Overview of Crew Operations for Transit to Mars

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Crewed Mars missions are estimated to be 700-1,200 days in length which is two to three times longer than any continuous human spaceflight mission to date. When architecting a Mars mission there are numerous resources that must be considered, evaluated, and planned for, including—but not limited to—mass, cost, performance, and risk. Crew time is a limited resource that will need to be appropriately allocated during future Mars missions. NASA's "Moon to Mars Objectives" specifically recognizes as Recurring Tenets the need to return crews safely to Earth while mitigating adverse impacts to crew health and maximizing crew time available for science and engineering activities within planned mission durations. Crew operations and the crew time allocation for a Mars missions will likely be different than current operational planning aboard the ISS due to communication delays, crew health and performance needs, transportation system needs, potential vehicle dormancy, and mass ejection. Crew will need to operate much more Earth independently and potentially be responsible for more operations since traditional Earth ground support will be delayed. Incidents requiring immediate crew action will therefore either be the responsibility of the crew or an automated feature of the transit vehicle. This paper discusses the operational challenges of a Mars transit mission and the associated activities that will need to take place during each operational phase of transit to and from Mars.

I. Acronyms

BH&P	=	Behavioral Health and Performance
EDL	=	Entry Decent and Landing
EOI	=	Earth Orbit Insertion
ESDMD	=	Exploration Systems Development Mission Directorate
EVA	=	Extravehicular Activity
ISS	=	International Space Station
IVA	=	Intravehicular Activity
LEO	=	Low Earth Orbit
MAV	=	Mars Accent Vehicle
MOI	=	Mars Orbit Insertion
NASA	=	National Aeronautics and Space Administration
PR	=	Pressurize Rover
RT	=	Recurring Tennant
SAC21	=	Strategic Analysis Cycle 2021
TEI	=	Trans Earth Insertion
TH	=	Transit Habitat

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TMI = Trans Mars Insertion

II. Introduction

Crewed Mars missions are estimated to be 700-1,200 days in length which is two to three times longer than any continuous human spaceflight mission to date. When architecting a Mars mission there are numerous resources that must be considered, including—but not limited to—mass, cost, performance, and risk. Crew time is a limited resource that will need to be appropriately allocated during future Mars missions. The National Aeronautics and Space Administration's (NASA) "Moon to Mars Objectives" [1] specifically recognizes the need to return crews safely to Earth while mitigating adverse impacts to crew health and maximizing crew time available for science and engineering activities within planned mission durations. While the missions themselves will be longer than past experience, the longer mission also increases demand on crew time for nominal and off-nominal operations. By examining crew time allocations, analysts can identify and characterize the relevant ways in which Mars missions differ from those in Low-Earth Orbit (LEO) and appropriate recommendations to the mission architecture.

Crew time allocation for Mars missions will be different than current operational planning aboard the International Space Station (ISS) for several reasons. Communication delays necessitate alternatives to the traditional near-real-time two-way communication strategies that are currently commonplace. Crew will need to be much more Earth-independent and thus responsible for day-to-day vehicle system and subsystem operations and monitoring because traditional ground support will be delayed. Incidents requiring immediate crew action will therefore either be the responsibility of the crew or an integrated autonomous feature of the transit vehicle. Additionally, crew health and performance needs, as well as transportation system needs, may require more crew time than typical ISS operations. The extended duration of a Mars mission means that crew members will be subjected to the hazards of the space environment for an unprecedented amount of time, increasing their health risks and potentially reducing their capacity to perform mission duties. Consequently, crew health and performance may require more designated crew time to maintain crew health and ensure the successful completion of the mission.

III. Background

A. NASA's Moon to Mars Objectives

In early 2023, the National Aeronautics and Space Administration (NASA) released a document outlining the Agency's Moon to Mars Objectives [2]. The purpose of NASA's Moon to Mars Objectives is to develop and document an objectives-based approach to its human deep space exploration effort [1]. The document creates a blueprint for sustained human presence and exploration throughout the solar system and provides a value proposition for humanity that is rooted across three pillars: science, inspiration, and national posture. The document contains 63 objectives, as well as nine Recurring Tenets (RTs) that capture common themes that are broadly applicable across the objectives. The crew transit operations timeline aims to address three of these recurring tenets[1]:

- RT-3: "Return crews safely to Earth while mitigating adverse impact to crew health"
- RT-4: "Maximize crew time available for science and engineering activities within planned mission durations"
- RT-5: "Maintainability and reuse: when practical, design systems for maintainability, reuse, and/or recycling to support the long-term sustainability of operations and increase Earth independence"

B. Scope

The NASA Mars Architecture Team (MAT) analyzes a variety of architectures for a human Mars mission. Several options that exist within the trade space involve some portion of the total crew descending to the Martian surface while the other crew remain in Mars orbit. It is important to note that this architecture and mission profile is just one of several being traded. The architecture mission considered in this paper is the System Analysis Cycle 2021 (SAC21) architecture [3].

The primary mission objective for the first crewed mission to Mars is to land humans on the surface and return them, and their cargo, safely back to Earth. The SAC21 architecture consists of a mission in which four crew travel to Mars, and two descend to the surface for 30 sols while the other two remain in Mars orbit, for a total mission duration of 850 days. The Transit Habitat (TH) is the notional element in which crew will live during transit to and from Mars [4]. The TH in combination with the notional transportation system forms the Deep Space Transport (DST). The TH serves as the habitable volume to include life support systems, logistics storage, EVA operations, and crew hygiene, medical, exercise, sleeping quarters capabilities.

For crew transit operations, the portion of the mission covered in this paper is the time between the crew's Earth Departure and Mars arrival, and vice-versa; it does not include surface operations. This paper also covers the operations of the crew that remain in orbit when the other two descend to the surface as shown in Fig. 1.

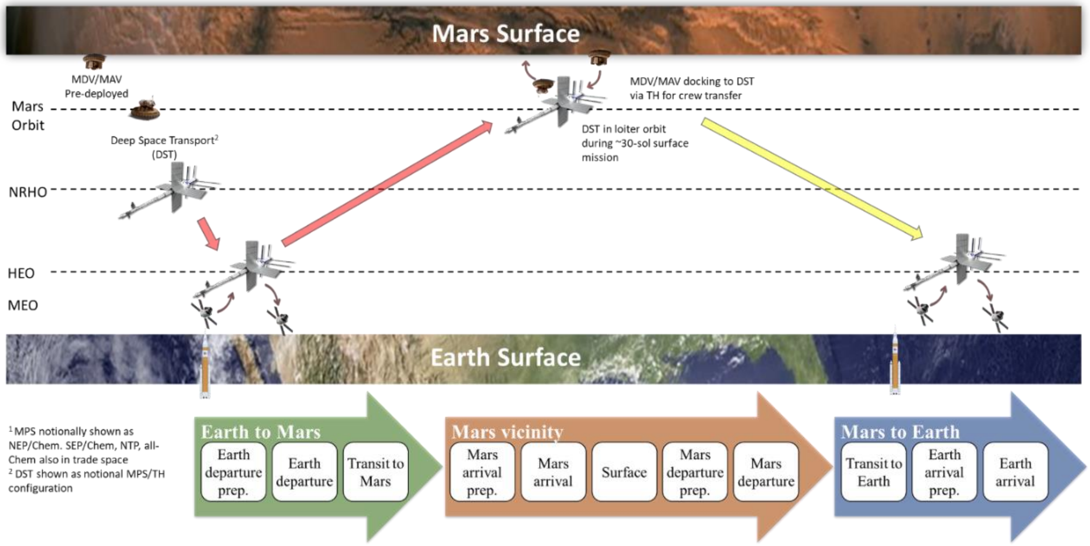

Fig. 1 Crewed Mars transit definition.

IV.Operational Experience on ISS

The ISS has been continuously crewed for over two decades. That operational experience has enabled the precise categorization of a variety of crew activities. Moreover, the ISS "Strategic and Tactical Planning" document [5] provides detailed crew time requirements for a standard crew workday. This document outlines requirements for daily workload, sleep, exercise, and personal time [5]. The requirements for crew activities can be grouped into to a few broad categories:

- Maintenance: the function of keeping items or equipment in, or restoring them to, a specified operational condition [6]
- Crew health and performance: astronaut health and ability to successfully accomplish the mission
- Utilization: the use of a platform and/or mission to conduct science, research, development, test and evaluation, public outreach, education, and commercialization [7]

In general, the more time spent on maintenance and crew health, the less time there is to spend on other activities such as utilization. Specific crew tasking, while outside of the scope of this study, helps inform the categories of crew time planning for Mars, and how these tasks may vary during different segments of the mission.

Table 1 ISS Guidelines for Standard Crew Workday, reproduced from Ref [5]

Crew Off Duty (13 hrs)	Sleep Period	8.5 hrs	
	Post Sleep Period	1.5 hrs	Includes a morning meal
	Midday Meal	1.0 hrs	
	Pre-Sleep Period	2.0 hrs	Includes an evening meal
Crew On Duty (8.5 hrs)	Operations	6.5 hrs	This time is used to calculate crew time at the tactical planning level.
	Operations Prep/Conferences per Section E.1.4	2.0 hrs	Daily Planning Conferences: ~15 minutes each duty day morning and evening.
			Work Preparation & Plan Familiarization: ~50 minutes for daily plan familiarization, report preparation, and evening prep work. ~20 minutes for morning prep work.
			Conferences per Table E.7-1, On Duty Crew Conferences
	Task List		As time becomes available (at the real time planning level)
Exercise (2.5 hrs)		2.5 hrs	Includes time for setup, cardiovascular/resistive exercise, stowage, and hygiene [cool down plus cleanup]. This is not operations.

Crew time required for maintenance is inherently probabilistic because it is driven by random failures. Fig. 2 shows a notional cumulative distribution function relating an amount of maintenance crew time to the probability that that amount of time is sufficient to complete all required maintenance activities. There is a minimum amount of crew time that will be required for preventative maintenance, which is preplanned activity dedicated to system health and upkeep prior to a system or component failure [8]; for example, a filter that needs to be changed every 60 days. On the other hand, corrective maintenance is defined as unexpected or unplanned crew time driven by a random failure of a component, orbital replacement unit, or system [8]. Since corrective maintenance is based on random failures, there is no way to know ahead of time how many or when systems will fail. As Lynch et al. explain, "while average or expected time requirements can be predicted, the actual required time for any given mission will be highly variable based on the actual failures that occur" [8]. Utilizing probabilistic assessment of maintenance demands can enable risk-informed crew time allocation.

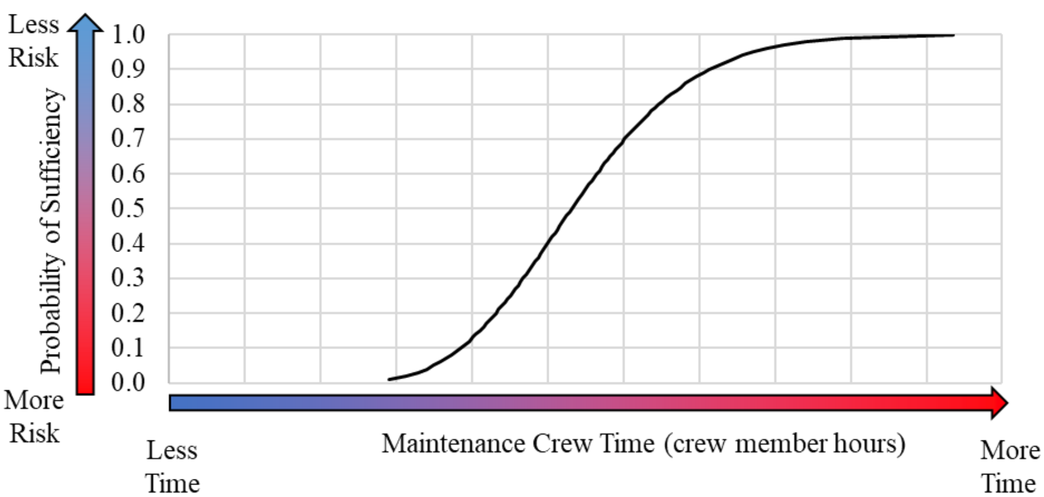

Fig. 2 Probability of having allocated sufficient crew time

V. Operational Changes for a Mars Mission

The ISS operations planners currently schedule crew time in 5-minute increments [9], in a highly regulated process due to the limited nature of crew time. How the crew's time is allocated for Mars missions is likely to be different than current operational planning aboard the ISS for several reasons. A communication delay, which may reach up to 44 minutes round-trip depending upon mission trajectory, necessitates alternatives to the traditional near-real-time, two-way communication strategies that are currently commonplace [10]. In addition, the amount of time devoted to maintaining crew health and managing medical and behavioral health challenges will likely shift due to crew being in space for longer than ever before. All the Mars mission vehicle systems (e.g., habitation, crew subsystems and propulsion integration) will likely also require some crew time to monitor and/or maintain, although there may be opportunities to automate some of these tasks. Finally, mass ejection cadence, process, and required crew time will likely vary from current ISS due to logistics storage and consumption profiles in addition to mass impacts to the propulsion system.

A. Communications

The communication delay for crew during a mission is proportional to their distance from Earth. Fig. 3 shows the distance from earth as well as the communication delay for the example 850-day Mars mission. The maximum communication delay this Mars mission trajectory is 44 minutes round trip [10]. This is the amount of time it would take for a message to be transmitted, received at the other end, and then a response to arrive back. This delay does not include any additional time for developing the message or troubleshooting any issues. This will create an entirely different paradigm from how crew typically utilizes Earth ground support. The crew and the vehicle will need to be able to operate more independently from Earth than current spaceflight. Thus any system or task that requires feedback sooner than the roundtrip communication delay will need to operate independently of the Earth mission control. Additionally, activities that traditionally involve discussion and troubleshooting between the in-space crew and Earth ground support—such as maintenance and EVA activities—may take longer to coordinate and train for, due to communication delays resulting in limited real-time feedback from mission control. Maintenance may therefore require longer periods of time to complete, and has the potential to interrupt or cross-over into other scheduled activities.

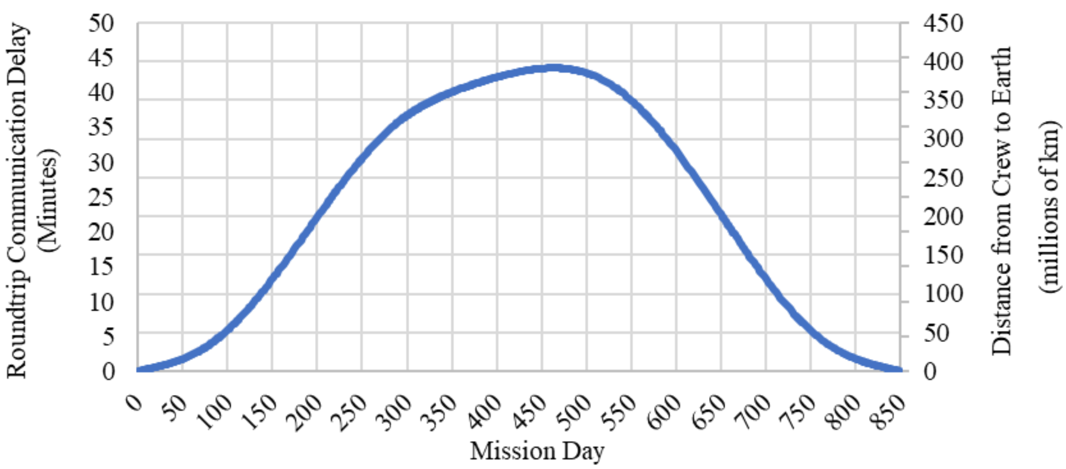

Fig. 3 Example round trip communication delay and distance from crew to Earth as a function of mission duration for the 850-day mission.

In addition, there are periods of time where crew does not have direct line of sight back to Earth due to solar conjunction, where the Sun is directly in between the crew and Earth as shown in Fig. 4. During this time, direct communication between Earth and the crew may be fully disrupted. The duration of this communication disruption is dependent on the trajectory and type of communications used. In the example 850-day mission presented here, the solar conjunction could result in a communication disruption of more than two weeks, depending on the exact sensitivity of the communication protocol. Engineering solutions (such as positioning a relay asset in space) can mitigate or remove the blackout. Otherwise, the crew and vehicle would need to be able to operate independently from Earth during the period of disruption.

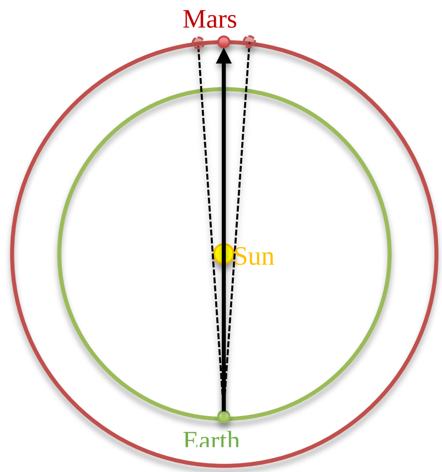

Fig. 4 Example of Earth-Sun-Mars conjunction.

B. Crew Health and Performance

A Mars mission is estimated to be 700-1,200 days long. As of 2022, the longest time a NASA astronaut has spent in space is 355 days[11], while the record for the longest period of time that a human has continuously spent in space is held by a Cosmonaut at 437 days in orbit [12]. Very few people have been in space for longer than a year, resulting in limited datasets that can be used to understand the impact of sustained human spaceflight. The full impact of spaceflight on the human body is not known for long-duration missions, nor is the variation between individual crew members well-understood.

Some countermeasures required to mitigate the negative effects of the deep space environment may need to increase as a function of mission duration. In-flight countermeasures involve nutritional health, physical fitness, pharmaceuticals, and sensory-motor training protocols [13]. Also, crew Behavioral Health and Performance (BH&P) is affected by missions in isolated, confined, and extreme environments [14]. A number of psychological stressors can impact BH&P, specifically bursts of high workload, lack of meaningful work/activity, and limited communication with home [14]. In order to maintain their BH&P, crew may need to be devote more time to maintaining good behavioral health and group dynamics. In addition, due to the communication delay making a traditional two-way conversation with Earth impossible, time for private medical and psychological conferences between crew and ground based medical personnel may decrease or take an alternate format.

C. Transportation System Needs

Transportation systems evaluated for human Mars missions are either high-thrust, low-thrust, or a combination of the two referred to as hybrid systems. A high-thrust transportation system requires major burns at four key points in the trajectory: departing Earth for Mars or Trans Mars Insertion (TMI), Mars arrival or Mars Orbit Insertion (MOI), Mars departure or Trans Earth Insertion (TEI), and Earth arrival or Earth Orbit Insertion (EOI). A low-thrust transportation system requires a continuous burn throughout the mission. During these trajectory maneuvers, crew may need to be actively engaged in of system monitoring and course correcting if an off-nominal event occurs. For high-thrust, this could require crew support four times during the mission, while with low-thrust this may require more constant monitoring. Additionally, a high-thrust event may have certain restrictions on crew activity. For example, crew may need to be secured to the vehicle during the event in their Intravehicular Activity (IVA) suits. Low-thrust activities may be similar to what happens currently on ISS when reboost maneuvers are conducted.

D. Potential Vehicle Dormancy

A Mars mission will require multiple elements to accomplish. In SAC21, a Pressurized Rover (PR) and a cargo lander are pre-deployed to arrive at Mars prior to the crew's arrival. If either of these vehicles need to operate in any way in their uncrewed state, the vehicle would need to be resilient enough to continue nominal operations. For example, assuming the dormancy period is longer than 30 days, and if there is a filter that needs to be changed every 30 days, then there would need to be a system in place to replace the filter. This could be accomplished by implementing atonomous systems, or by creating redundancy in the system.

In the SAC21 example mission, four crew travel to Mars and two crew go to the surface, resulting in two crew remaining in the TH. In a scenario where all crew descend to the surface, the TH would be left uncrewed and need to undergo dormancy operations. Dormancy operations can vary depending on the implementation strategy; regardless of the strategy, it will likely take crew time to prepare the vehicle for that uncrewed state to ensure habitability when they return to the TH.

E. Mass Ejection

The amount of energy needed for transportation is proportional to payload mass. Depending on the type of transportation system used, certain trash disposal and mass ejection strategies may reduce that energy requirement. In general, ejecting unnecessary mass reduces the total propellant required for the mission.

Ejected materials would likely consist of trash, consumed logistics, or other unused logistics that are no longer needed. Logistics represent "all equipment and supplies not installed as part of the vehicle that are needed to support mission activities. Logistics can be further divided into specific categories, including consumables, maintenance items, spares, utilization, outfitting, as well as any packaging required" [15].

Crew time will be required to consolidate items for ejection. If ejections are not accomplished regularly, built up trash in the vehicle may make it challenging to find things within the habitat, slow day to day operations, create the potential for microbial cross-contamination, or cause odors (e.g., from food packaging waste and waste containment bags). Alternatively, if mass is not ejected as frequently, the mass could be used for other purposes and may require crew time for processing and configuration to use.

VI. Operational Phases

Operationally, a Mars mission can be broken down into the mission phases shown in Fig. 5. The operational phases are defined at the level at which there is significant operational differences from the adjacent phases. The Earth to Mars segment of the mission breaks down into Earth departure preparation, Earth departure, and transit to Mars. This is followed by the Mars vicinity segment which comprises Mars arrival preparation, Mars arrival, Mars surface (during which time some fraction of crew remain in orbit), Mars departure preparation, and Mars departure. The mission concludes with the Mars to Earth segment which is composed of transit to Earth, Earth arrival preparation, and Earth arrival.

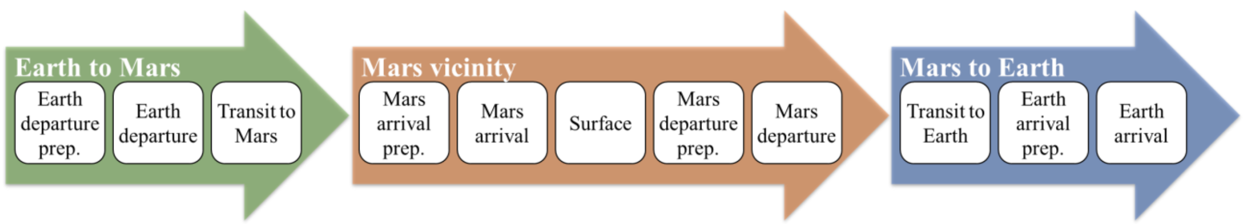

Fig. 5 Operational phases of a human Mars mission.

Throughout the mission there are some activities whose rates are expected to remain constant during all operational phases, including the time devoted to sleeping and eating. One notable caveat is that while the activity's duration may not change, *when* crew performs the activity during a duty cycle may change. For example, crew sleep during rendezvous proximity operations and docking may require changes to the crew duty day to ensure crew are awake during critical mission phases, and crew may need to sleep shift to get into a Mars sol circadian rhythm. On the other hand, there are some activities that are expected to occur during all phases of the mission but may vary in length of time. Specifically, the amount of time devoted to countermeasures (e.g. physical fitness, sensory-motor training protocol, etc.) may be more than typical ISS operations due humans being in space longer than ever before and will need to maintain their health as much as possible. The method and time devoted to communication with Earth will likely change as the communication delay increases. For example, crew may need to perform more frequent task switching due to having to chat in communication threads, or getting new information which changes priorities or the task definition. Time spent on utilization will likely fluctuate throughout the mission as we have different operational requirements during different mission phases.

A. Earth to Mars

The first segment of the mission, the transit from Earth to Mars, begins when crew reaches LEO and ends a few weeks prior to Mars arrival. It can be divided into three main operational phases: Earth Departure Preparation, Earth Departure, and Transit to Mars.

1. Earth Departure Preparation

The Earth Departure Preparation operational phase involves pre-checking transportation and habitation vehicle systems, including but not limited to checking fuel levels and scanning for any leaks, and any other crew-in-the-loop checkout of certain DST integrated systems. It may also include transferring logistics from any logistics module and offloading any trash from the transit habitat into Orion, as crew readies for their departure from LEO. During this phase, crew will be responsible for bringing any dormant systems of the transit habitat online and ensuring elements are in correct position for their journey, working with Mission Control in real-time. During this phase, crew's time is primarily devoted to departure preparation and nominal tasks like eating, sleeping, and exercising.

2. Earth Departure

Following the preparation phase, crew depart the Earth system for Mars. The transit vehicle will perform the requisite propulsive maneuvers to enter the designated Mars-bound trajectory. During this time crew may monitor the maneuvers with mission control and may need to be in specific orientations within the vehicle for the planned maneuvers.

3. Transit to Mars

The bulk of the mission both to and from Mars is in deep space transit. Depending on the mission trajectory, crew may be in deep space for several months to years. During the outbound transit to Mars, crew time will be spent in preparation for Mars arrival—performing utilization tasks, monitoring vehicle systems, reviewing trainings for surface operations, and maintaining physical health to mitigate the effects of extended microgravity.

During this period, one of the most crucial crew tasks will be real-time monitoring of the integrated DST and habitation systems and performing the needed preventative and corrective maintenance activities.

B. Mars Vicinity

The Mars vicinity segment consists of five major phases: Mars arrival preparation, Mars arrival, Surface, Mars departure preparation, and Mars departure.

1. Mars Arrival Preparation

The Mars arrival preparation phase begins a few weeks prior to MOI. During this time, there is an expectation that the crew would sleep shift from Earth days to Martian sols prior to entering Mars orbit. A Martian sol is 24 hours, 39 minutes, and 35 seconds. To operate during daylight, it is anticipated that crew will operate on Martian sols through the Mars departure phase. However, this has implications for Earth ground support on monitoring surface ops, such that operational decisions regarding mission control shift schedules will need to be made due to the misalignment in day to sol duration.

If possible, crew will need to perform checkouts of EVA and IVA suits and make any associated preparations. Similarly to crew preparing to land on Earth, crew can take measures before reentry to mitigate symptoms post-landing to prepare for the Mars Entry Decent and Landing (EDL) and upcoming surface operations. These measures may include, fluid loading, orthostatic intolerance compression garments, and others [16].

To ensure crew are ready for this next phase, physical and behavioral health may also be evaluated. In addition, the notional TH described would need to transition from maintenance support of the full in-space crew complement, to having fewer or no crew during the surface mission duration. This may call for increased preventative maintenance activities, wrapping up any ongoing utilization, and logistics coordination to ensure that the crew remaining in orbit is able to support both the orbiting DST and the needs of the surface crew.

2. Mars Arrival

The Mars arrival phase begins at MOI with a transportation system maneuver, followed by additional maneuvers to a rendezvous with the pre-deployed assets such as the crewed Mars landing system. From there, crew will need to prepare and execute rendezvous and docking operations with the EDL vehicle. Once docked, there will be some system check out procedures, especially if the EDL vehicle was pre-deployed to Mars orbit and has been sitting dormant for an extended period. After docking and checkout, the transfer of crew and any required cargo to the EDL vehicle can begin. Crew will likely have limited time to get the EDL systems ready and online for EDL so operations will need to be streamlined. Certain activities might be performed while the vehicle is docked, but some can only occur after undocking.

3. Surface

The surface phase begins once crew land on the surface. The SAC21 architecture looks at two crew staying in orbit while two crew go to the surface; however, this section will only focus on the operations of the on-orbit crew. More details and assumptions for surface operations can be found in HEOMD-415 [17].

Once crew land on the surface, it is estimated they will need 3-7 sols of gravity readaptation time [17]. During that period, the on-orbit crew may be responsible for remote operations of surface elements, or the surface elements will require some increased autonomy to be able to operate themselves. It is expected that a portion of the working time for the on-orbit crew to be spent as real time operations support for the surface crew, because the communication delay at that point in the mission may be too long to rely on Earth-based operations support in real-time. For the on-orbit crew to be able to support the surface crew, they will need access to the relevant data that is typically handled by Earth ground support.

The on-orbit crew will also need to continue vehicle maintenance operations, as well as any potential Mars orbit utilization. In addition, orbital correction maneuvers of the DST may be needed. It is unknown how involved crew will need to be in these maneuvers, but the maneuvers should be considered in future planning leveraging knowledge from ISS and Gateway.

4. Mars Departure Preparation

The Mars departure preparation phase begins a few sols prior to ascent [17]. To help maximize crew time on the surface, the on-orbit crew may help remotely prepare the Mars Accent Vehicle (MAV) or monitor surface elements to ensure they are ready for dormant periods. The on-orbit crew will also need to prepare for docking, which will likely be similar to ISS operations when waiting to receive crew. During the ascent, the on-orbit crew may be required for real-time monitoring and docking preparations to mitigate risks during a critical mission phase. Once docked, crew will need to ensure any additional planetary protection measures have gone into place before opening the hatch. They will likely need to transfer samples from the MAV to the DST and ensure they are secured in the appropriate environment for the trip home. The surface crew will likely need time to readapt to microgravity, during which time pre-flight checkout of the DST prior to heading back to Earth can also be accomplished.

5. Mars Departure

The Mars departure phase begins at TEI. Like Earth departure, crew will be responsible for monitoring the maneuver, but without the real-time support of Earth based ground support, and crew safety operations during engine burns will need to be specified depending upon propulsion type. A portion of mass will likely be ejected from the TH before the TEI burn. If the TH has excess mass no longer required for the mission, that mass will need to be re-stowed or jettisoned prior to TEI.

C. Mars to Earth

The final segment of the mission, the transit from Mars to Earth, begins after crew departs from Mars, and ends when crew arrives back at Earth. It can be broken down into three main operational phases: Transit to Earth, Earth arrival preparation, and Earth arrival.

1. Transit to Earth

The transit back to Earth mirrors the outbound transit to Mars. During the transit to Earth, crew will still be responsible for vehicle monitoring, as well as nominal and off-nominal maintenance. Depending on the chosen mission trajectory, the transit to Earth segment of the mission can be significantly longer or shorter than the transit to Mars segment. For example, in the SAC21 mission trajectory, the transit to Earth segment is roughly twice as long as the transit to Mars segment. As in the transit to Mars segment, crew will need to maintain their physical and behavioral health through various countermeasures including nutrition, medical care, and exercise.

2. Earth arrival preparation

As crew reach Earth vicinity, they will prepare for rendezvous and proximity operations between the transit vehicle and Orion. This phase is similar to Mars arrival preparation, with the notable difference of having to prepare collected Mars samples for transfer into Orion. Depending on the payload capacity of Orion, samples may be kept at Gateway or in the TH, or returned to Earth via an alternative vehicle.

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3. Earth Arrival

Upon arrival at Earth, crew will perform the rendezvous and proximity operations between the transit vehicle and Orion. Crew will need to transfer into Orion, along with any logistics and samples that they have brought back, before they begin their descent to the surface. Upon Earth surface arrival, crew will be met with appropriate planetary protection [18] protocols to ensure the preservation of Earth's biosphere from back-contamination from Mars. Any infrastructure and logistics associated with crew quarantine and sample return are integral to the overall mission architecture. Most importantly, crew will likely be in a much more physically and mentally deteriorated state than with Lunar and LEO missions and will thereby require extensive support upon their return.

VII. Forward Work

Forward work includes quantifying the impact of crew time drivers and building categories of crew activities for different mission phases. Current efforts to right-size crew for an initial Mars mission include an examination of crew tasking, to ensure that all tasks required can be accomplished by a given number of crew members. This work will be incorporated further into the crew time allocation effort. Forward work will assess the interactions of different crew time drivers. This data can then be used to help estimate how much time each driver is expected to take and anticipate how changes in the architecture will impact crew time allocation, thereby influencing and informing architectural trades. Forward work will investigate architectural and/or strategic gaps as they relate to crew time allocation, identify areas where more research could be conducted to reduce crew time allocation, and identify the potential for investment in Earth-Independent systems that minimize crew time burdens. Finally, forward work will aim to inform how much time is available for crew to meet the mission objectives with respect to utilization and will help determine what could be accomplished during the mission.

VIII. Conclusion

Crew operations and the crew time allocation for a Mars missions will likely be different than current operational planning aboard the ISS due to communication delays, crew health and performance needs, transportation system needs, potential vehicle dormancy, and mass ejection. Crew operations and time allocation is an integral topic for planning a Mars mission. Understanding the mission scope, and how a Mars mission differs from LEO and lunar missions, can help inform the crew time planning efforts for a long-duration mission. Furthermore, understanding the time required for vehicle maintenance and crew health maintenance will inform key mission architecture decisions. This paper discussed the operational challenges of a Mars transit mission and the associated activities that will need to take place during each operational phase of transit to and from Mars.

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