NASA Crew Health & Performance Capability Development for Exploration: 2022 to 2023 Overview

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Overview

- **ECLSS-Crew Health & Performance System Capability Leadership Team**
- **Human System Capability Gap Updates**
- **Crew Health & Performance Capability Areas:**
  - *Spacesuit Physiology & Performance*
  - *Crew Health Countermeasures*
  - *Exploration Medical*
  - *Food Systems*
- **Conclusions**

What is an SCLT?

- System Capability Leadership Team
- Cross-agency, program-independent

Responsibilities:

- Identify capability gaps & develop strategies for closure
- Make recommendations on technology development and support architecture studies
- Establish key performance parameters and monitor progress
- Analyze assets required to execute capability advancement and recommend acquisition strategies
- Maintain cognizance of state of ECLSS & CHP capabilities
- Coordinate with commercial and international partners to identify opportunities

Capability Gaps

CAPABILITY | The ability to meet an exploration objective through Architecture, Engineering, Development, Technology, Operations or Research for a given set of constraints and level of risk.

Current Capabilities (state of the art)

Capabilities we have today, supporting or available for human or robotic missions….

THE DIFFERENCE IS THE

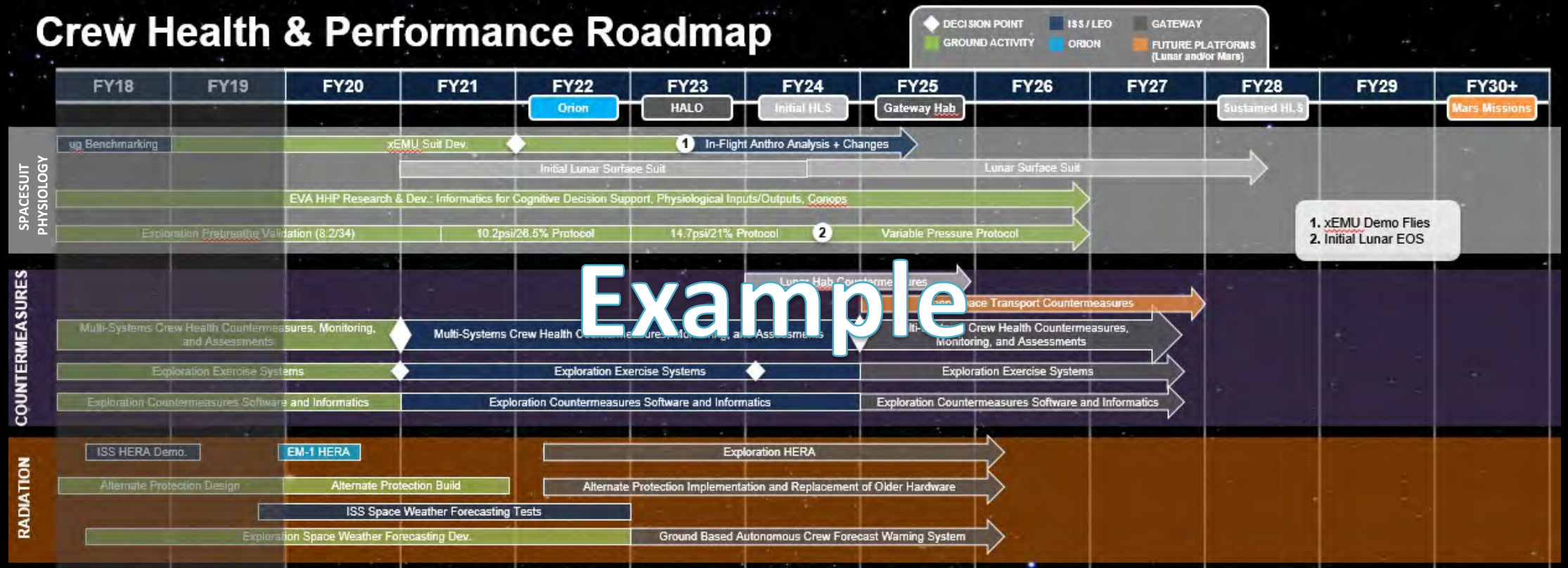
⬅ **GAP** ➡

Future Needed Capabilities (Envisioned Future)

Anticipated future capabilities based on future mission architectures and agency strategic planning

Importance of Capability Gaps

- SCLT Roadmaps aim to include:
  - All work that is ongoing across the agency – regardless of funding source – that is relevant to Capability Gap closure
  - Future work – with identified capability products and schedule – considered necessary to close each Capability Gap



ECLSS-CHP SCLT Capability Areas

4 ECLSS Capability Areas

LIFE SUPPORT
- Atmosphere Management
- Water Management
- Waste Management

ENVIRONMENTAL MONITORING
- O_2, CO_2, N_2
- Humidity
- Trace Chemicals
- Microbes
- Particles
- Sound

FIRE SAFETY
- Detection
- Protection
- Suppression
- Cleanup

LOGISTICS
- Tracking
- Relocating
- Clothing
- Trash

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS)

6 ~~5~~ CHP Capability Areas

SPACESUIT PHYSIOLOGY
- Physiol. Inputs & Outputs
- ConOps/Crew Capabilities
- Informatics & Decision Support
- Injury & Risk Mitigation
- Atmosphere/Pre-breathe

COUNTERMEASURES
- Exercise Systems
- Sensorimotor
- Physiology Monitoring
- Informatics

RADIATION PROTECTION
- Space Weather Forecasting
- Monitoring
- Shielding
- Health Risk Models
- Biomedical CM

EXPLORATION MEDICAL
- Diagnostic
- Treatment
- Imaging
- Pharmacy

FOOD & NUTRITION
- Pre-packaged
- Food Resources
- Dietary Tracking
- Health & Performance

CREW HEALTH AND PERFORMANCE (CHP) SYSTEMS

ECLSS CHP SCLT

New: EARTH INDEPENDENT HUMAN OPERATIONS TECHNOLOGIES
- Decision Support & Situation Awareness Tools
- Human-Hardware Maintenance Interfaces and Tools
- Procedure Execution Support Tools
- Asynchronous Distributed Operations Management Systems
- Integrated Earth-Independent Human Systems Simulation Technologies

Close alignment with TX.06 on NASA Technology Taxonomy

Evolving Habitation Systems for SUSTAINABLE HUMAN EXPLORATION

Use ISS as Testbed for Evolution of ECLSS and CHPS

International Space Station (ISS)

- Demonstrate new capabilities
- Increase reliability data of existing capabilities

Continue Testbeds on Commercial Platforms in LEO

Notional Commercial Platform in LEO

Infuse Technologies into Gateway

Orion and Gateway

- Toilet
- CO_2
- Environmental monitoring
- Low-mass exercise countermeasure
- Radiation monitoring
- Medical system
- Fire suppression and cleanup
- Dormancy/autonomy

Infuse Full Long Duration Microgravity ECLSS and CHPS into Mars Transport

Mars-class Transportation

- High-reliability and high loop closure ECLSS
- Broad spectrum environmental monitoring
- Long shelf-life, low water food system
- Countermeasures to support self-egress
- Medical diagnostics, treatment, and decision support

Complementary Ground Tests and Analogs

- Food system analog to evaluate crew impacts
- Integrated reliability testing
- Partial gravity drop tower and suborbital flight material flammability evaluations
- CHPS integrated analogs

Human Landing System and Sustained Lunar Surface ECLSS-CHP Infusion

- Partial gravity and exploration atmosphere fire safety
- Exploration spacewalk pre-breathe and conops
- Surface habitat: regenerative ECLSS and CHPS adapted for surface
- Pressurized rover: ECLSS waste collection and transfer

Mars Surface ECLSS-CHPS

- Robust microbial and chemical monitoring
- Planetary protection compatible surface waste disposal

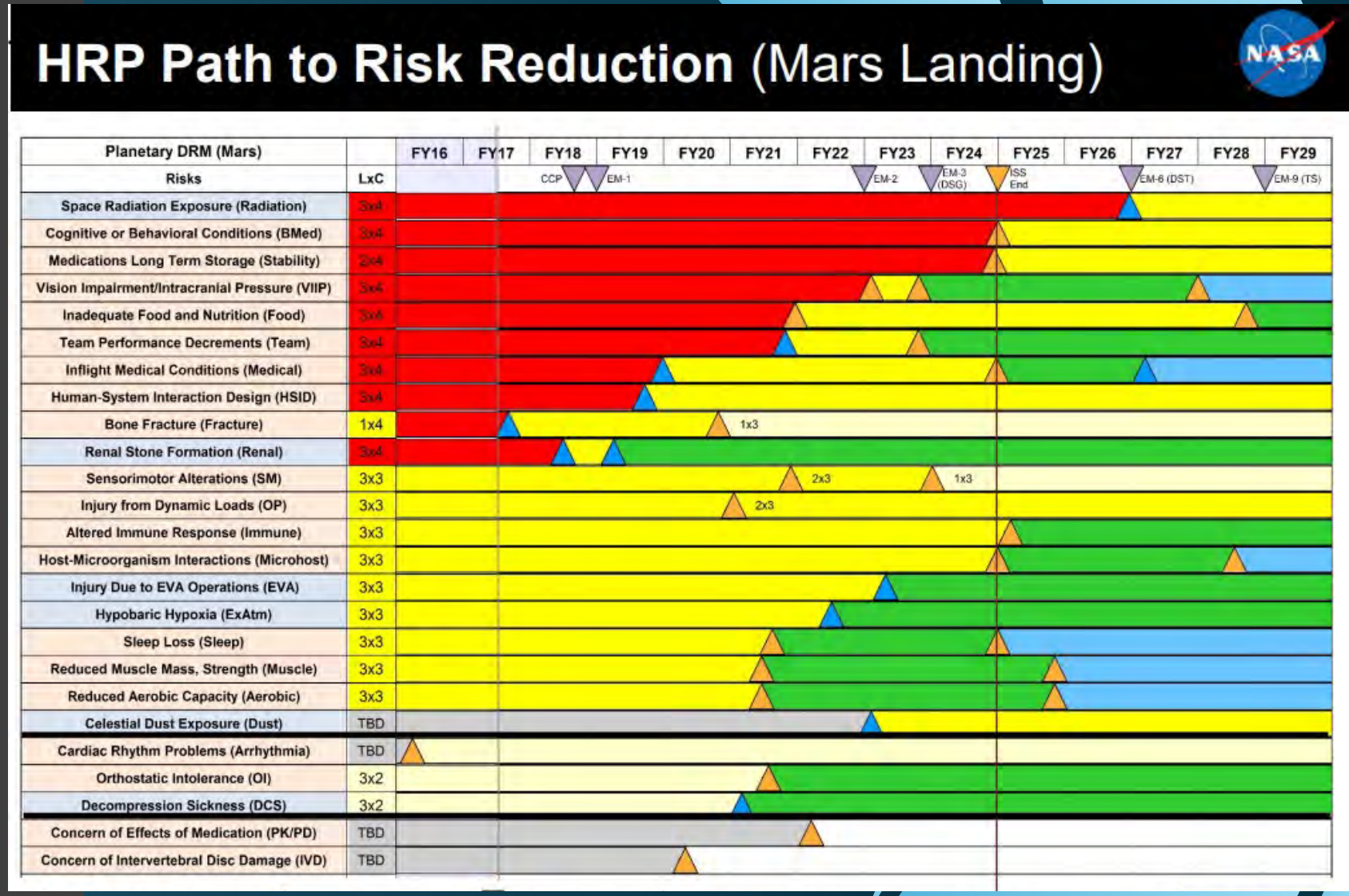
ECLSS = Environmental Control and Life Support Systems | CHPS = Crew Health and Performance Systems | LEO = Low-Earth Orbit

GRAPHICS NOT TO SCALE 20220513

Human System Risks

- NASA uses Human System Risks to aid in identifying and prioritizing human *research* needs

- But… no linkage between Human System Risks (research) and Capability Gaps (tech dev)



Human System Capability Gaps

- What?
  - Integrated set of capability gaps
  - Mapped to Human System Risks
  - Utilized by CHP community
  - Configuration managed by HSRB
- Why?
  - Facilitate fully integrated roadmaps
  - Demonstrate alignment of agency investments with Human System Risks
  - Improve ability to communicate Human System Risk implications of agency investment decisions

Example of Human System Capability Gaps

ID	Capability Gap Name	Capability Gap Statement	Primary Associated Human System Risks
1.1	Medical Concept of Operations, Mission Planning, and Level of Care	Medical concept of operations and an appropriate Level of Care to enable each exploration mission concept.	• Medical Conditions • Cognitive or Behavioral Conditions
1.2	Medical Simulations, Protocols & Training	Medical simulations, protocols, and training, utilizing a Crew Health & Performance Integrated Data Architecture, to enable increasingly earth-independent medical operations.	• Medical Conditions • Cognitive or Behavioral Conditions
1.3	Medical Imaging, Diagnostics, and Treatment	Imaging, diagnostic, and treatment technologies for anticipated and unanticipated medical conditions that meet mass, volume, power, and data constraints, and decrease reliance on ground support during increasingly earth-independent operations.	• Medical Conditions • Renal Stone • Concern of Venous Thromboembolism (VTE) • SANS • Cardiovascular (OI & Arrhythmia) • Urinary Retention
1.4	Behavioral Health and Performance Technologies	Behavioral health diagnosis, treatment, and support tools to enable behavioral health and performance during increasingly earth-independent operations.	• Cognitive or Behavioral Conditions • Sleep Loss

2022 Human System Capability Gaps

Gap No.	Human Systems Risk / Human Systems Capability Gap	Aerobic	Behavioral Med	Bone Fracture	Cardiovascular	Crew Egress	DCS	Dynamic Loads	Electrical Shock	EVA	Food and Nutrition	HSIA	Hypoxia	Immune	Medical Conditions	Microhost	Muscle	Non-Ionizing Radiation	Pharm	Radiation Carcinogenesis	Renal Stones	SANS	Sensorimotor	Sleep Loss	Team Risk	Urinary Retention	CO2	Dust	Hearing Loss	Toxic Exposure
1.1	Med. Risk Model and Tools		●												●															
1.2	Med. ConOps		●												●															
1.3	Med. Imaging, Diagnostics, Treatment			●	●				●	●					●			●			●	●				●				
1.4	Med. Decision Support		●			●						●			●				●				●							
1.5	Med. Simulation		●									●			●															
1.6	Semi-Autonomous Behavioral Med.		●																					●	●					
1.7	Safe and Effective Pharmaceuticals																		●											
2.1	Exercise Countermeasures	●	●	●	●	●								●	●		●						●							
2.2	Exercise VIS	●	●	●	●	●								●	●		●						●							
2.3	Bone Countermeasures			●																	●									
2.4	Sensorimotor Countermeasures					●																	●							
2.5	Cardiovascular Countermeasures				●	●																								
2.6	Neuro-ocular Countermeasures					●																●								
2.7	Biomedical Radiation Countermeasures		●		●															●										
2.8	Probabilistic Radiation Risk Models				●															●										
2.9	Immune Countermeasures													●	●															
2.10	Microbially-Induced Disease														●	●														
2.11	CHC Informatics	●	●	●	●							●			●		●						●							
2.12	Radiation Biomarker Technologies		●		●															●										
3.1	Food System		●								●				●	●														
3.2	Food Impact to CHP	●	●		●						●			●	●															
3.3	Food Intake Tracking										●																			
3.4	Food System Efficiency										●																			
4.1	Suited Fit and Injury							●		●																				
4.2	Suited Phys. and Performance		●			●				●																				
4.3	Autonomous Monitoring and Support									●		●																		
4.4	DCS Prediction and Mitigation						●			●			●																	
5.1	CHP IDA	●	●	●	●					●		●			●		●						●							
5.2	In-Situ Sampling	●			●						●	●			●		●		●				●							
5.3	Onboard Integrated Data Systems											●																		
5.4	Onboard Command Center											●																		
5.5	Autonomous Operations Simulation											●																		

● 2021 Mapping ● Added Mapping ● Removed Mapping

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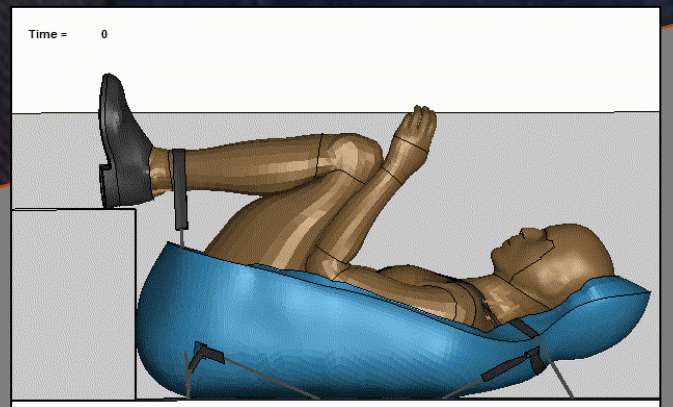
National Aeronautics and Space Administration

CHP Capability Area Updates

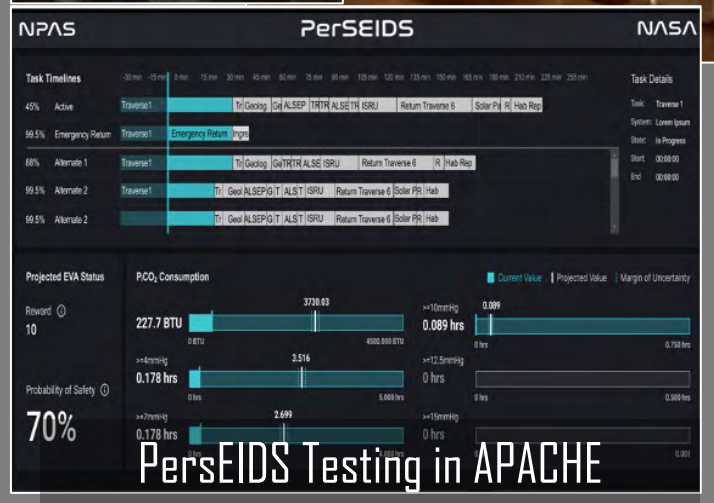
SPACESUIT PHYSIOLOGY & PERFORMANCE

Protecting crew health and performance during suited testing, training and operations

- Decompression sickness risk quantified and efficiently mitigated for exploration destinations
- Suited injury risk quantified and mitigated for all anthropometries
- Physiological & cognitive capabilities & constraints understood for all tasks
- Physiological & cognitive monitoring and decision support solutions identified for operations with delayed or interrupted space-ground comm



Suited Fit & Injury Technologies



PersEIDS Testing in APACHE

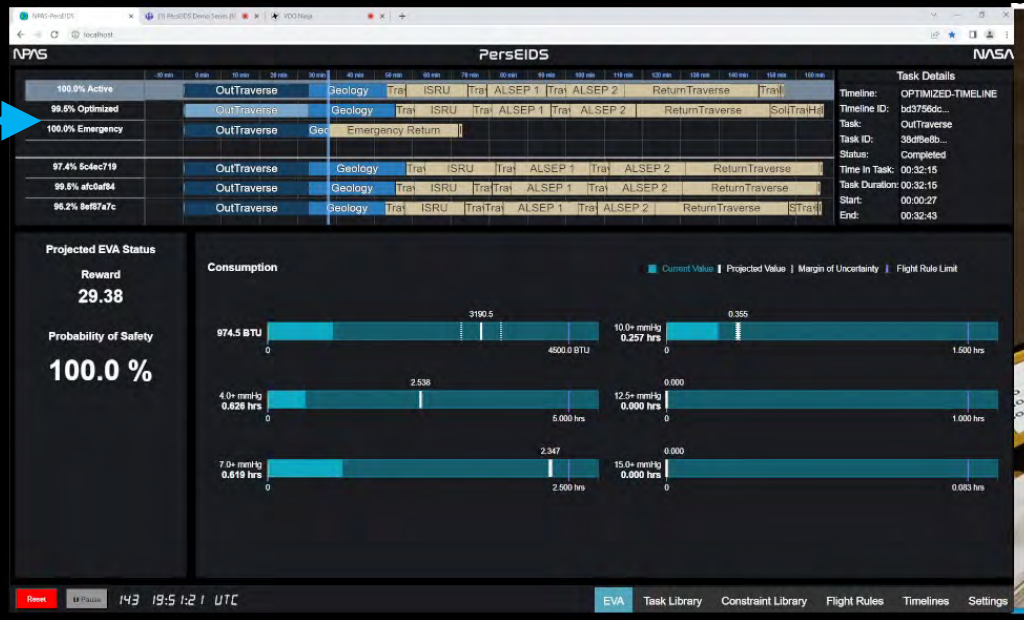
Current Capabilities (ISS)

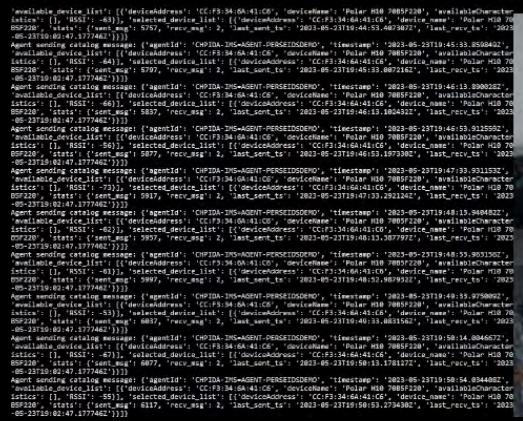
- Prebreathe protocols only valid for microgravity EVAs & specific atmospheres
- Ground, ISS, and Apollo suit injuries documented; 27 potential injury mechanisms identified
- Crew capabilities & constraints adequately known for ISS EVA only
- Limited crew state monitoring (metabolic & heart rate); fully ground-based decision support

Capability Gap	Gaps	Priority	Projects
Spacesuit Fit & Injury	2938	Mid-term Enabling	Spacesuit Fit & Injury Technologies (S-FIT)
Suited Physiology & Performance	2937	Mid-term Enabling	Crew State & Risk Model (CSRM)
Suited Autonomous Health Monitoring & Decision Support	2941	Near-term Enabling	Personalized EVA Informatics & Decision Support (PersEIDS)
Decompression Stress Prediction & Mitigation	2943	Mid-term Enabling	Aerospace Estimation Tool for Hypobaric Exposure Risk (AETHER)

Personalized EVA Informatics & Decision Support (PersEIDS)

Emergency return *timeline projection/ simulation*





APACHE Test Environment

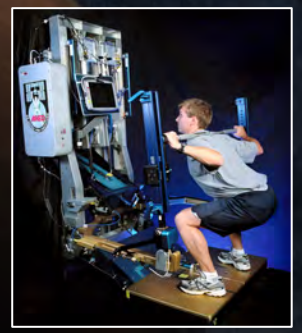
CREW HEALTH COUNTER-MEASURES

- Reduced mass and volume; increased reliability
- Maintain/monitor fitness in-flight to enable unassisted landing egress & EVA
- Validated lunar & Mars fitness standards (incl. sensorimotor)

Current Capabilities (ISS)

- Advanced Resistive Exercise Device
- COLBERT (treadmill)
- CEVIS (cycle ergometer)

Mass: ~4300 lbs *
Volume: ~19 m^3
Power: ~2100 Watts


Exercise devices and other technologies to mitigate the effects of spaceflight on crew health & performance

EPIC / HERMES Informatics

Sensorimotor Balance Board

ESA's E4D Exercise Device Prototype

Capability Gap	Gaps	Priority	Projects
CHC and Performance Informatics	2954	Near-term Enabling	EPIC / HERMES
Expl. Exercise System	2952; 2947	Near-term Enabling	E4D (ESA) | Ex VIS | Zero-T2 Study
Expl. Sensorimotor Countermeasures (CM)	3492	Near-term Enabling	Balance Board
Expl. Cardiovascular CM	3514	Mid-term Enhancing	Fluid Loading Protocol | Orthostatic Intolerance Garment
Expl. Behavioral Health & Performance CM	New	TBD	BHP Roadmap in definition

EXPLORATION MEDICAL

Protocols, technology, and supplies to address in-mission medical conditions

- In-flight diagnostics and treatment for 100 of 120 medical risk conditions
- Autonomous medical skill and & decision support systems

Current Capabilities (ISS)

- Conventional medical capabilities with real-time supervision & support always available from ground
- Regular resupply of consumables and replacement of equipment as needed

Long-Duration Pharma

Multi-functional Medical Devices

BHP Diagnostics & Treatment Aides

Capability Gap	Gaps	Priority	Projects
Imaging, Diagnostics & Treatment	2950	Near-term Enabling	Regenerable IV Fluid Device Development (Mini IVGEN); Multifunctional Integrated Medical Device; SANS Diagnostic Devices; Mini X-ray;
Medical Ops Decision Support & Informatics	2904; 2905	Near-term Enabling	Automated Medical Inventory System (AMIS); Ex. Electronic Heath Record; Hololens Tech Demo; CHP Integrated Data Architecture
Long-Duration Pharmaceuticals	3508	Mid-term Enabling	Medications Vacuum Testing; Exploration Formulary
Behavioral Health and Performance Medical Technologies	2911	Near-term Enabling	Autonomous BHP Diagnostic/Treatment Aides

FOOD & NUTRITION

Safe, acceptable, nutritious & resource-efficient foods for exploration missions

- 100% of nutrient stability >5-year shelf life
- Food acceptability >90%
- < 30% launched water content
- Exploration in-flight nutrition intake monitoring

Current Capabilities (ISS)

- 1.5 year shelf life, fresh food resupply every 2-3 months
- ~215 standard food items, µg plant experiments
- ~47% launched water content
- In-flight nutrient intake monitoring in development

Airflow test in Ohalo growth chamber prototype

Reduced Water Content Food

Aero/hydroponic crop experiment

CHAPEA: 1 year Food Study

Capability Gap	Gaps	Priority	Examples
Long Duration Food System	2944	Near-term Enabling	Crop systems (VEGGIE, APH; OHALO III, XROOTS); Alternative nutrition sources (bacterial, algae, fungi); Synthetic biology approaches (CUBES)
Food System Efficiency	2945	Near-term Enabling	Prepackaged food water content reduction
Food Impacts to Health and Performance	2946	Near-term Enabling	Crew Health and Performance Exploration Analog (CHAPEA)

Conclusions

- Human System Capability gaps facilitate an integrated approach to NASA's human-centered research and technology development
- Human research at NASA is led by the Human Research Program; details on HRP projects can be found at *humanresearchroadmap.nasa.gov*
- This paper summarizes NASA's current technology development efforts associated with four different CHP capability areas: Spacesuit Physiology & Performance; Crew Health Countermeasures; Food; and Exploration Medical Systems
- Roadmaps for each capability area aim to ensure at least one technological solution is available to address each identified Capability Gap
- Gap closure does not in itself assure the health and performance of crewmembers in future spaceflight missions; definition of an integrated CHP System is a priority for NASA's human-centered research and technology development integration

Questions?