister (OS) is the critical element […] central to the entire MSR mission. Lack of a well-defined OS design continues to impact and constrain many MSR designs […] including back planetary protection.
- The V&V program is not sufficiently mature.
- The current architecture includes helicopters as a backup capability […] out of concern for Perseverance's reliability and longevity.

MIRT's Architecture Evaluation Methodology

- MIRT developed guidelines for architecture evaluation, including mission element and organizational simplification, cost reduction and annual cost constraints, launch readiness and delay resilience, sample return dates, risk reduction, and increased technical and programmatic margins.
- MIRT evaluated more than 20 variants of the current architecture
  - ESA and MSR Project members participated significantly in all technical interchange meetings and informal studies/analyses
  - Figures of Merit and success metrics were developed for design analysis of current mission elements
  - Perseverance reliability analyses were developed, with additional life testing planned for validation
  - Cost modelling of each variant was conducted using detailed equipment lists, and PDR-level grassroots analyses for CCRS
  - While the Sample Receiving Project (SRP) was not part of the IRB's assessment, SRP annual cost was considered for budget and programmatic balance within the Planetary Sciences Division in accordance with the 2023 Decadal Survey recommendation
- Key criteria in architecture selection
  - Decouple launch dates as needed to spread funding requirements
  - Perseverance life-time and mission reliance/risk
  - Minimize overall campaign risk and ensure resiliency for launch opportunities and surface life-time
  - Consider ESA's ERO launch readiness date (LRD) and maturity of CCRS (successful technical PDR in December 2023)
  - Preserve Mars-unique skill sets at JPL and other Centers

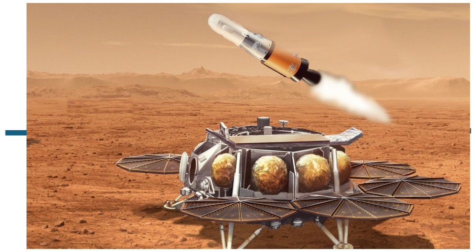
SMD's Response to Mission Architecture: Revised Mission Design (1 of 3)

2030



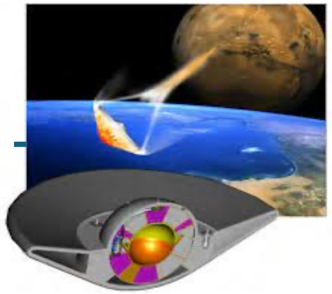
ESA Earth Return Orbiter (ERO) w/ Capture Containment and Return System (CCRS)

2035



Sample Retrieval Lander (SRL) with Mars Ascent Vehicle (MAV) and Orbiting Sample (OS)

2040



Mars Sample Direct Return to Earth, landing in Utah

- SMD concurs with the IRB that the current architecture is well constructed but is complex and is highly constrained.
- SMD concurs that variants of the current architecture as well as other potential architectures should be explored to focus mission design on Campaign goals and overall simplicity.
- SMD has revised the current architecture to increase robustness, resilience, and reduce cost risk
  - Alternative architectures are being pursued with industry and the NASA Centers and JPL

SMD's Response to Mission Architecture: Revised Mission Design (2 of 3)

- In SMD's revised mission design:
  - Perseverance would complete sample collection outside Jezero crater and return to the crater floor, transitioning into a quiescent "safe" state to await arrival of SRL; science could continue after sample delivery to the MAV
  - NASA maintains its partnership with ESA by prioritizing ERO launch first in 2030, within the ESA Ministerial-agreed launch window
    - Overall programmatic risk and NASA cost are reduced with the ESA ERO contribution, and the development maturity of ERO and CCRS
    - NASA's near-term cost risk is lowered with the successful December 2023 CCRS PDR, which included a grassroots cost estimate
    - ERO will be in-orbit when MAV launches the OS, which improves OS orbital tracking by ERO and other assets
    - Mars communications infrastructure will be refreshed prior to SRL arrival with ERO carrying ELECTRA radios
    - LRD slip to 2030 allows time to close the OS design and related Back Planetary Protection techniques and inter-Agency coordination, and develop effective V&V plans across the Campaign
  - SRL/MAV launches second in 2035
    - Launch phasing options allows flexibility
    - Perseverance reliability assessments and life tests can be completed prior to SRL/MAV PDR
    - MAV and SRL development can continue at a low level in parallel to alternative architecture studies for risk reduction; Results of industry, Center, and JPL studies can inform the mission architecture and its elements
    - SMD's revised architecture affords the least delay within the MIRT's constraints in returning samples to Earth over the current architecture's LRDs; return in 2040
- SMD concurs with the IRB that nuclear power can increase overall mission robustness, baselining a Radioisotope Thermoelectric Generator (RTG)
  - The RTG is essentially cost neutral, increases SRL mass margins and reduces SRL mechanical complexity
  - MAV will have a more benign thermal environment, increasing overall MAV reliability
  - Surface operations will be more robust with minimal season or dust storm limitations

SMD's Response to Mission Architecture: Revised Mission Design (3 of 3)

- Lowers NASA cost risk and provides budget resilience
- SMD's Life Cycle Cost (LCC) estimate of $8-11B validates the IRB LCC estimated range
    - This estimate is achievable with later LRDs due to higher-fidelity cost models and CCRS grassroots estimates developed during SMD's response process
- Supports the Agency's key, unique workforce skill sets to sustain Mars landing capability meeting the 2035 SRL LRD while still decoupling LRDs to meet annual budget caps and keeping the program balanced
- SMD concurs that the OS impacts the overall mission, but the MAV is the primary driver of architecture complexity, cost and risk. To explore alternative architectures as recommended by the IRB, the Agency is releasing a competitive solicitation to investigate significantly different approaches, or specific mission architecture elements, that can reduce cost and increase robustness.
    - Significantly smaller and lower-mass MAV designs enable substantially different SRL architectures.
    - SMD is seeking providers across the commercial, space, and defense industries with this solicitation.
    - NASA Centers and JPL will also be tasked to bring their unique expertise to bear in planetary mission design and applicable technologies.
- SMD non-concurs with the IRB-2 recommendation to return the High Gain Antenna to SRL considering the minimal improvement in mission robustness and low SRL mass margins.
- SMD also non-concurs with the IRB-2 recommendation to accommodate a single more capable helicopter
    - The mass and volume constraints from adding the RTG results in the inability to accommodate a sample retrieval helicopter.
    - The 2035 SRL LRD allows NASA to continue investigating possible accommodation of one Ingenuity-class helicopter for sample retrieval redundancy.

Organizational Structure and Management

Organizational Structure and Management

IRB Key Takeaways:

- Leadership at NASA HQ must properly organize and staff the Mars Exploration Program and the MSR Campaign with a clear and unified reporting structure and a well-defined chain of command. Leadership must also strengthen community and stakeholder engagement and provide the expertise necessary for proper programmatic control and assessment.
- The entire management and organizational structure for MSR should be revisited in order to reduce overhead and to delegate authority and accountability to key contributing partners and Project elements. This effort should include reintegrating the MEP and MSR into a single office that reports to the SMD Associate Administrator (SMD AA) and NASA Associate Administrator (NASA AA)
- Have JPL retain its MSR campaign-level technical role of leading cross-functional technical teams that provide integrative support to the MSR campaign
- There are deficiencies in the organizational and programmatic oversight structure; as well as unclear roles, accountability, and authority
- Establish separate SRBs for SRL, MAV, and CCRS that provide independent programmatic assessment (including JCLs) and adhere to conflict-of-interest and independence screening as described in the NASA SRB Handbook.

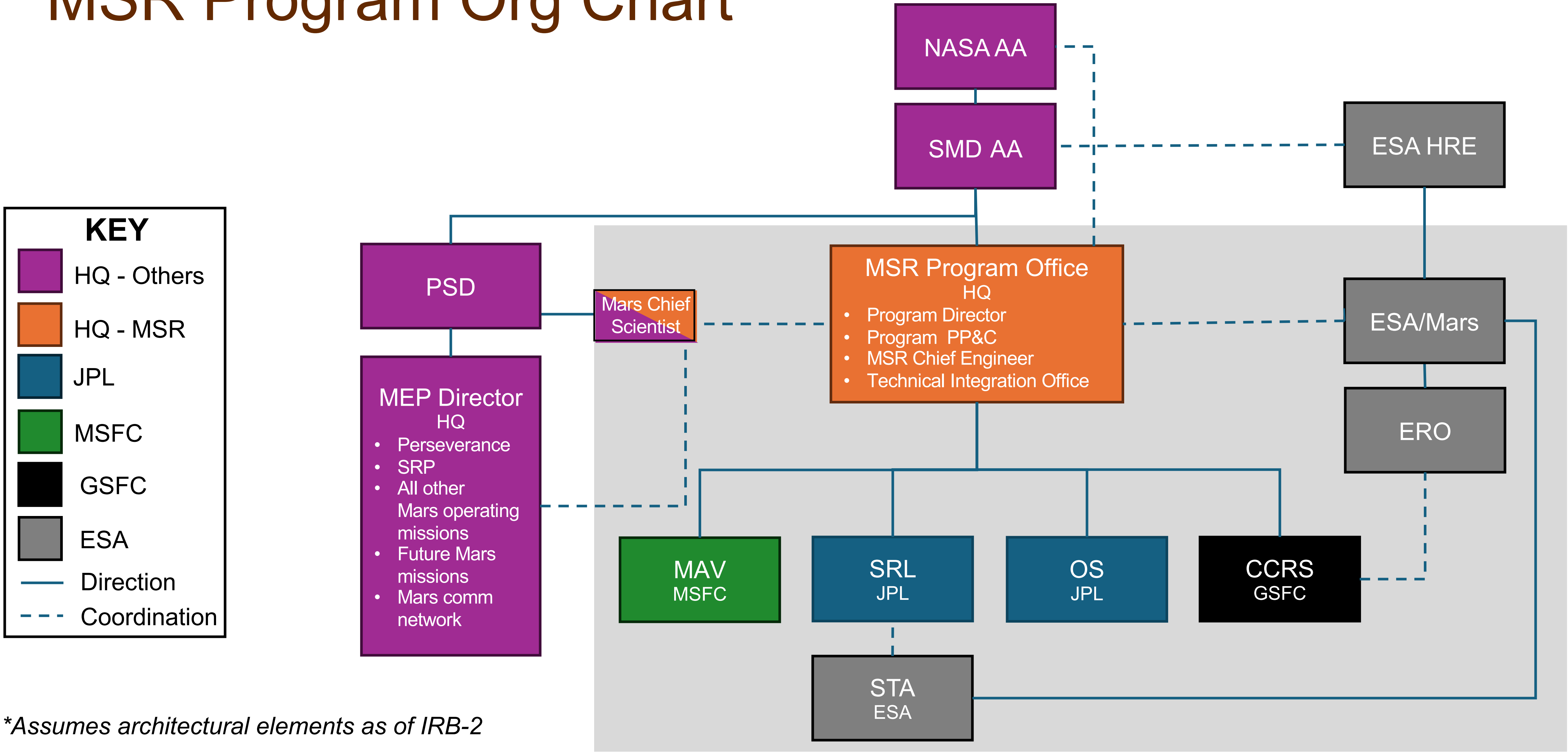
MIRT Program Organization Evaluation Methodology

- The MIRT interviewed roughly 50 SMEs internal and external to NASA to gather information and then conduct qualitative analysis
- Two organizational structures were considered by the MIRT
  1. Remerging of MEP and MSR into one program with deputies or program managers under a single program director; the Program Director (PD) reports directly to SMD AA
  2. Maintaining the current structure with MEP and MSR staying separate programs; MEP reports to PSD and MSR reports to the SMD AA
- Key criteria for MIRT consideration
  - Ensure direct Program Director (PD) visibility, access and accountability with SMD and Agency leadership
  - Ensure clear lines of authority, responsibility and accountability
  - World class leadership for both science and program management
  - Increased capability of HQ to analyze Project Planning and Control (PP&C) functions at the Campaign/Program level, and improved oversight of Project PP&C
  - Increase requirements control at the HQ level—Level 1 and Level 1.5 requirements
  - Expanded communication and coordination with international partners

SMD Response (1/2)

- SMD non-concurs with the recommendation to merge MSR and MEP. They will be retained as separate programs
  - Sustains MSR PD's laser-focus on MSR development
  - Maintains elevated priority with the MSR PD reporting directly to SMD AA, and indirectly to the NASA AA
  - Separate program budgets within the Planetary Science theme allow stakeholders to link annual appropriations to performance
  - Grounds external program advocacy (OMB, Congress, etc.) and focuses internal program direction
- SMD non-concurs with the recommendation for JPL to retain its MSR campaign-level technical leadership role. The MSR Program Office will lead campaign-level technical integration. The MSR PO will:
  - Appoint an MSR Chief Engineer, with appropriate engineering capability in the HQ PO, that reports directly to the Program Director
  - Leverage critical JPL and center skills and SMEs where they reside by establishing a distributed Technical Integration Office, ensuring Mars world-class skills are retained and employed on MSR and future Mars/planetary missions
  - Establish Level 1 and 1.5 Control Boards at HQ
  - Move MSR PP&C to the MSR Program Office
  - Be modeled after NASA's Moon-to-Mars program office
- SMD non-concurs with the recommendation to structure MSR as a Tightly Coupled Program. NASA will appropriately tailor the program plan with input from Chief Program Management Officer to apply applicable components of NPR 7120.5 policy for programs
  - SMD will expand frequency of engagement between the MSR PD and senior management – SMD AA, NASA AA, etc., outside formal engagements such as quarterlies and Baseline Performance Reviews (BPRs)

MSR Program Org Chart



**Assumes architectural elements as of IRB-2*

SMD Response (2/2)

- SMD will competitively select a world-class Mars Chief Scientist to cover both MEP and MSR to unite the community and stakeholders
  - Retains overall Mars science as part of the PSD portfolio
  - Builds advocacy and ensures scientific synergy for sample science as well as post-MSR Mars science
- SMD will elevate MAV and OS to Level 2 for correct level of development oversight and independent review
  - MSR Program will coordinate with the NASA CPMO to determine what NPR 7120.5 tailoring is appropriate for mission success
- SMD will have individual, independent SRBs for the Program and all Level 2 projects
  - Lower-level SRBs will have direct participation on the Program SRB
  - OS project life-cycle reviews should be conducted by the SRL SRB
  - Retain Center-level Independent Review Teams

Communications and External Coordination

Communications and External Coordination

IRB Key Takeaways

- The strategic and high scientific value of MSR is not being communicated effectively
- NASA is not sending a consistent and unified message to Congress, the scientific community, and to the public regarding MSR's scientific and strategic importance to the nation.
- MSR Program leadership lacks sufficient access to NASA executive leadership.
- NASA should initiate engagement with the White House Office of Science and Technology Policy and relevant regulatory agencies in order to establish protocols for decision-making and chain-of-command structure during safety inspection of the Earth Entry System at the UTTR landing site
- NASA and ESA should collaborate more closely in order to better integrate the ERO spacecraft and CCRS teams into a one-team approach wherein ESA plays a larger role in order to provide greater programmatic resilience to the overall campaign

MIRT Communications and External Coordination Evaluation Methodology

- The MIRT conducted interviews with SMEs spanning NASA/SMD leadership, Human Exploration leadership, and communications professionals
- The MIRT evaluated best practices for communications strategies and initiated dialogues between MSR and Agency leadership focused on aligning science priorities and advocacy

SMD Response

Communication

- The Mars Chief Scientist, Planetary Science Division Director, and NASA Chief Scientist will coordinate the science messaging within SMD and through a broader agency plan that includes the scientific groundwork provided by MSR in support of Moon-to-Mars/Artemis program.
- NASA Senior leadership will continue to advocate for MSR with all stakeholders as one of NASA's highest science priorities, and Planetary Science's highest decadal priority, within a balanced science portfolio.
- Frequent, direct meetings will be held between the MSR PD and the NASA and SMD AAs to ensure program status is well understood and will be scheduled based on the development phase and cadence of activity.

External Coordination

- SMD AA and MSR PD will expand open and transparent communications with ESA at all levels, especially for driving requirements and margins across interfaces.
- In collaboration with other relevant agencies, NASA will develop and implement a plan for MSR, based on OSIRIS-REX experience, for decision-making and chain-of-command structure during safety inspection of the Earth Entry System at the UTTR landing site.

Science Mission Directorate (SMD) Mars Sample Return (MSR) Independent Review Team (MIRT) Response to individual Independent Review Board 2 (IRB-2) Recommendations

IRB #1.1: The relative science merit of the 10 samples on the ground at Three Forks should be independently evaluated against additional samples currently on Perseverance and samples that may be collected during continued science operation of the Perseverance rover. Science merit should be a key input to landing site selection for MSR and operational strategies for the Perseverance rover, Sample Retriever Lander (SRL), and Mars Ascent Vehicle (MAV).

Response: SMD concurs with this recommendation. SMD's goal is to return 30 diverse samples, which provides the optimum science value. Eighteen samples represent a science threshold in the revised architecture. Either 18 or 30 samples would meet sample canister's minimum dimensional requirements for reliable in-orbit retrieval at Mars. In the revised architecture, cost and the required mass of the SRL/MAV are comparable between 18 & 30 samples. The Three Forks depot (10 samples) represents a contingency set that meets the minimal Decadal Survey science requirements and is worthy of return if it is not possible to return a more comprehensive set of samples.

IRB #1.2: NASA should develop and implement a formal, metrics-based and timeline-based plan for operating Mars 2020 with a focus on direct transfer to the SRL or placing one or more additional depots. Whether Perseverance 1) remains at the second certified landing site, 2) conducts sorties from that site, or 3) drops a second cache and is permitted to continue along its traverse towards a third certifiable landing site should depend on factors including the science value of the samples collected to date, the health of the rover, the mission architecture, and arrival dates of future flight elements.

Response: SMD concurs with this recommendation. The Perseverance rover will drive the crater rim for exploration and sampling. Exploring the Jezero crater rim area maximizes science by expanding exploration/sampling to ancient Mars and planetary evolution, hydrothermal processes, different habitable environments, and areas of aqueous alteration, none of which exist inside the crater. Reliability assessments prior to and during this extended traverse outside the crater will be conducted to assure sample delivery. The current architecture does not allow safe landing above the crater floor; therefore, SMD intends for Perseverance to return to the Jezero crater floor to await SRL arrival. Perseverance Science will continue after the sample transfer for return to Earth assuming continued Senior Review support, available funding, and rover health.

IRB #1.3: NASA should direct Mars 2020 to certify a landing site outside Jezero Crater as soon as feasible.

<u>Response</u>: SMD non-concurs with this recommendation. Landing sites outside the crater are not feasible due to engineering/mission architecture (landing) constraints at altitudes above the crater floor.

<u>IRB #1.4</u>: Mars 2020 and MSR should develop a joint plan that balances the risk of degradation or failure of Perseverance against obtaining the highest value samples near the crater rim and beyond. The plan should be appended to the existing memorandum of agreement between MEP and MSR.

<u>Response</u>: SMD concurs with this recommendation. Perseverance health, traverse capability and collected samples, as well as Mars Science Laboratory (MSL) Curiosity rover future degradation/failure events, will be the bases of metrics, and a detailed timeline will be developed with constraints based on reliability expectations of Perseverance.

<u>IRB #1.5</u>: NASA should revise the MSR Program requirement (6.1.1) related to the capability to return 30 sample tube assemblies and implement a requirement that is based on science value, the MSR timetable, and other factors relevant to successfully achieving the optimum science from MSR, including total sample mass.

<u>Response</u>: SMD concurs with the intent of this recommendation. The new Mars Chief Scientist (see response #3.2), in collaboration with the Perseverance Science Team, Planetary Science Division Director, and Mars Exploration Program Director, will ensure the samples selected for return represent the highest value samples to satisfy Decadal Survey science recommendations. With respect to number of samples, see response #1.1.

<u>IRB #2.1</u>: NASA should develop a strategy and implement a compelling communication plan that reflects MSR as an Agency priority and as a priority for the nation that has historically dared to do the seeming impossible in space. NASA's senior leadership should vigorously participate in the execution of that plan.

<u>Response</u>: SMD partially concurs with this recommendation. SMD concurs that MSR is an Agency priority. Senior leadership will continue to advocate for MSR with all stakeholders as SMD's highest Planetary Science decadal priority and will coordinate communications plans that include the scientific groundwork provided by MSR in support of Moon-to-Mars/Artemis program. The new Mars Chief Scientist (see response #3.2), the Planetary Science Division Director, and the NASA Chief Scientist will coordinate the science messaging with SMD communications and the Agency.

<u>IRB #3.1</u>: Combine the current MEP and MSR programs and establish an integrated Mars Exploration Program office at NASA HQ, reporting directly to the SMD AA and encompassing all the activities within the Mars enterprise.

<u>Response</u>: SMD non-concurs with this recommendation. SMD is retaining the current organizational structure, keeping MEP and MSR as two separate programs, to keep the MSR

Program Director laser focused on mission development. The MSR Program Office in SMD at NASA HQ (referred to simply as the MSR Program Office in the remainder of this document) has budgetary, technical, and systems integration responsibilities, and will leverage expertise across the Agency. The MSR Program Office (MSR PO) will be responsible for overall program performance within cost and schedule, and projects will be accountable to the MSR PO and their Center/JPL. There will not be a MSR Program Office at a NASA Center nor at JPL, which may require changes to the MSR task at JPL. This structure retains the elevated priority of the MSR Program Director reporting directly to the SMD Associate Administrator and indirectly to the NASA Associate Administrator.

IRB #3.2: Unify and strengthen the scientific and programmatic leadership and advocacy within this new, integrated Mars Exploration Program in order to enhance communication with senior NASA leadership, the planetary science community, and other stakeholders.

Response: SMD partially concurs with this recommendation. SMD non-concurs with combining the MEP and MSR programs (see response #3.1). SMD concurs with unifying and strengthening leadership and advocacy under a world-class Mars Chief Scientist to cover both the MEP and MSR programs. The Mars Chief Scientist will link MSR and broader Mars exploration science objectives and unite the community and stakeholders. NASA's plan will retain overall Mars science as part of the Planetary Science Division portfolio and will create advocacy for sample science as well as post-MSR Mars science.

IRB #3.3: Establish full programmatic responsibility and authority within the Mars Exploration Program office at HQ, separating the budget from the Planetary Science Division and creating a properly-staffed Program Planning and Control (PP&C) group within the new HQ program office. All Projects within the integrated MEP should report programmatically to the HQ MEP PP&C group.

Response: SMD partially concurs with this recommendation. SMD non-concurs with combining the MEP and MSR programs (see response #3.1). SMD is retaining the authority, accountability and responsibility of the MSR Program Director to successfully deliver the samples to Earth, and is enhancing and staffing the MSR Program Office's PP&C organization to appropriately manage PP&C for the program. Project-level PP&C will remain the responsibility of the Level 2 Projects and their respective Centers, and report programmatically to the MSR Program Office. SMD does not intend to separate the MSR budget from the Planetary Science Division (PSD) since it is an independent line in the PSD budget already which provides adequate transparency.

IRB #3.3.1: The HQ MEP PP&C should set project analysis and reporting standards and should conduct independent monthly programmatic assessments based on Project-provided data.

Response: SMD partially concurs with this recommendation. SMD non-concurs with combining the MEP and MSR programs (see response #3.1). SMD is enhancing the PP&C

functions within the MSR Program Office and is in the process of establishing analysis and reporting standards for the program and its projects. In this construct, all projects within the MSR Program will conduct project-level PP&C and report programmatically to the MSR Program Office.

IRB #3.4: Have JPL retain its MSR campaign-level technical role of leading cross-functional technical teams that provide integrative support to the MSR campaign.

Response: SMD non-concurs with this recommendation. The MSR Program Office will lead campaign-level technical integration. SMD will leverage the critical skills and subject matter experts residing at JPL, and other NASA Centers by establishing a distributed Technical Integration Office, under the direction of the new MSR Chief Engineer in the MSR Program Office. This will enhance active collaboration across elements while utilize subject matter experts, thereby providing more comprehensive integrative support to the MSR campaign with fewer layers of management and greater cross-project collaboration.

IRB #3.5: Give full technical responsibility and authority for the individual MSR projects to their respective labs/field centers with the directors held fully accountable for their organization's contribution.

Response: SMD concurs with this recommendation. SMD will raise the MAV and OS projects as Level 2 projects. NASA Centers are responsible for the technical, cost and schedule performance of their projects. Independent Review Teams will be retained as a Center resource to ensure that visibility, project resource needs, and performance are clearly understood and managed by their respective Centers. Concurrently, SMD will establish Standing Review Boards for all Level 2 MSR projects.

IRB #3.6: Enhance project business office PP&C staffing and capabilities (e.g., tools, processes) in order to ensure the implementation of the depth and breadth of programmatic management necessary for a large complex mission (e.g., planning, maintenance, tracking, assessment, analysis/forecasting, schedule cost/risk analysis, control).

Response: SMD concurs with this recommendation. The MSR Program Office is enhancing its PP&C functional support by recruiting individuals with the requisite skill sets to execute program-level PP&C and to develop an MSR Program PP&C plan. The MSR Program is collaborating with Center(s) leadership to ensure that project-level PP&C teams are adequately staffed with personnel possessing the appropriate capabilities and experience and are executing required PP&C functions for project performance and risk.

IRB #4.1: NASA senior leadership should manage and advocate for MSR as a priority for the nation.

<u>Response</u>: SMD concurs with the intent of this recommendation. NASA Senior leadership will continue to advocate for MSR with all stakeholders as one of NASA's highest science priorities, and Planetary Science's highest decadal priority, within a balanced science portfolio.

<u>IRB #4.2</u>: The director of the integrated MEP must be a world-class leader who is responsible for prioritizing sample return from Mars utilizing current assets, coordinating with ESA, and meeting overall science goals that are consistent with the recommendations of the Planetary Science and Astrobiology Decadal Survey.

<u>NASA Response</u>: SMD partially concurs with this recommendation. SMD non-concurs with combining the MEP and MSR programs (see response #3.1). SMD concurs with the need for the leadership of the MSR Program to be populated with world class leaders to maximize mission success. Therefore SMD is establishing a Mars Chief Scientist position to link MEP and MSR science, advocate for the science requirements and benefits of MSR, and ensure MSR-related elements in both MEP and MSR will meet the science recommendations of the Decadal Survey.

<u>IRB #4.3</u>: The director of the integrated MEP should report on the status of MSR to the NASA Associate Administrator at no less than a bi-weekly cadence.

<u>NASA Response</u>: SMD partially concurs with this recommendation. SMD non-concurs with combining the MEP and MSR programs (see response #3.1), however, the MSR Program Director will schedule frequent, direct meetings with the NASA and SMD Associate Administrators to ensure MSR status is well understood. The frequency of the meetings will be based on the development phase of the program and the cadence of activity. These interactions will be less formal and more frequent than Baseline Program Reviews (BPRs) and MSR Quarterlies.

<u>IRB #5.1</u>: Decouple the ERO and SRL development schedules by transferring full responsibility for the integrated ERO mission to ESA. This arrangement will allow GSFC to work with ESA and Airbus without going through JPL.

<u>Response</u>: SMD concurs with this recommendation. SMD accepts and supports ESA's ability to successfully accomplish ERO, recognizing ERO's importance to ESA and its goals in Mars exploration, and the MSR Program Office will move forward accordingly. SMD has established closer ties between MSR's Capture, Containment, and Return System (CCRS) and ESA's ERO to ensure these "mission partners" operate efficiently.

<u>IRB #5.1.1</u>: Focus the NASA/JPL efforts on the elements and infrastructure that are required to get the OS into a defined and stable Mars orbit through all available assets (in collaboration with ESA for Trace Gas Orbiter (TGO) relay communications), while ESA focuses on OS retrieval and OS return to Earth.

Response: SMD concurs with this recommendation.

IRB #5.1.2: JPL should continue to lead overall campaign technical integration and management of Level 1.5 requirements including backward planetary protection, in proper coordination with ESA.

Response: SMD non-concurs with this recommendation. Technical Integration will be led out of the MSR Program Office's Chief Engineer's Office. Level 1 and 1.5 requirements will be managed by the MSR PO, including the Engineering Change Boards. The program's distributed Technical Integration Office (TIO) is part of the MSR PO's Chief Engineer's Office. The TIO provides program-level system engineering integration across the MSR campaign. The TIO will consist of Mars-specific disciplines that reside at JPL and other NASA Centers as needed, augmented by subject matter experts, such as risk management from GSFC, rocket expertise from KSC, MSFC or JSC, and technologists from ARC or GRC, etc. as appropriate.

IRB #5.1.3: Accept ESA's ability to successfully accomplish ERO, recognizing ERO's importance to ESA and its goals in Mars exploration.

Response: SMD concurs with this recommendation.

IRB #5.1.4: Give GSFC full responsibility and authority for leading the CCRS development (including the JPL components) as a deliverable payload to ESA.

Response: SMD concurs with this recommendation.

IRB #5.1.5: ESA should provide adequate visibility into driving technical parameters and margins and should help facilitate closure of the CCRS design.

Response: SMD concurs with this recommendation. SMD, MSR and ESA will continue transparent communications at all levels, especially for driving requirements and margins across interfaces (see response #5.1.6).

IRB #5.1.6: NASA and ESA should collaborate more closely in order to better integrate the ERO spacecraft and CCRS teams into a one-team approach that incorporates contractual considerations into a modified interagency agreement.

Response: SMD partially concurs with this recommendation. SMD non-concurs that a modification to the existing interagency agreement is needed. SMD fully agrees with creating a more collaborative relationship between CCRS and ERO. SMD/MSR and ESA have established a dedicated ERO-CCRS Interface Co-Engineering Team to perform co-engineering activities between CCRS and ERO (ESA/Airbus) teams.

__IRB #6.1__: Close the OS design and all associated interfaces before the Program's preliminary design review season. Even if there are changes in the overall MSR Program plans, and these changes cause changes in the OS, the necessity of closing the OS design as soon as possible (and before other elements' designs are finalized and reviewed) remains undiminished.

<u>Response</u>: SMD concurs with this recommendation. SMD will elevate the OS to a Level 2 project to focus management of requirements and interfaces. The OS is the anchor point for overall lander system design and is managed through formal interface documentation and control boards. An OS design maturity review was conducted in March 2024, to confirm that the overall design is sufficiently mature and that critical design phase plans are reasonable.

__IRB #7.1__: Results of JPL's ongoing microbiological testing of the proposed UV treatment should be reviewed by NASA's Office of Safety and Mission Assurance as well as relevant US regulatory agencies. If the results are accepted as preliminary validation of the UV design, then the reviewing organizations should select an independent laboratory for additional decontamination testing and final validation of compliance with backward planetary protection requirements. NASA should work closely with ESA on review and validation of the MSR design for UV decontamination.

<u>Response</u>: SMD concurs with this recommendation. SMD will continue to engage with U.S. government agencies in reviewing backward planetary protection, in concert with NASA's Office of Safety and Mission Assurance, National Space Council's Interagency Working Group (IWG) as part of the National Strategy for Planetary Protection.

__IRB #8.1__: All aspects of the MSR design for compliance with backward planetary protection requirements should be reviewed and accepted by NASA's Office of Safety and Mission Assurance as well as the relevant US regulatory agencies.

<u>Response</u>: SMD concurs with this recommendation. SMD will review and obtain concurrence by NASA's Office of Safety and Mission Assurance (OSMA) per NPR 8715.24, Planetary Protection Provisions for Robotic Extraterrestrial Missions and NASA-STD-8719.27, Implementing Planetary Protection Requirements for Space Flight.

__IRB #8.1.1__: In addition to UV decontamination of possible Martian biohazards, safety reviews should cover models and testing for breaking the chain of contact and robust containment of non-sterilized material from Mars.

<u>Response</u>: SMD concurs with this recommendation. The models exist, are being used, and testing is defined. Review and concurrence by NASA's Office of Safety and Mission Assurance (OSMA) will be performed per NPR 8715.24, Planetary Protection Provisions for Robotic Extraterrestrial Missions and NASA-STD-8719.27, Implementing Planetary Protection Requirements for Space Flight.

IRB #8.2: NASA should initiate engagement with the White House Office of Science and Technology Policy and relevant regulatory agencies in order to establish protocols for decision-making and chain-of-command structure during safety inspection of the Earth Entry System at the UTTR landing site.

Response: SMD concurs with this recommendation and a plan based on the OSIRIS-REX engagement strategy will be developed for MSR and implemented based on its projected landing date.

IRB #9.1: NASA should examine other potential architectures or variants of the current architecture in order to determine whether there are options that offer greater technical robustness and schedule resilience to launch phasing or launch delays, while fitting within annual budget constraints and lowering programmatic risk. Actively seek and analyze alternatives that might provide larger technical margins than the current architecture while also being technically simpler at the individual project, system, and subsystem levels. The mindset should be simplicity in design, taking advantage of heritage design and approaches, examining mission classification specific to each project element, and execution of a robust cross-cutting V&V program. Enlist independent programmatic analysts to assess each technically viable alternative in order to determine whether the alternative can be implemented with high confidence and lower cost and schedule risk within the annual budget constraints imposed by NASA.

Examine which path forward best balances technical and programmatic constraints, given the current status of the Program and the recommendations made in this report.

Alternate architectures should be carefully compared to variants of the existing architecture in terms of technical, schedule, and cost risk.

Response: SMD concurs with this recommendation. SMD has evaluated multiple architectures considering technical robustness, launch dates and sample return-to-Earth dates, cost/schedule risk, risk to a balanced science portfolio, maintaining partnership accords, and workforce skill retention. The revised mission design incorporates upgrades and benefits to the original architecture including: 1) RTGs to improve reliability and thermal stability, 2) serialized launches to accommodate budget constraints, 3) makes multiple launch readiness opportunities available, 4) provides multiple landing locations within Jezero crater floor, 5) refreshes telecommunications, 6) lowers near-term cost risk, 7) increases operational robustness (not seasonally constrained), (8) improves system margins and robustness, and 9) provides time to mature SRL and MAV. It also descopes the helicopters. The most significant architectural challenge is successfully delivering MAV to the surface of Mars. SMD has determined that both the OS and MAV designs are the drivers of the overall MSR architecture, and a smaller/lighter MAV is the key to a smaller, lighter, less complex, and lower cost and risk Sample Retrieval Lander (SRL). Additionally, since the MAV is arguably the most critical new MSR development, the organizational structure *and procurement options for MAV should be assessed to maximize the potential for mission success.*

SMD's architecture cost analysis confirmed the IRB-2 estimated life cycle cost range was accurate and is supported by higher fidelity estimates that were not available to IRB-2 at the time. In accordance with the IRB-2's recommendation, SMD evaluated architecture variations under clear guidelines for yearly budget constraints, resulting in acknowledgment that the lifecycle cost will likely be in the $8 to $11B. Therefore, SMD is releasing a competitive solicitation to industry with the intent to identify significantly different, viable architectures and/or architecture elements to lower cost, return samples earlier, and/or increase campaign resilience. The industry, center and JPL studies will be required to return at least 10 samples collected by Perseverance, possibly including the Three Forks depot. These solicitations may result in modifications to the architecture by altering specific elements (e.g., the MAV), discover a new overall architecture for MSR, or confirm that SMD's revised architecture is the most viable. In parallel, NASA SMD will engage NASA centers and JPL to provide their unique expertise and technology capabilities for additional out-of-the-box options.

IRB #9.2: If a significantly different alternate architecture is determined to be the best way forward for the Program, the MSR Program should consider reallocating responsibilities among participants or adding other experienced and qualified sources when developing an acquisition strategy for the alternatives.

Response: SMD concurs with this recommendation.

IRB #10.1: Establish MSR as a Tightly-Coupled Program consisting of three projects (SRL, MAV, and ERO/CCRS).

Response: SMD concurs with the intent of this recommendation. The MSR Program is a unique program implementation for SMD that is not readily aligned with a Tightly Coupled or a Single Project Program. Rather than force fitting a program structure, the MSR Program Office will work with SMD and the NASA Chief Program Management Officer (CPMO) to appropriately tailor components from various program types for mission success and will document in the program plan. SMD is elevating the OS to a level 2 project so the MSR program will consist of four projects (SRL, MAV, ERO/CCRS and the OS).

IRB #10.2: Set separate programmatic baselines (i.e., Management Agreements, Agency Baseline Commitments) for SRL, MAV, and CCRS, reporting to the MSR Program Office (according to NPR 7120.5).

Response: SMD concurs with this recommendation.

IRB #10.3: UFE must be re-established at a minimum of 30% for each project in order to manage risks (i.e., SRL, CCRS, and MAV [...] to manage risks to a 70% confidence level).

<u>Response</u>: SMD concurs with this recommendation.

<u>IRB #10.4</u>: If the most important budgetary constraint is annual cost, NASA HQ should provide commitments for annual cost ceilings in order to guide the development of the go-forward program, while de-emphasizing lifecycle cost as a critical measure of MSR programmatic success.

<u>Response</u>: SMD concurs with the intent of this recommendation. NASA agrees with the need for balance within the science portfolio. We have a well-established process for establishing cost, schedule and life cycle commitments at confirmation. NASA will work to its cost and schedule commitments while maintaining balance within the science portfolio through constraints associated with annual phasing of the budget and work.

<u>IRB #10.5</u>: To increase the probability that the MSR program can succeed within the directed annual budgetary constraints, the Program should consider a range of options including launch delays and alternate architectures that provide greater architectural robustness and resiliency.

<u>Response</u>: SMD concurs with this recommendation. SMD examined more than 20 different architectural modifications and budget profiles to meet annual life cycle budget guiderails and will move forward with an architecture best suited for mission success within the constraints assigned. Proposed annual budget profile will be set by NASA and formalized through the Fiscal Year 2026 budget request and future budget formulation processes, and set for MSR at Confirmation per the NPR 7120.5.

<u>IRB #10.6</u>: Conduct the Program PDR only after all of the projects have demonstrated at their PDRs/KDP-Cs that they have congruent technical, schedule, and cost baselines.

<u>Response</u>: SMD concurs with this recommendation.

<u>IRB #10.7</u>: Postpone programmatic baselines (MAs/ABCs) for SRL, MAV, and CCRS until credible technical baselines can be achieved for the present architecture or alternative architectures that add greater robustness and resiliency. Programmatic baselines must then be established with robust reserves in order to ensure that the projects have the resources required for mission success.

<u>Response</u>: SMD concurs with this recommendation.

<u>IRB #11.1</u>: As a Tightly Coupled Program, establish separate SRBs for SRL, MAV, and CCRS that provide independent programmatic assessment (including JCLs) and adhere to conflict-of-interest and independence screening as described in the NASA SRB Handbook.

<u>Response</u>: SMD concurs with the intent of this recommendation. SMD will establish separate Standing Review Boards (SRBs) for its projects, except OS will be reviewed with

SRL. The MSR Program Office will collaborate with the CPMO to appropriately tailor SRBs to this unique program implementation in accordance with NASA policy.

IRB #11.2: The program SRB should comprise a crosscut of independent program-level experts combined with the Chairs and a subset of other relevant members from the individual projects SRBs.

Response: SMD concurs with this recommendation.

IRB #11.3: Each MSR Independent Review Team (IRT) activity should be retained with the addition of SRB cross-cutting support but with the traditional focus of supporting the needs of the executing institution.

Response: SMD concurs with this recommendation.

IRB #11.4: Perform SRB-chaired PDRs and establish individual baselines for each of the Projects.

Response: SMD concurs with this recommendation.

IRB #11.5: In accordance with NPR 7120.5F, JCL analysis is required at KDP-C for the Projects (SRL, MAV, CCRS) with the Program-level SRB integrating those analyses into a broader programmatic assessment of the end-to-end effort at KDP-II.

Response: SMD concurs with this recommendation.

IRB #11.6: PDR entrance and success criteria leading to KDP-C should include an assessment of the integrated technical and resources baseline.

Response: SMD concurs with this recommendation.

IRB #11.7: The Program and each MSR Project (SRL, MAV, and CCRS) should report to their respective SRBs on a quarterly basis.

Response: SMD concurs with this recommendation.

IRB #12.1: Establish SRL/MAV and ERO/CCRS as individual programmatic partners in order to allow each grouping to focus on building intercultural bridges between organizations.

Response: SMD concurs with this recommendation. SMD is implementing a new MSR organizational structure to remove unnecessary interfaces and layers between projects, creating direct links between them.

IRB #12.2: Clarify the domain and phase structures, enable multi-institutional group members to communicate directly and make decisions across institutions, and empower those groups to resolve conflicts. This approach will develop cross-site visibility and shared understanding.

Response: SMD concurs with this recommendation. SMD has added a MSR Chief Engineer and a TIO to the MSR Program Office to ensure free and open communication between groups and empowers them to resolve conflicts.

IRB #12.3: Invest in periodic and sustained in-person interactions between engineers working on parallel or related tasks across programmatic partners (i.e., the domains). The MSR Program Office should fund and facilitate team members visiting their collaborators in other institutions as part of developing intercultural fluency and inter-organizational visibility. In-person gatherings of sub-groups with multi-institutional representations should occur at a regular cadence in order to supplement online meetings.

Response: SMD concurs with this recommendation.

IRB #12.4: The MSR Program should facilitate intercultural training among team members in order to facilitate conflict resolution and better understanding of engineering and management issues.

Response: SMD concurs with the intent of this recommendation. The MSR Program Office will identify strategies to foster greater understanding, collaboration, and conflict resolution.

IRB #12.5: Place team members on location at a collaborating institution, as ESA has done at Goddard Space Flight Center.

Response: SMD concurs with this recommendation. MSR PO is embedding key team members on location at collaborating institutions to greatly improve the cross-collaboration and contribute to overall mission success.

IRB #12.6: Document multi-organizational decisions and changes in order to ensure robust multi-institutional communication, baseline control, and flow down.

Response: SMD concurs with this recommendation. A program-wide accessible data system will be used to capture decision documents, configuration management actions, and baseline changes.

IRB #13.1: Develop integrated and detailed V&V plans (with credible schedules and costs) to a level of confidence that is appropriate for this flagship mission prior to completion of preliminary design review activities.

<u>Response</u>: SMD concurs with this recommendation. These plans will be developed by the MSR Program Office.

<u>IRB #13.2</u>: Ensure that each integrated V&V activity has properly recognized and scheduled the development of all required ancillary elements including flight software, ground software, ground support equipment, hardware-in-the-loop, testbeds, and simulations.

<u>Response</u>: SMD concurs with this recommendation. These plans will be developed by the MSR Program Office.

<u>IRB #13.3</u>: Ensure clear system V&V leadership and coordination across elements. Ensure reasonable time and staffing allocations to complete proper V&V of the integrated systems.

<u>Response</u>: SMD concurs with this recommendation. This will be led by the MSR Program Office.

<u>IRB #13.4</u>: Address fault management and contingency planning in the development of detailed V&V plans.

<u>Response</u>: SMD concurs with this recommendation. The MSR Program Office will implement consistent with NPR 7123.1.

<u>IRB #14.1</u>: Restructure the engineering organization by removing overlapping layers in the phase-lead organization and by strengthening cross-project-domain working groups.

<u>Response</u>: SMD concurs with this recommendation. The phase-lead and domain working groups have been reviewed by the MSR Program Office and are being strengthened to reduce overlapping layers.

<u>IRB #14.2</u>: Transition the phase lead role from the Program Office to the Project Offices so there is only one layer of phase leadership.

<u>Response</u>: SMD non-concurs with this recommendation. The phase-lead roles have been evaluated by SMD and the MSR PO, and will appropriately remain at the program level to ensure integration of all elements contributing to a specific phase. The MSR Chief Engineer will determine the appropriate phase lead structure at the program level.

<u>IRB #14.3</u>: Elevate the responsibility of the two cross-project domains (backward planetary protection, OS) so that these domains are integrating all activities associated with their domain across the program.

<u>Response</u>: SMD concurs with this recommendation, including elevating OS to a Level 2 Project. The Backward Planetary Protection and OS cross-project domains will be led at the

Program-level to have elevated responsibility to integrate all activities associated with the domains.

<u>IRB #14.4</u>: MSR must continue to retain strong cross-organizational engineering management of the integrated system's functionality, operations, and interfaces. All system elements must be represented, independent of the schedule relationship between the individual Projects.

<u>Response</u>: SMD concurs with this recommendation. The MSR Program Office has established the position of MSR Chief Engineer, reporting to the Program Director, to lead the Campaign's systems engineering and project integration function. The addition of the MSR Chief Engineer role and the TIO creates strong cross-organization engineering management of the integrated system, including its functionality, operations and interfaces.

<u>IRB #15.1</u>: Formally include other (existing and future) orbital assets in the baseline concept of operations, and plan on managing those assets in order to maximize MSR robustness.

<u>Response</u>: SMD concurs with this recommendation. SMD and MSR PO will update Level 1.5 requirements to recognize use of multiple assets to maximize MSR robustness (e.g., ExoMars Trace Gas Orbiter). The MSR Program Office will increase its participation in the International Mars Relay Coordination Working Group for management of the orbital assets.

<u>IRB #15.2</u>: Extend the NASA-ESA agreement to include use of TGO as a telecommunication relay link for SRL.

<u>Response</u>: SMD concurs with this recommendation. ESA and SMD have initiated the process to extend the Interagency Agreement to include the use of TGO.

<u>IRB #15.3</u>: Add back the HGA on the SRL for robustness and resiliency.

<u>Response</u>: SMD non-concurs with this recommendation. SMD has concluded that the HGA size that can be accommodated on SRL does not offer significant Direct-To-Earth (DTE) downlink capability for the mass and volume accommodations required, nor does it significantly add robustness or resiliency. The ELECTRA communication payload is a reliable capability on ERO that provides reliable SRL communications back to Earth.

<u>IRB #16.1</u>: If mass and accommodation complexity of two helicopters are driving the SRL design in a way that jeopardizes design closure of the system and/or creates significant risks (to SRL in general, or helicopter accommodation in particular), a single higher-reliability helicopter accommodation solution is better than two compromised helicopters (or no helicopter) in order to preserve the capability as part of the present architecture.

Response: This recommendation is no longer applicable. SMD will accommodate the Radioisotope Thermoelectric Generator (RTG) in the revised architecture, which does not allow accommodation of helicopters. SMD has determined that greater mission robustness is realized through addition of an RTG by removing the mechanism complexity of the solar arrays, providing a benign thermal environment for MAV, providing overwintering capability should it be needed, and increasing design mass margins. Careful evaluation of Perseverance reliability and entering a quiescent state to wait for MSR SRL, significantly reduces the need for backup helicopter(s). For added risk reduction, the MSR Program will investigate methods to accommodate one backup helicopter with the RTG, within budget constraints.

IRB #17.1: As a large program with multiple partners, MSR must have a rigorous and thorough baseline management and change control process at the top level in order to ensure that all interfaces and associated high-level requirements are fully socialized, documented, and controlled. Starting now, the Program needs to establish a mechanism to document and communicate the working baseline (e.g., a Baseline Description Document [BDD]) for each Project and at the Program level. The contents should at a minimum include those issues that drive system schedule, cost, and impact to partner organizations. There should also be an effective baseline management process and change control process (including impact assessment).

Response: SMD concurs with this recommendation.

IRB #17.1.1: The formal baseline management and change control process that rigorously follows the standard NASA guidelines should be implemented by PDR. A key goal of decoupling is to enable agility at the lower levels due to the rigor and stability that are induced by formal control of the higher-level requirements. In coordinating the various change control processes at the different MSR organizations, focus should be placed upon maintaining common baselines.

Response: SMD concurs with this recommendation. The MSR Program Office will manage interfaces across the MSR program elements. Management and change control processes follow Agency configuration management and control standards.

IRB #18.1: SRL is encouraged to increase the interactions with LSP in order to keep the trade space open to options as the mission requirements including mass and performance are settled.

Response: SMD concurs with this recommendation. The MSR PO and SRL will continue to engage with LSP on development of the Launch Service Interface Requirements Document (LSIRD) essential to define the spacecraft to LV interface requirements.

IRB 18.2: The NASA/ESA agreement should provide visibility into development and certification of the vehicles.

Response: SMD non-concurs with this recommendation. ESA is responsible for the certification of their launch vehicles. The MOU allows sufficient insight into the ESA launch vehicle process through the Joint Management and Implementation Plan (JMIP), which is consistent with SMD practice.

IRB #19.1: The MSR Program will require a commitment for onsite presence in order to enable the monitoring of progress, delivery of hardware, and prompt disposition of risks and issues. Plans seem to have accounted for the inefficiencies of the current hybrid approach, but expectations should be clearly stated for the many functions that require an onsite presence. NASA and ESA should be proactive and prepare for a sustained onsite effort of highly skilled personnel beyond the present levels (possibly 10-15% higher) during implementation.

Response: SMD concurs with the intent of this recommendation. SMD recognizes the importance of having workforce on-site to promote relationship building and to foster communication and cooperation. Within the scope of their authority, Project managers will direct schedules for both direct and matrixed personnel for on-site presence. NASA Centers are responsible for the cost and schedule performance of their projects. SMD and ESA will explore the benefits of residents co-located with MSR's European partners and NASA Centers/Industry partners.

IRB #20.1: Simplifying and finalizing designs and procurements are important in order to adapt to the changing market. Supply chain management should be specifically added as a responsibility to designated existing Program and Project personnel, or new positions should be added in order to address issues and to ensure critical review, so surprises are minimized.

Response: SMD concurs with this recommendation. The Agency is establishing a Supply Chain Management Office function to support projects and work with other government agencies to mitigate risk associated with industry wide supply chain issues, and the MSR PO will engage this office to ensure coordination and support. The Agency Supply Chain Office will present at all MSR Key Decision Points (KDPs).