HRP Investigator’s Workshop

Assessing the Number of Crew for Mars Against Trade Space Parameters

February 16, 2024

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Introduction

Missions to Mars will differ from all previous human spaceflight missions in that the onboard crew of astronauts will be required to operate in an Earth-independent manner given the long communication delays on Mars missions. Without a systematic, repeatable process to determine the number and composition of crew necessary to successfully accomplish these missions, NASA increases the risk in that crew sizes may be too small to meet primary mission objectives under nominal conditions and, more consequentially, the crewmembers may not have the expertise needed to successfully respond to unforeseen failures without the real-time expertise in the Mission Control Central (MCC) team on which NASA has come to rely.

We present a framework for trade space analysis along with results from human-performance models developed in IMPRINT. We discuss the implications of model results on the trade space for number of crew for missions to Mars.

This work was funded by the NASA Engineering and Safety Center (NESC) with support from NASA’s Human Research Program (HRP).

Team Members

Name	Discipline	Organization
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Assessment Support		
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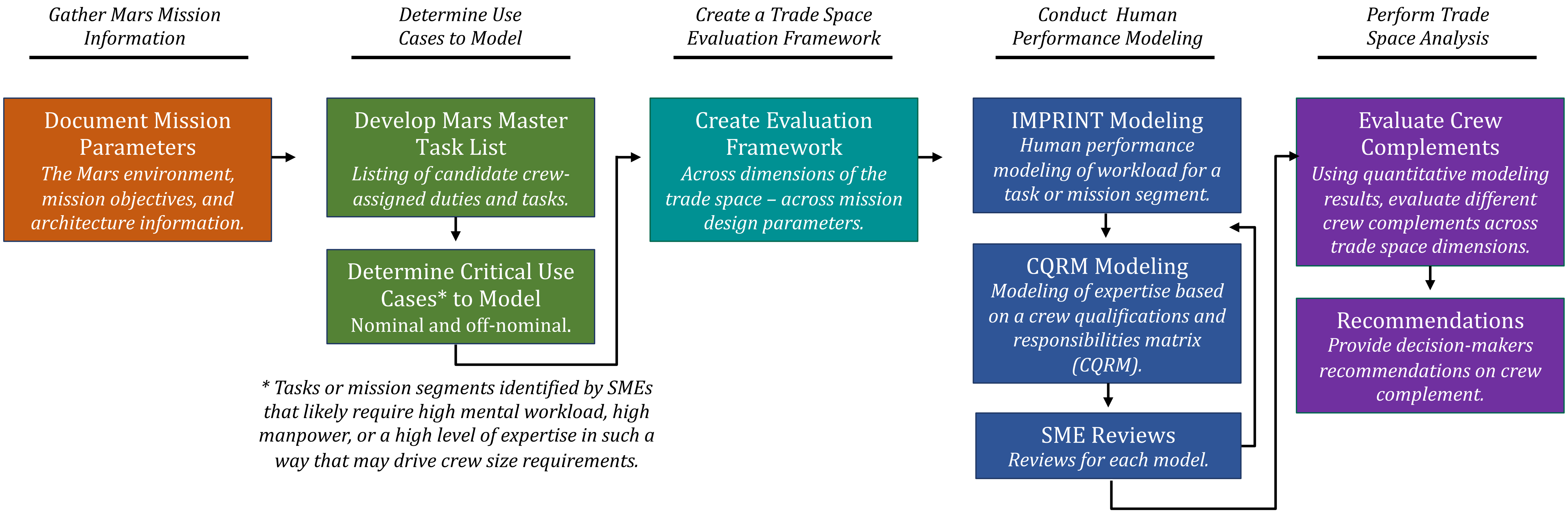
Linda Burgess	Planning and Control Analyst	LaRC/AMA
Erin Moran	Technical Editor	LaRC/AMA

Proposed Solution

To define a methodology for performing trade space analysis for crew complement determination for future missions to Mars using quantitative data from human performance modeling.



References:
Militello et al. (2019). *Towards and Optimally Crewed Future Vertical Lift Vehicle: Crewing Strategy and Recommendations*. Prepared for U.S. Army Combat Capabilities Development Command Aviation & Missile Center.
Lippert, A.F. , Scripture, B. L., “A Review of Department of Defense Manpower Analysis to Inform Crew Size Determination for NASA’s Manned Missions to Mars” (Master of Human System Integration Capstone). Naval Postgraduate School, Monterey, CA. (2021)
L. Shattuck, N. Shattuck, P. Matsangas. Personal communication with NPS researchers. (2020)

IV Operations for Planetary Surface EVA Model

Model Leads: Dr. Alan Hobbs, Robert Sargent

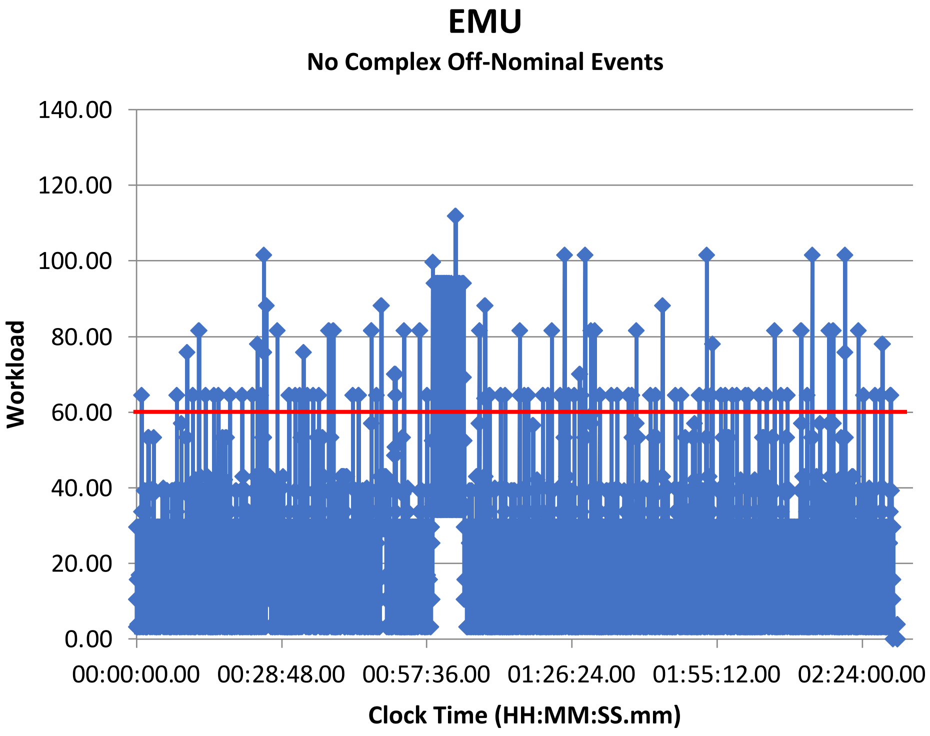
Model Assumptions

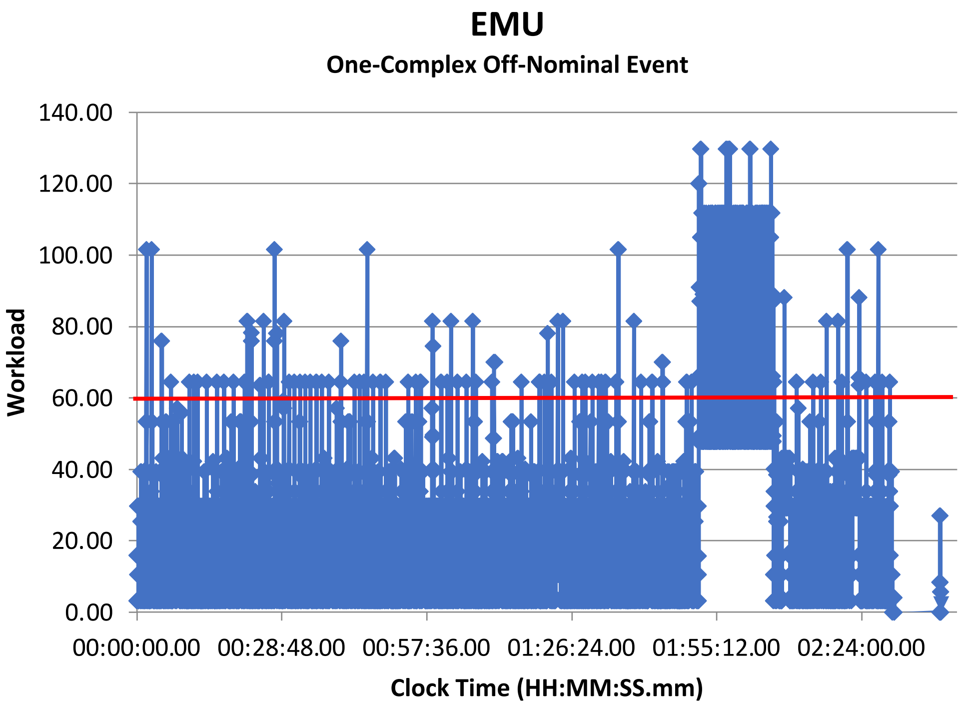
- Two crewmembers (EV1 and EV2) will conduct the EVA on the planetary surface
- Support crew on orbit around Mars will provide all the real-time IV support to the EVA crew that is currently provided by MCC

Model Limitations

- ISS EVA is an imperfect analogue of a planetary EVA on Mars
- Some support tasks currently performed by people may be automated in the future
- ISS EVA 79 progressed relatively smoothly. May be a best-case analogue.

ISS EMU Flight Controller Workload





	Time Averaged Workload	Percent Time in Overload	Peak Workload
No Complex off-Nominal Events	22.96	2.12	111.95
One Complex Off-Nominal Event	24.72	7.56	129.76

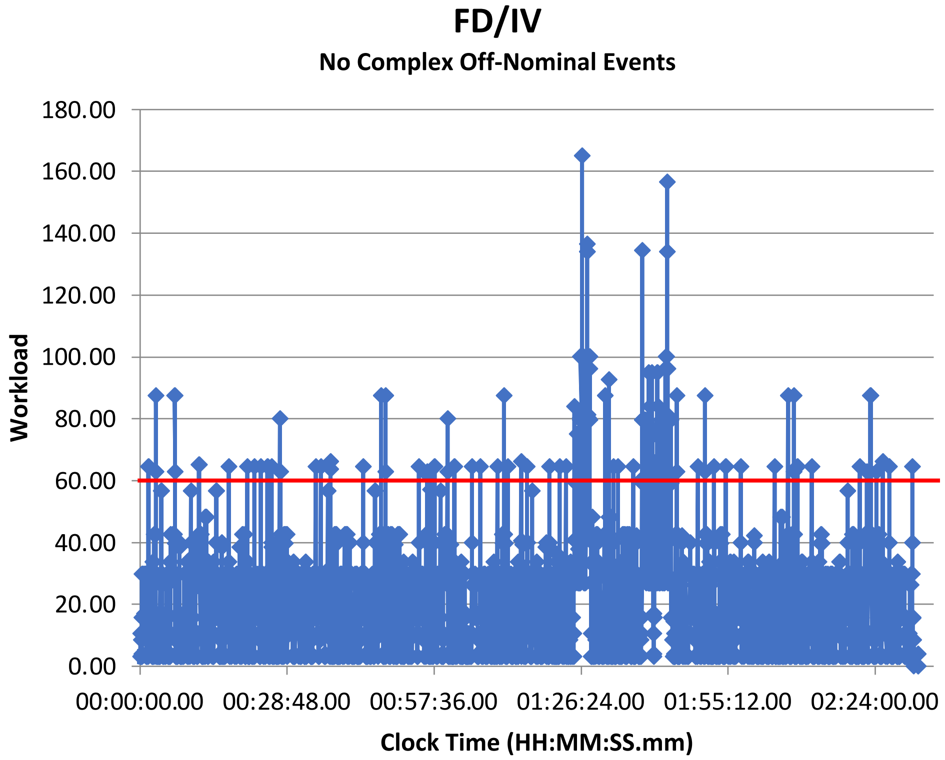
EMU Workload Metrics for 2.5-hour Period of an ISS EVA

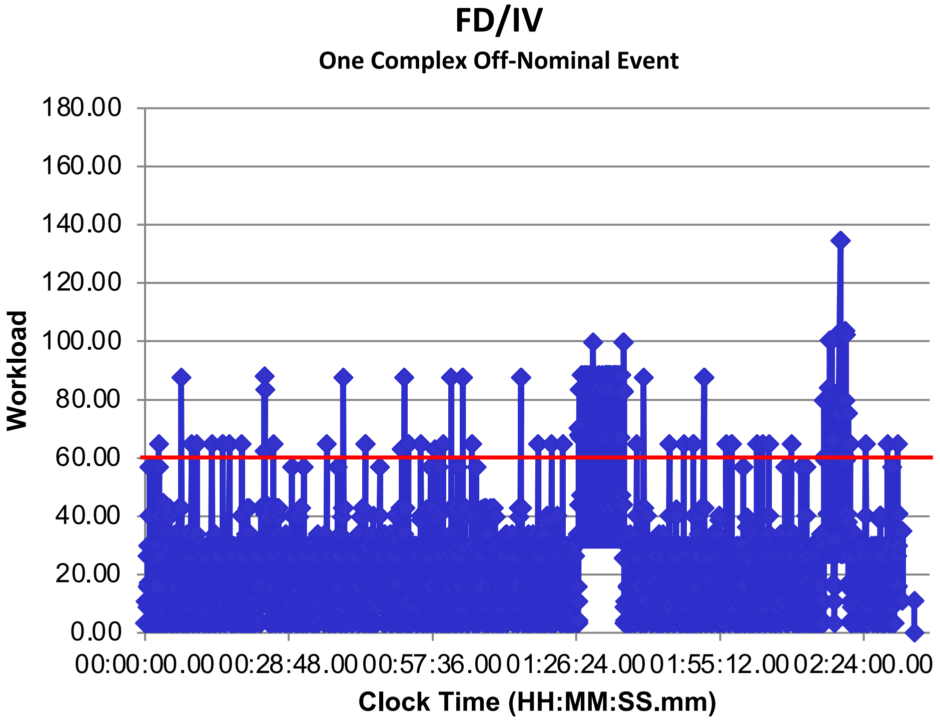
Green (workload is "**acceptable**" and will not impact task performance)

Yellow (workload is "**high**" and may impact task performance)

Red (workload is "**unacceptably high**" may severely impact task performance)

Hypothetical Combined ISS FD/IV Position Workload





	Time Averaged Workload	Percent Time in Overload	Peak Workload
No Complex off-Nominal Events	18.93	2.16	164.97
One Complex Off-Nominal Event	20.80	3.50	134.25

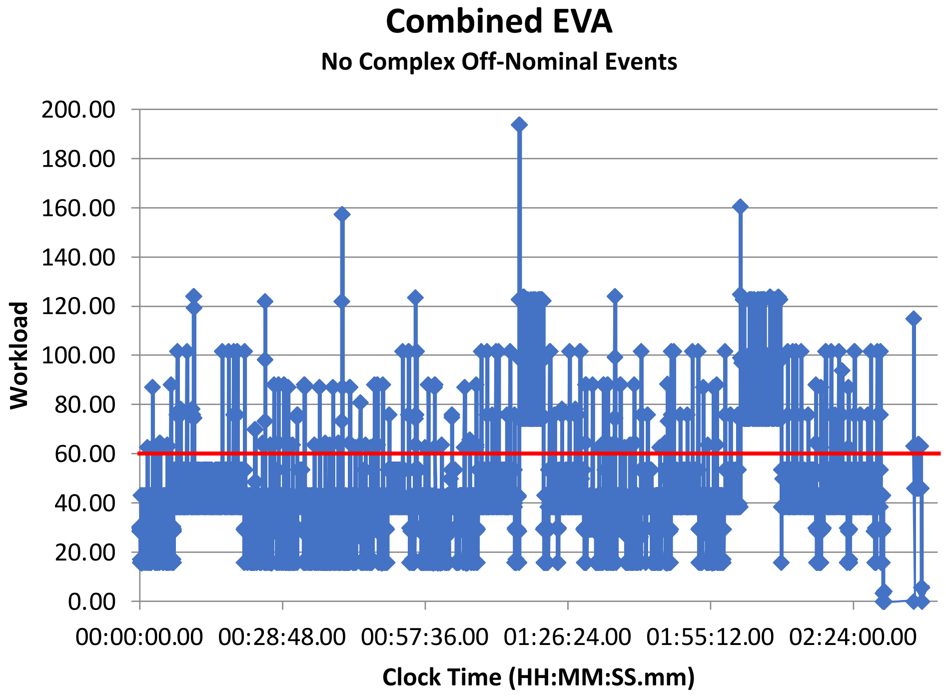
Hypothetical Combined ISS FD/IV Position Workload Metrics for 2.5-hour Period of a Mars EVA

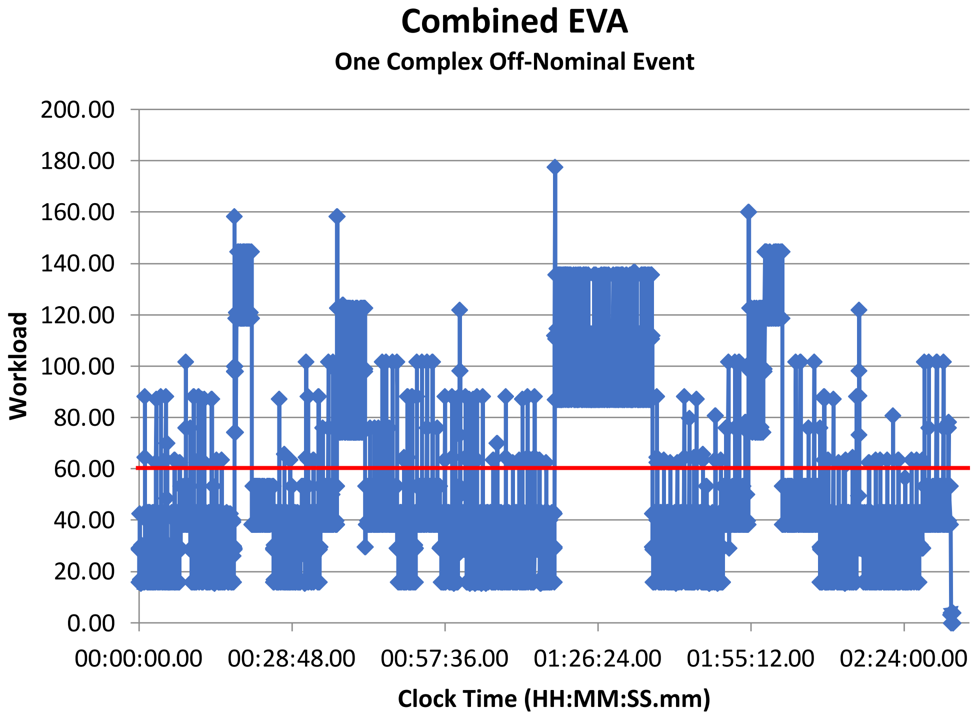
Green (workload is "**acceptable**" and will not impact task performance)

Yellow (workload is "**high**" and may impact task performance)

Red (workload is "**unacceptably high**" may severely impact task performance)

Hypothetical Combined ISS EVA, EVA Task and EMU Flight Controller Position Workload





	Time Averaged Workload	Percent Time in Overload	Peak Workload
No Complex off-Nominal Events	42.42	11.48	193.89
One Complex Off-Nominal Event	52.17	24.02	177.49

Hypothetical Combined EVA, EVA Task and EMU Position Workload Metrics for 2.5-hour Period of a Mars EVA

Green (workload is "**acceptable**" and will not impact task performance)

Yellow (workload is "**high**" and may impact task performance)

Red (workload is "**unacceptably high**" may severely impact task performance)

Preliminary Findings: IV Planetary Surface EVA Model

- IMPRINT modeling results predict that during Mars surface EVAs, workload for a crewmember performing a combined set of FD/IV duties will be acceptable if Mars planetary surface EVAs have a less ambitious timeline, are more flexible, and occur at a slower pace than current ISS EVAs.

- IMPRINT modeling results predict that during Mars surface EVAs, a crewmember performing a combined set of EVA, EVA Task, and EMU flight controller duties will experience an unacceptably high level of workload.

- Based on analysis of IMPRINT modeling results and evaluations by MCC EVA flight controllers and a flight director, two astronauts orbiting Mars would not be able to adequately manage the workload necessary to provide real-time support to astronauts performing an EVA on the surface of Mars.

Note: These preliminary findings are not crew size recommendations and need to be considered within the context of the model limitations, including the limitations of modeling an ISS EVA as an analog for a Mars EVA. They present a starting point to discuss crew complement for missions to Mars.

Future Work

Future work for modeling IV support for a Mars EVA includes:

- Accounting for workload differences between the ISS EMU modeled here and the new Artemis spacesuit
- Considering parameters in the trade space that could be “dialed” to enable a Mars IV crew to support a surface EVA such as:
    - Automating ISS EVA flight controller tasks
    - Changing operational considerations such as the cadence of surface EVAs

Summary

The assessment team:

- Defined a methodology for trade space analysis for crew size determination using quantitative data from human performance modeling
- Developed an evaluation framework
- Built human performance models that output workload and expertise based on Mars mission use cases
- Performed trade space analysis of crew complements (number of crew and expertise) using modeling results

Dimensions for Evaluation	Crew Complement A	Crew Complement B	Crew Complement C
Operational Impact	○	○	○
System Resilience	○	○	○
Human Performance	○	○	○
Team Coordination	○	○	○
Cognitive Support	○	○	○
Organizational Constraints	○	○	○
Costs	○	○	○
Technology Capabilities	○	○	○
Human Health	○	○	○
Overall			

Evaluation Framework

The assessment team is NOT making recommendations on the number of crew, rather the recommendations are on the trade space analysis methodology.

Backup Charts

Use Cases Modeled

The assessment team conducted literature reviews and SME interviews, created evaluation criteria, and selected three Mars mission use cases to build as IMPRINT models:

- **IV Operations for Planetary Surface EVA Model**
- **Robotic Arm Assisted EVA Operator Model**
    - *HRP provided funding support*
- **Mars Transit Crew Model**

The assessment team selected a fourth Mars mission use case to develop a custom model for:

- **Personnel, Expertise, and Training Model**

References:
Dempsey, D. L. (2013, May). TEE/Audit Policy. Presented to the Flight Operations Integration Group (FOIG), NASA, TX.
Holden, K., Munson, B., Russi-Vigoya, N., Dempsey, D., Adelstein, B. (2019). Human Capabilities Assessment for Autonomous Missions (HCAAM) Phase II: Development and Validation of an Autonomous Operations Task List Final Report. Internal NASA Report: unpublished.
L. Shattuck, N. Shattuck, P. Matsangas. Personal communication with NPS researchers. (2020)

Conduct Human Performance Modeling

Human performance models output quantitative measures of workload that indicate an operator's capacity to perform tasks. The assessment team developed quantitative metrics to classify workload as "acceptable", "high", or "unacceptably high".

Green (workload is "**acceptable**" and will not impact task performance)

- Percent time in overload is less than 3%

AND

- Time averaged workload is less than 30.0

Yellow (workload is "**high**" and may impact task performance)

- Percent time in overload is greater than 3% but below 30%

OR

- Time averaged workload is above 30.0 but below 40.0

Red (workload is "**unacceptably high**" may severely impact task performance)

- Percent time in overload is above 30%

OR

- Time averaged workload is above 40.0