Quantifying Medical Risk on a Long Duration Lunar Mission: A Demonstration of NASA's IMPACT Tradespace Analysis Tool

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HUMAN RESEARCH PROGRAM

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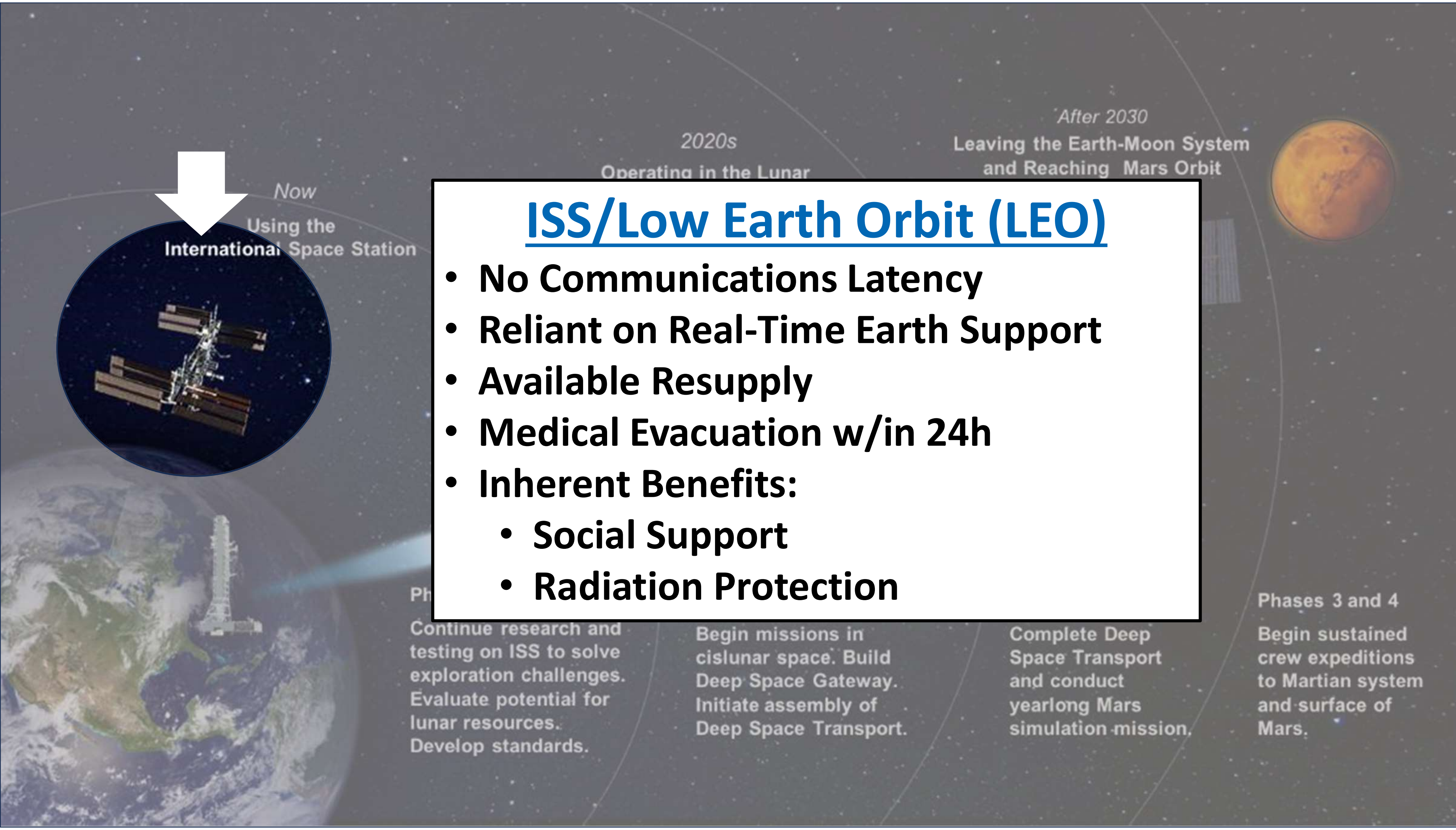
EXPLORATION MEDICAL CAPABILITY

Agenda

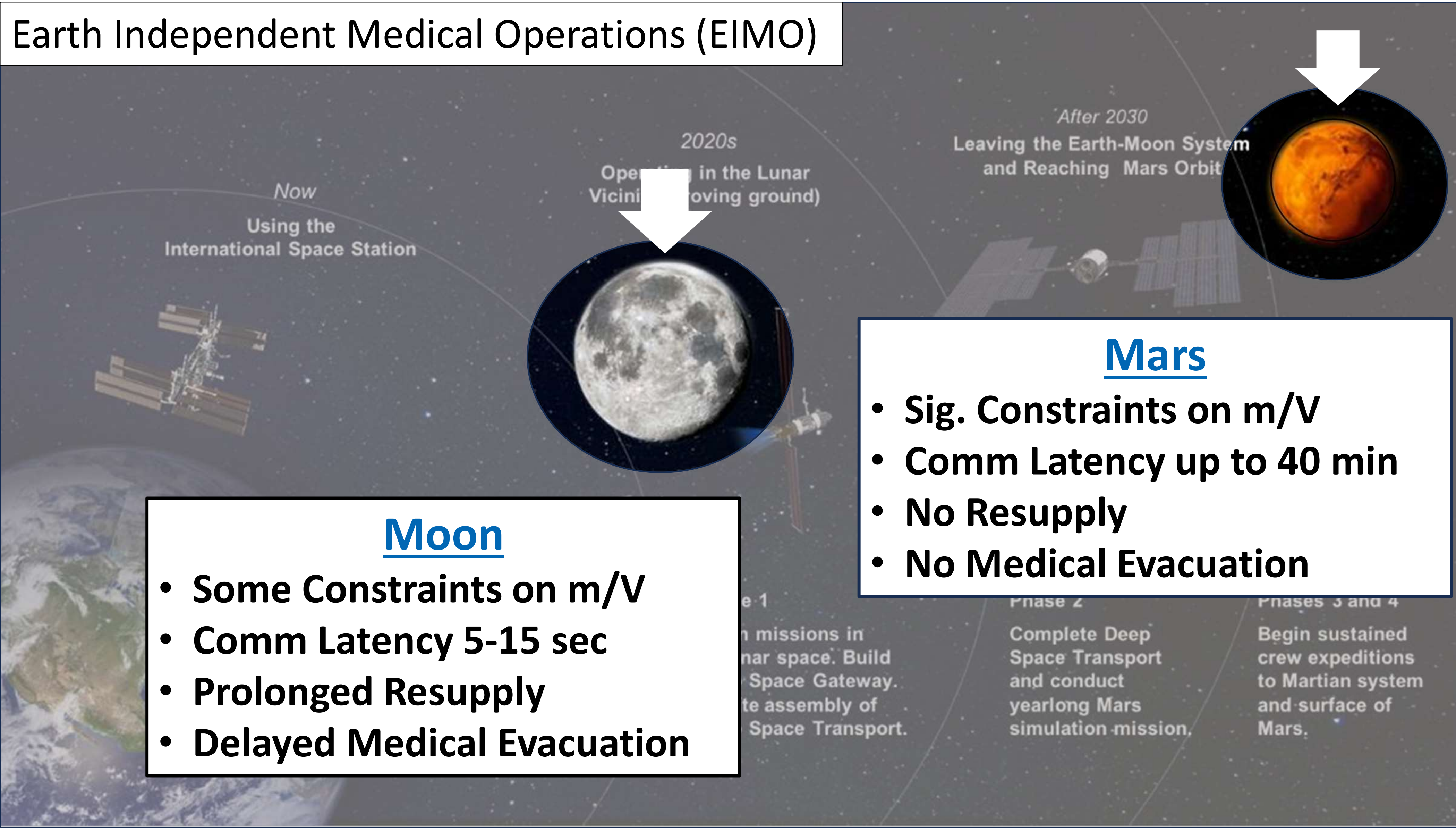
- Medical Challenges for Moon and beyond
- IMPACT Tool
- Long Duration Artemis Mission DRM
- Risk Metrics and Resources
- Future Directions

ISS/Low Earth Orbit (LEO)

- No Communications Latency
- Reliant on Real-Time Earth Support
- Available Resupply
- Medical Evacuation w/in 24h
- Inherent Benefits:
  - Social Support
  - Radiation Protection



Earth Independent Medical Operations (EIMO)



Moon

- Some Constraints on m/V
- Comm Latency 5-15 sec
- Prolonged Resupply
- Delayed Medical Evacuation

Mars

- Sig. Constraints on m/V
- Comm Latency up to 40 min
- No Resupply
- No Medical Evacuation

Approaches to Medical System Design

- Heuristic Approach
  - Uses Experience
  - Limited by Available Data
  - Design by Committee
  - Struggles with Complexity
  - Prone to Bias/Blind spots

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- Data Driven Approach
  - Models Missions w/ Inputs
  - Uses best available evidence
  - Draw from other datasets
  - Adjustable with Complexity
  - Performance Based on Design

Combined Approach

- Optimized for Crew Needs

IMPACT

What is IMPACT?

Informing **M**ission **P**lanning via **A**nalysis of **C**omplex **T**radespaces

Evidence Base

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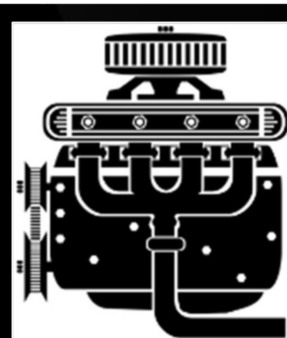
Computational Engine (PRA)



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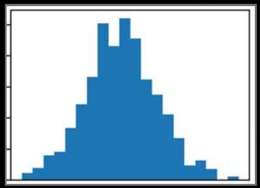
IMPACT

- Exploration-focused
- Evolution of Integrated Medical Model (IMM)
- Operational in 2024

Modeling Engine (MEDPRAT)

Mission Parameters

200,000 Trials

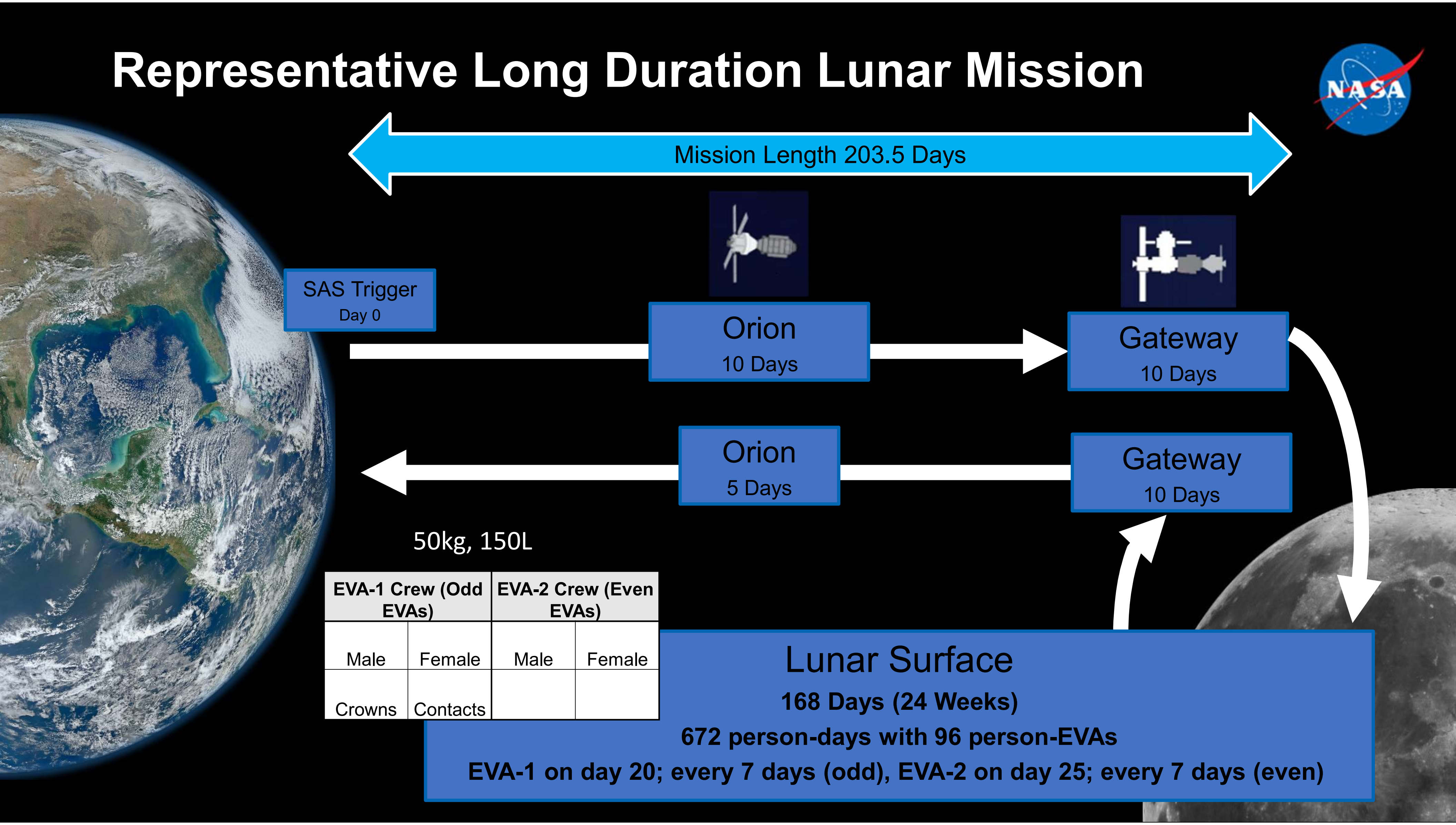


Calculate Risk Metrics

- Loss of Crew Life (LOCL)
- Return to Definitive Care (RTDC)
- Task Time Lost (TTL)
- Resource Utilization

Mission Parameters

- Constraints on Mass and/or Volume
- Pre-existing Medical Conditions
- Risk Metric Thresholds
- Resources Included
- New Vehicles or Technologies



EVA-1 Crew (Odd EVAs)		EVA-2 Crew (Even EVAs)	
Male	Female	Male	Female
Crowns	Contacts		

Results

Risk Metrics

Medical Risk on Long Duration Lunar Mission	
Loss Of Crew Life	0.008 events/mission
Return To Definitive Care	0.30 events/mission
Task Time Lost	103 days/mission

Medical Events

Spaceflight Medical Condition	# of Events
Lunar Dust Exposure	168
Spacesuit Contact injury	17
Spacesuit Paraesthesia	12
Sleep Disturbance	11
Barotrauma	10
Spacesuit Hand Injury	8
Headache	6
Spaceflight Rash	5
Corneal Abrasion	5
Skin Abrasion	4

Conditions Contributing to Risk

LOCL	Events/ Mission	RTDC	Events/ Mission	TTL	Days/ Mission
Decompression Sickness	0.0025	Wrist Fracture	0.140	Spacesuit Shoulder Injury	19.1
Traumatic Hypovolemic Shock	0.0013	Eye Foreign Body	0.046	Barotrauma	9.8
Respiratory Failure	0.0007	Decompression Sickness	0.021	Spacesuit Contact Injury	8.2
Urinary Tract Infection	0.0006	Corneal Abrasion	0.011	Upper Ext. Sprain	5.5
Abnormal Uterine Bleeding	0.0005	Risk for Pregnancy	0.010	Lower Ext. Sprain	5.2

Resource Contribution

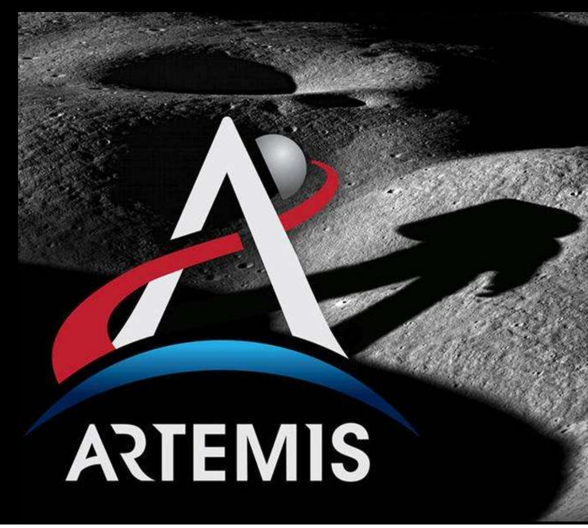
Top Resources by Mass	Top Resources by Quant.
Multimodal Vitals -Assessment Device	Lozenges
Skin Cleanser	Anti-inflammatories
Normal Saline Intravenous Fluid Bags	Nasal Steroids
Medical Device Cleaner	Topical Hydrocortisone
Mupirocin	Antihistamine
Mental Health - Cranial Stim Device	Eye Drops
Ultrasound Gel	Modafinil pills
Oxygen Mask and Tubing	Gauze pads

Take Aways

- IMPACT results inform decision making
  - Evidence based data driven
  - Can identify blind spots and support mission planners
- Medical risk for long duration lunar missions
  - Certain conditions contribute disproportionately
    - e.g. Wrist Fracture and DCS
  - IMPACT can help identify these conditions and map to interventions
  - Risk represents the unknown aspects of Lunar missions
- Medical system design shaped by likelihood and consequence
  - EVA drives a large portion of risk for surface operations

Future Directions

- IMPACT in operational use this year
- Use IMPACT now to simulate early Artemis missions
- Continue to update the model with best available evidence
  - Add new conditions, revise medical event data, add new resources
- Collaborate with commercial spaceflight companies
- Enable progressive Earth-independence
  - Design pre-flight medical training curricula
  - Develop in-flight training modules and simulations
  - Assist with medical resource selection



Questions?

EXPLORATION MEDICAL CAPABILITY

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