



DATA SCOPE

To Support Exploration Missions

EIMO TIM 2023-B

Date: 21 August 2023

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Time: 12:00pm-5:00pm CT

Earth Independent Medical Operations (EIMO)

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EIMO is "The gradual transition of medical care and decision making from terrestrial to space based assets, enabling support of astronaut health and performance and reducing overall mission risk."

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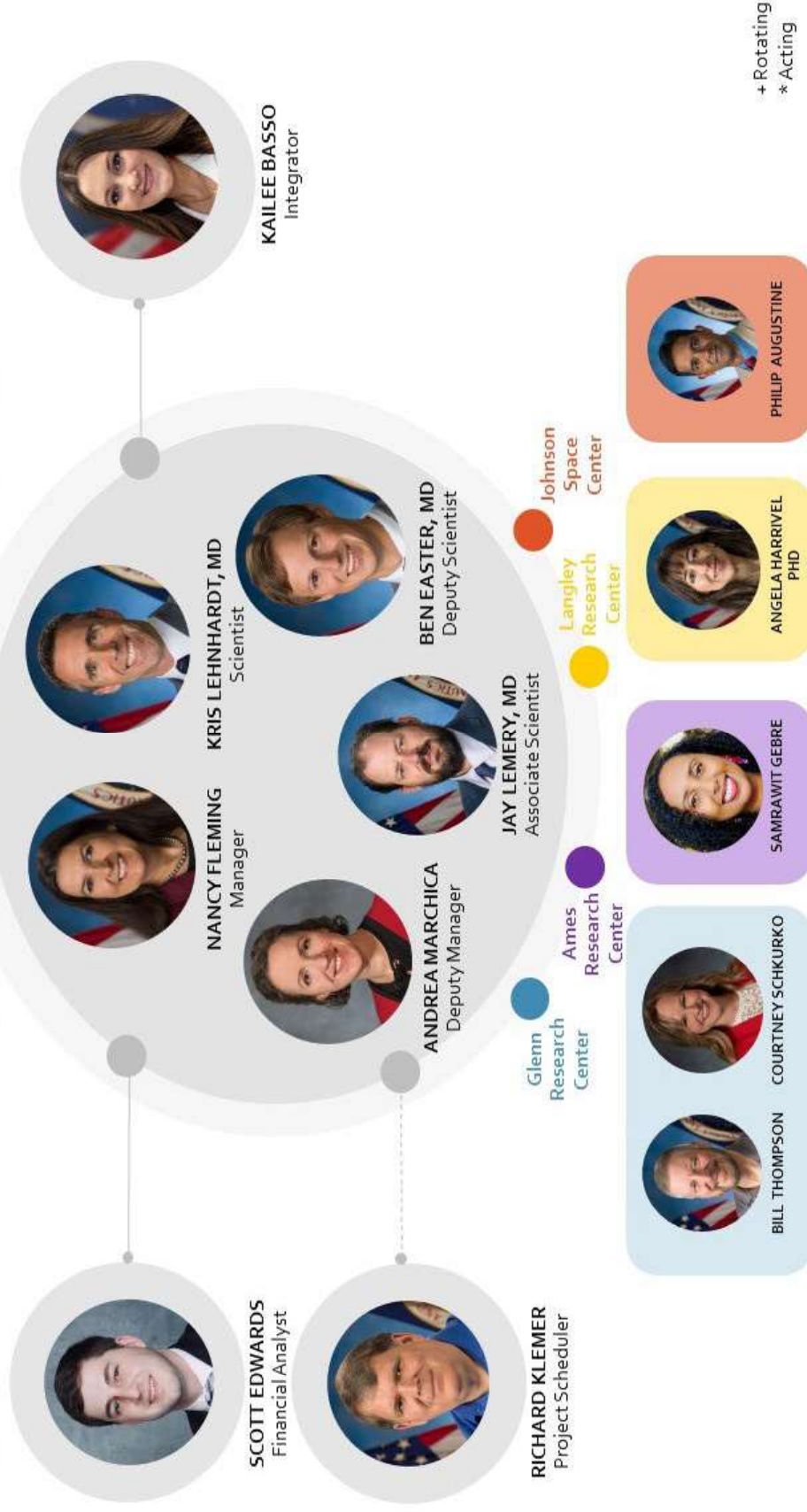
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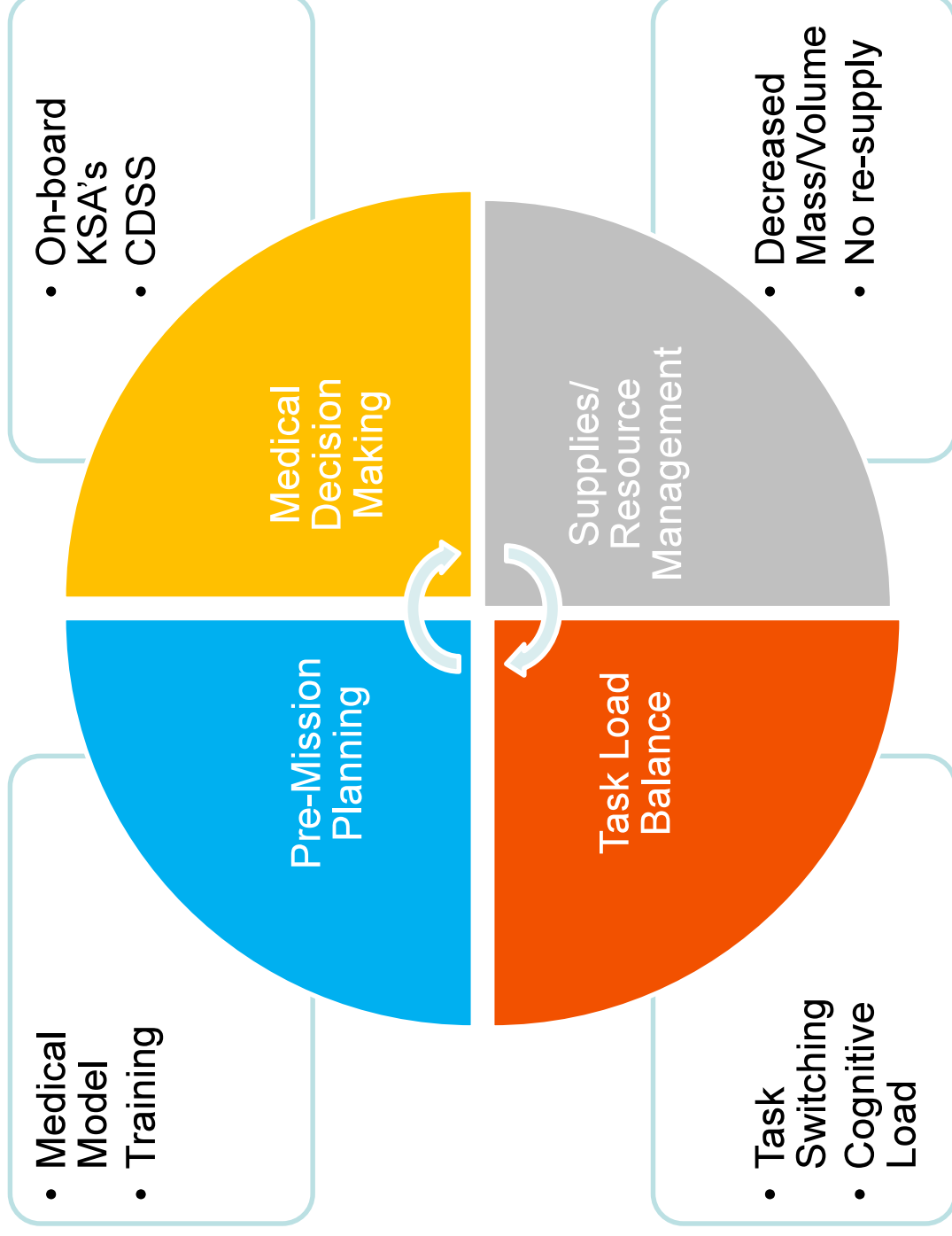
ExMC Element Attendees



Exploration Medical Capability (ExMC) Leadership Organization Chart



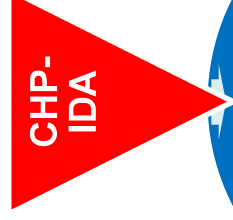
EIMO Components



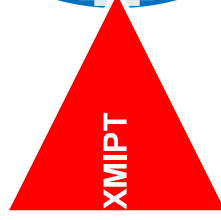
EIMO INTERSECTS



Crew Health and Performance – Integrated Data Architecture (CHP-IDA) system as a platform to enable the amalgamation of a variety of crew-relevant data sources and applications.



Exploration Medical Integrated Product Team (XMIPT) at NASA is seeking solutions to increase the mass, power, and volume efficiency of its exploration medical system.

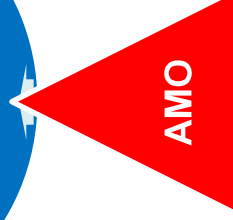


EIMO

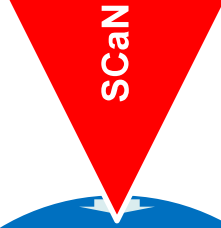
XMIPT

SCaN

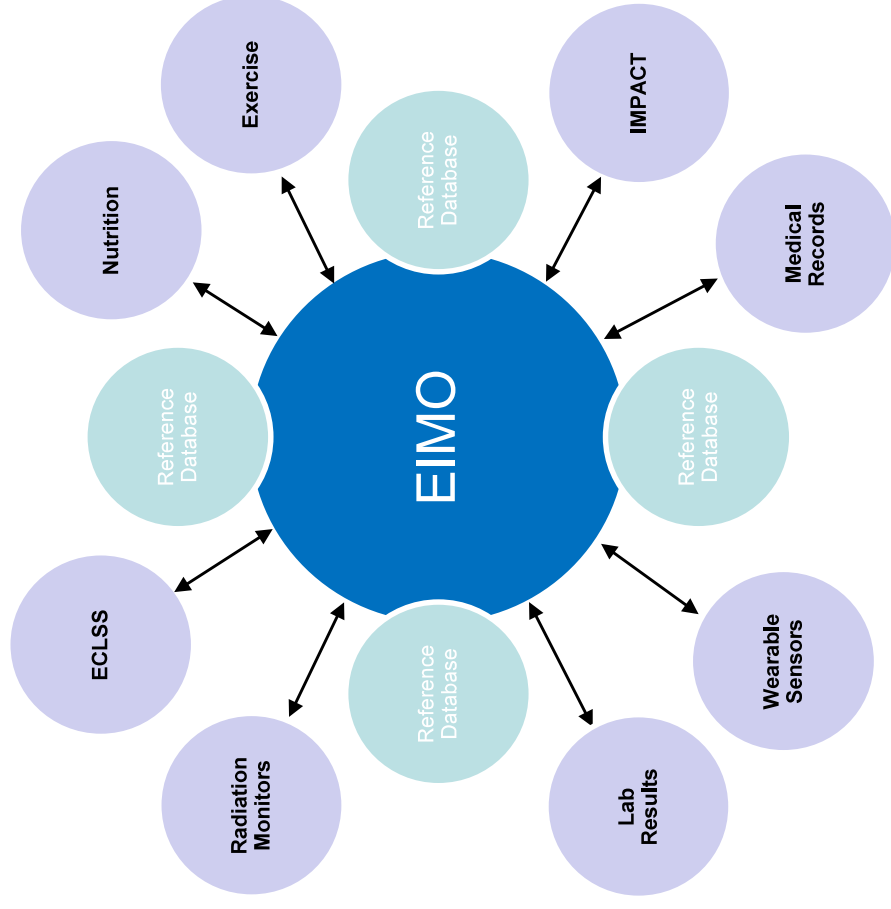
Autonomous Medical Operations (AMO) project is developing an on-board software-based Medical Decision Support System (MDSS) which will enable astronauts to diagnose and treat emergent conditions in a timely manner.



Space Communication and Navigation (SCaN) provides communications and navigation services over the full operational life cycle of a mission from launch to de-orbit.



EIMO Ecosystem



- EIMO utilizes embedded reference databases and real-time data streams from multiple sources to assess Crew Health & Performance
- EIMO makes recommendations using AI-supported natural language processing and machine learning techniques

EIMO (Earth Independent Medical Operations)
ECLSS (Environmental Control & Life Support System)
CHP-IDA (Crew Health & Performance Integrated Data Architecture)
XMIPT (Exploration Medical Integrated Product Team)
AMO (Autonomous Medical Operations)
SCaN (Space Communications and Navigation)
IMPACT (Informing Mission Planning via Analysis of Complex Tradespaces)



Purpose



The purpose of the TIM is to identify, prioritize and plan forward work on EIMO

From the perspective of potential stakeholders, what **technical capabilities** are needed to enable **EIMO**?

1 — **Pre-Mission Planning**

- Creation of a medical model?
 - Informs resourcing, trade-space analysis, crew knowledge/skill/ability (KSA)
 - Augment IMPACT to provide: optimal crew KSA; ground/JITT training; set research priorities by capability capacity to reduce risk; resource allocation

2 — **Acute/ Emergent Medical Management Decision Making and Continuity of Care**

- Elevating the on-board KSA
 - Highly skilled provider
 - Clinical Decision Support System (CDSS)

3 — **Supplies and Resource Management**

- Upmass must be carefully chosen for exploration class missions
 - Mass/volume severely constrained, stability risk for medications
 - Cannot re-supply (extremely challenging if even possible)
 - Regenerable and/or on-demand resourcing (3D printing, plant based pharmaceutical production)

4 — **Task Load Management**

- Task switching and Cognitive Load
 - Identify tasks that can be automated or system monitored: inventory management; resource location; storage/retrieval of medical records; trend analysis, scheduling/reminders; diagnostic testing; treatment suggestions

Pre-Mission Planning



Compared with current LEO operations, pre-mission planning is likely to be even more critical with EIMO.

- maturation and operational integration of the IMPACT probabilistic risk assessment and trade space tool
- maturation and implementation of onboard routine medical training/practice modules as well as Just-In-Time Training (JITT) for diagnostic and therapeutic interventions
- estimation of the optimal crew knowledge, skills and abilities (KSA)
- details of what ground and JITT training may be most beneficial, set research priorities for risk reduction
- reallocate remaining in-flight resources to achieve the lowest possible risk based on updated in-mission data

Medical Management & Continuity of Care



- **Acute/Emergent Medical Management**

- Distance creates communication latency and reduced data transmission bandwidth
- High baseline KSA with access to significant on-board reference material & CDSS
 - JITT, knowledge databases
 - Leverage mixed reality augmentation, artificial intelligence & machine learning

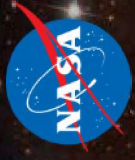
- **Prolonged Medical Management**

- Non-emergent medical condition management less dependent on real time ground support
- Requirement for high baseline KSA and access to on-board CDSS

- **Continuity of Care**

- Use of point of care diagnostics, multi-modal monitoring and smart sensor/sensor fusion should be considered as contributing data streams to inform CDSS

Supplies & Resource Management



Medical resourcing has historically been chosen via expert clinical opinion. Any supplies/use mismatches were mitigated by either the short duration of the mission or by sending additional supplies into orbit on the next resupply mission. Exploration class missions will not be able to rely on resupply and will have to confront expired or reduced efficacy medications. This means supplies must be carefully chosen to account for mass and volume restrictions, medication stability, and their potential for re-use.

Task Load Management



LEO operations allow crew members to offload many medical decisions, monitoring, and other tasks to ground based support allowing the Crew Medical Officer (CMO) to focus directly on patient care and avoid task saturation and increased stress during both routine and acute care scenarios.

EIMO, will require CMO's to perform these functions in a progressively independent manner which will create higher task demand, increased task switching, and higher cognitive load. This has been shown to impair decision making. One solution to this is to identify tasks which can be delegated to computerized tools integrated with the onboard medical system. More advanced systems may even be able to passively monitor crew for early signs of behavioral or medical anomalies, provide diagnostic assistance, autonomously suggest treatments, and guide crew members through procedures.

Solutions-Rapid Development Capability



Development of a library of Training videos/modules to be used in pre-mission training, in-flight refresher training and “just-in-time” training. Content areas include CPR/ALS, and discipline specific material, e.g., emergency medicine.

Training could be stratified based on baseline knowledge, skills and abilities (KSA) to maximize the benefit of the trainee whether they are a physician, medic or mission specialist.

Solutions Requiring Research Effort



- Development of Generative Pre-Trained Transformers (GPT) building on previous work in the field, e.g., BioGPT, MedGPT, ChatGPT4 will require a significant amount of baseline work. Challenge is finding sufficient data to train a model relevant to astronaut demographics.
- Opportunities exist to leverage Natural Language Processing through potential public-private partnership(s) with the goal to create a clinical decision support system enabling autonomous diagnosis and treatment recommendations in the absence of SME support.
- Development of sensor fusion algorithms to leverage sensors currently in use could determine which data streams are relevant, identify additional sensors as needed and create system to monitor individual sensor output and integrated multi-sensor output for predictive capability.

EIMO DATASCOPE



Artificial Intelligence based Clinical Decision Support System (CDSS) capable of enabling Autonomous Medical Operations would require very large datasets to train and establish. This training and assembly can be conducted pre-flight. Significant amounts of data will be necessary to support machine learning via in-flight CDSS operations.

What is the projected amount on-board data storage and computing capability that EIMO could be expected to; 1) need, 2) have access to?

Public & COTS Databases to Consider



NTRS

"The NASA STI Repository (also known as the NASA Technical Reports Server (NTRS)) provides access to NASA metadata records, full-text online documents, images, and videos. The types of information included are conference papers, journal articles, meeting papers, patents, research reports, images, movies, and technical videos – scientific and technical information (STI) created or funded by NASA."



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CDSS Elements/Considerations



- Environmental controls [ECLSS]
- In-flight [with pre-flight baselines] Metrics
 - Countermeasures data
 - Behavioral
 - Physiologic [wearables, monitoring devices]
 - Lab data
- Personalized medical records
- Medical Risk database [IMPACT]
 - Medical Inventory
 - KSA
 - Trade space risk assessments
- Open source & COTS databases
- Ground support inputs

Key Points, Assumptions, Challenges



- A. CDSS could be considered Safety-Critical software
- B. EIMO database(s) and CDSS will be co-located/operated in a CPU environment (no cloud)
- C. Radiation hardened/tolerant systems are generations of processing power behind (RAD750 running at 200MHz) and levels may not support in-flight machine learning
- D. COTS hardware routinely fails outside of Earth's magnetosphere

DATASCOPE Topic 1



Topic 1:

We are seeking an in-flight integrated data architecture [IDA] interface to integrate numerous, disparate data sets, to assist with predictive crew health and performance analytics and clinical decision support [CDSS]. Is generative AI the 'way to go' when considering operating systems and user interfaces for spaceflight IDA?

Topic 1 Elements



- A. Environmental Controls (ECLSS)
- B. In-flight (with pre-flight baselines)
 - Countermeasures data, behavioral metrics, physiological metrics (wearables, monitoring devices), laboratory data
- C. Personalized medical records
- D. Medical risk database (IMPACT)
 - Medical resources, KSA, trade space risk assessments, risk quantification
- E. COTS medical databases
- F. Ground support inputs

DATASCOPE Topic 2



Topic 2:

Acknowledging the aforementioned on-board data storage and computing capabilities re: generative AI, to what degree could dedicated, terrestrial LLM ‘training’ use cultivated datasets to bridge the gap re: AI data requirements?

a) Given the sparsity of data (and unknowns) in the space environment, what other considerations exist re: training models with limited data sets ?

DATASCOPE Topic 3



Topic 3:

What considerations would be necessary in training LLMs on disparate datasets for integration into a larger CDSS?

- We are particularly interested in integrating a NASA ExMC product into IDA, as a discrete dataset. This is “Informing Mission Planning via Analysis of Complex Tradespaces” (IMPACT), a risk assessment tool which allows tradeoff analyses on resource utilization and/or astronaut knowledge/skills/abilities, against a medical risk database of 120 medical conditions. This is important when considering ex: the use of a critical medicine early on in a long-duration mission or when a Chief Medical Officer is incapacitated. What should we consider by integrating this product with a larger IDA system, in-mission?

DATASCOPE Topic 4



Topic 4:

We seek innovative solutions from industry to make sure we're capturing the cutting-edge ideas and technologies of today, to build systems that will fly over a decade from now. To that end, what does this group think are the most effective ways to engage with thought leaders and innovators?

- RFI's?
- Targeted conferences?
- Interactive solution activities, *i.e.*, Hack-a-thons?

DATASCOPE Topic 5



Topic 5:

As this project evolves from concept to testing, what would a ground test environment [lab] look like, specifically re: metrics of success in integrating input vectors and full-fledged IDA that can both pull and push information to the end users. What skillsets and levels of expertise should direct this work?

DATASCOPE Addendum



Addendum:

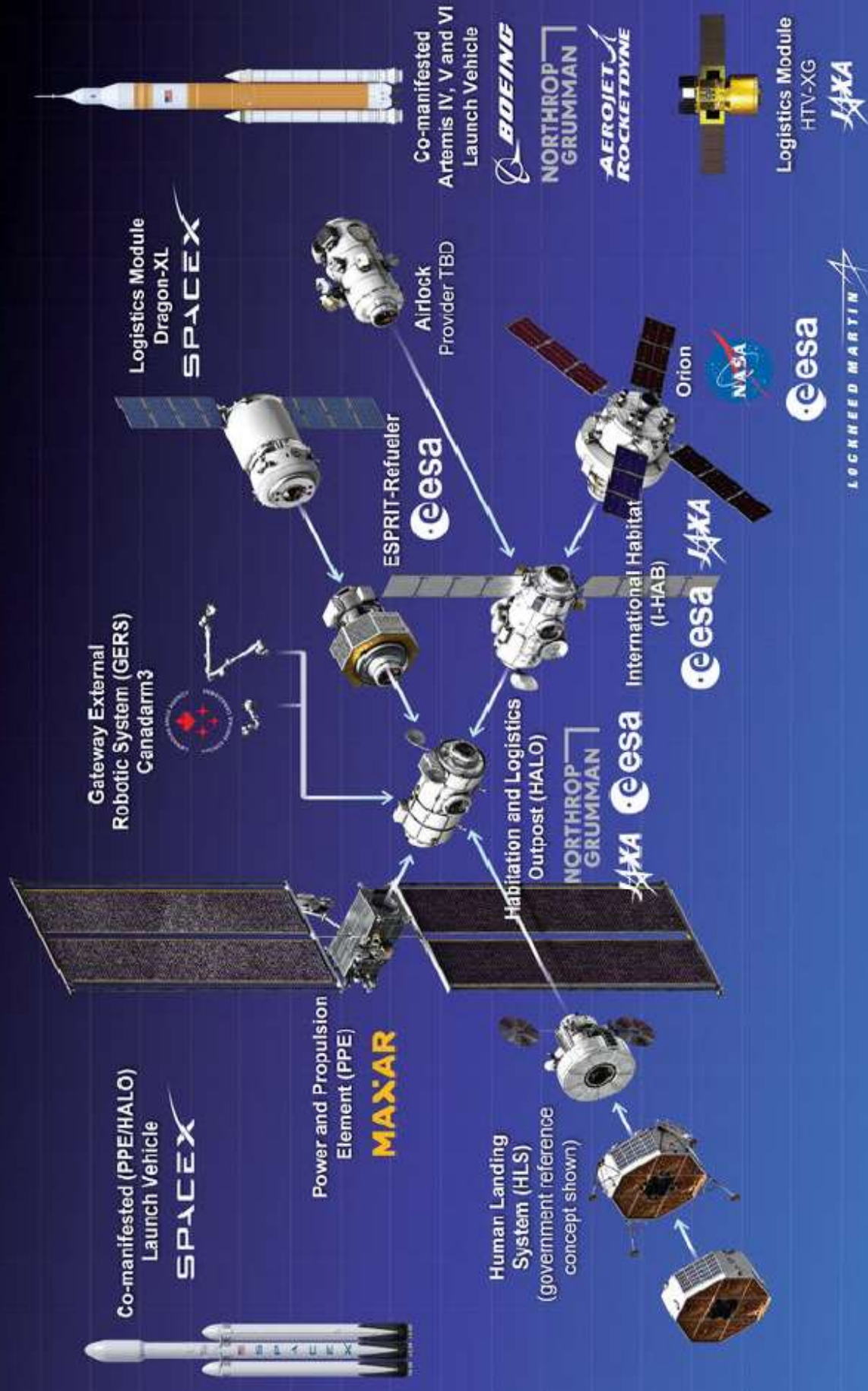
Future ELMO TIMs will focus on crew training, supplies & resource management, and task off-loading. What else should we consider re: this Datascope in meeting these other ELMO requirement domains?



BACK-UP SLIDES



GATEWAY Integrated Spacecraft Configuration



Theaters for Exploration



EXPLORATION CAMPAIGN AND CAMPAIGN SEGMENTS

HUMAN PRESENCE IN LEO

PARTNER ENABLED

HUMAN LUNAR RETURN

PARTNER ENABLED

HUMANS TO MARS



Increased Crew Size & Longer Durations in Micro-gravity

COMMUNICATIONS RELAYS

HUMAN LANDING SYSTEM

PORTABLE UTILITY PALLET

SURFACE HABITAT

CARGO LOGISTICS LANDER

Fission Surface Power

Habitation Systems

Mobile Expedition Duration / Mobile Exploration Range

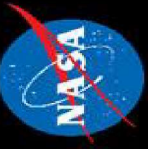
Partial Gravity Operations

In-Situ Resource Utilization

Autonomous Robotics Systems & Contingency Crew Transportation

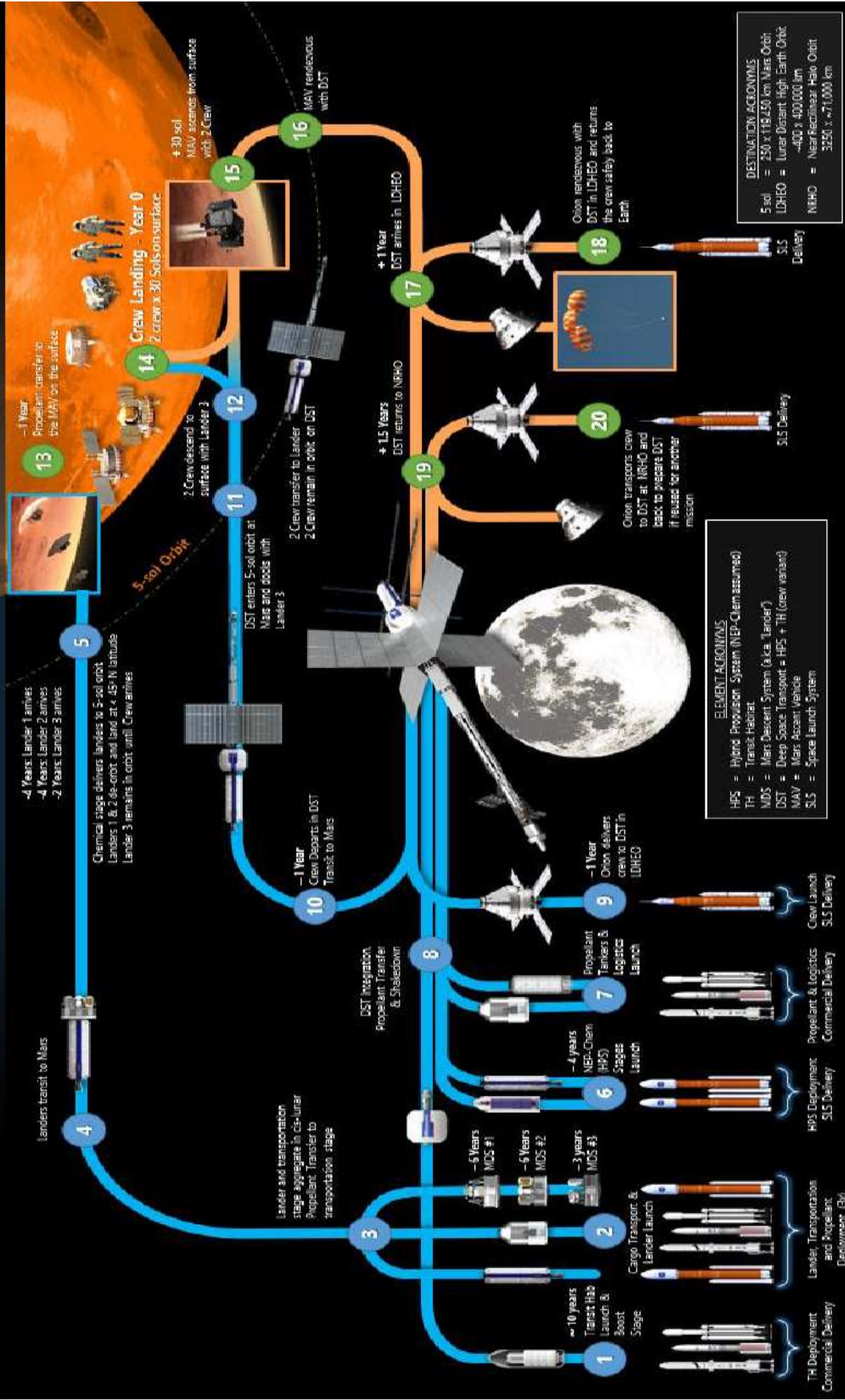


EIMO Project



Notional Human Mars Mission Overview

Short Stay, Date-Agnostic (Events = # years before *Boots on Mars*)



EIMO Project