

HRP Risk Approach Plans

June 2026

Index of Legend Symbols

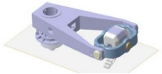


M2M Deliverable



Lunar Deliverable

For Data Field



For Legend



Animal Models



Artemis



Atmospheric Chamber



Bedrest



Centrifuge



CLDP



For Data Field



For Legend



Commercial Freeflyers/PAM



Drop tower/sled



Isolation



ISS



Neutral Buoyancy Lab



Parabolic Flight

Organization Graphic Identifiers



Extravehicular Activity and Human Surface Mobility



Commercial Crew



Human Landing Systems



Flight Operations



Office of the Chief Health and Medical Officer



Mars Campaign Office



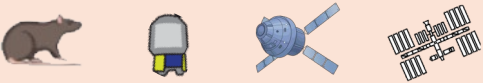
Health and Medical Technical Authority

Behavioral Health (BH) and Performance Risk Approach Plan

HRR Knowledge Gap

Risk Characterization / Formulation

BH-109: Characterize in-mission and **long-term effects** of long-duration spaceflight on behavioral health and performance.



- 1** Impacts of exploration spaceflight on in-mission and long-term behavioral health and performance: BHP Ops by 2031 (interim), 2034

CM Development / Evaluation

BH-201: Identify **indicators, measures, and thresholds**, to inform semi-autonomous behavioral health and performance monitoring

- 2** Recommendations to inform crew selection for Mars: BHP Ops by 2027 (interim), 2034
- 3** Recommendations for semi-autonomous monitoring system, integrating relevant measures and evidence/threshold-based guidelines for countermeasures: BHP Ops by 2031 (interim), 2034

BH-202: Identify evidence-based **design recommendations** for habitat/vehicle interfaces, to mitigate impacts to behavioral health and performance

- 4** Recommendations to inform habitat/sub-system design: HMTA by 2027 (interim), 2034

BH-203: Develop, test/refine, and validate **countermeasures** to support behavioral health and performance for future exploration missions

- 5** Behavioral health training curriculum/modules: BHP Ops by 2031
- 6** Countermeasures for in-mission social support: BHP Ops by 2031
- 7** Family and crew social support toolbox to enable post-mission re integration: BHP Ops by 2031
- 8** Validated countermeasures to support behavioral health & performance: BHP Ops by 2034

BH-204: Identify, test and refine **therapeutic interventions** for treating adverse behavioral outcomes associated with exploration missions

- 9** Therapeutic interventions to treat adverse health outcomes: BHP Ops by 2031 (interim), 2034

LEGEND: Isolation ISS Artemis Animal Models M2M Deliverable

TIMELINE:

2a 4a

2025



2027

Risk Maps to ESDMD-0404

1a 3a 5 6 7 9a

2031



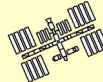
1b 2b 3b 4b 8 9b

2034



2035

Bone Risk Approach Plan

HRR Knowledge Gap	Risk Characterization / Formulation BONE-101: Characterize changes in bone density and structure (quality) in astronauts. BONE-102: Characterize bone turnover and other biochemical markers of skeletal health. BONE-201: Identify/develop/apply tools (e.g., computational modeling or alternative) to inform the estimation bone strength and probability of overloading bones and fracture assessment. BONE-301: Identify, develop, and implement monitoring tools for bone health following long-duration spaceflight.  1 Bone Standards and Recommendations: OCHMO by 2028 MRI Informing Pharmaceutical Use TTO 2027	CM Development / Evaluation BONE-401: Identify and test preventative and mitigating countermeasures for changes induced by spaceflight.  1 Bone Standards and Recommendations: OCHMO by 2028 MRI Informing Pharmaceutical Use TTO 2027
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LEGEND:  Isolation  ISS  M2M Deliverable

Carcinogenesis Risk Approach Plan

	Risk Characterization	Countermeasure (CM) Development, Evaluation, Validation, & Integration
HRR Knowledge Gap	Cancer-103: Determine the effects of radiation quality on cancer initiation, promotion, progression. Cancer-104: Determine the effects of radiation dose and dose-rate on cancer initiation, promotion, progression.   1 NSCR update with Qnew development (2025) Cancer-202: Evaluate the contribution of genetic background/diversity on carcinogenesis risk. Cancer-203: Evaluate the tissue-specific risks of space radiation exposure on cancer outcomes. Cancer-204: Evaluate the sex-specific risks of space radiation exposure on cancer outcomes.   2 NPR 8900 Baseline (PEL evaluation) (2025) 3 NPR 8900.1B Acceptance – Characterization Data (2030)	Cancer-403: Identify and/or develop potential biomarkers to support health surveillance and countermeasure implementation. Cancer-504: Identify and validate safe and effective countermeasures to reduce radiation carcinogenesis. Cancer-604: Operationalize validated pharmaceutical countermeasures and surveillance technologies for spaceflight.    4 8 Clinical Practice Guideline (CPG) Recommendations (2030, 2035) 5 Countermeasure Identification (2033) 6 8900 Acceptance - Mitigation Data (2035) 7 Integrated CM Toolkit (2035)

LEGEND:



M2M Deliverable

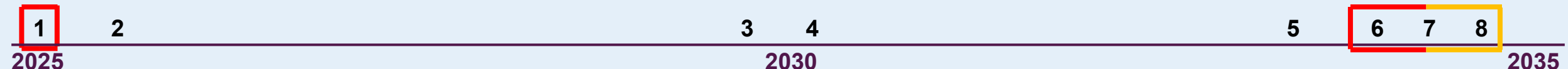


ISS



Artemis

TIMELINE:



Risk Maps to ESDMD-0308



Earth Independent Human-System Operations (EIHSO) Risk Approach Plan

HRR Knowledge Gap

Risk Characterization / Formulation

EIHSO – 102: Characterize human-system performance **impacts due to increasingly Earth-independent missions** (e.g. communication delays) and determine indicators of meaningful change to enable mission objectives

- 1 Impacts of increasingly earth-independent mission operations on human-system performance: FOD, MCO by 2027 (interim); update 2034



CM Development / Evaluation

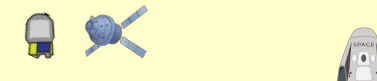
EIHSO – 202: Develop and validate **monitoring countermeasures** of human-system performance (procedure execution, anomaly resolution) during increasingly Earth-independent operations (e.g. communication delays)

- 2 Recommendations for semi-autonomous monitoring dashboard: BHP Ops, FOD by 2031 (interim), 2034



EIHSO – 203: Develop & validate candidate **requirements for design** of vehicles, habitats, interfaces (e.g. displays for complex info presentation, fine motor decrements) to support increasingly Earth-independent operations

- 3 Recommendations to inform habitat/sub-system design: HMTA by 2027 (interim), 2034
- 4 Guidelines, multi-modal methods to mitigate touch screen manipulation decrements: HLS by 2027 (interim), 2031



EIHSO – 204: Develop and validate **countermeasures** to enable human-system performance (**procedure execution, decision support**) for increasingly earth independent crews

- 5 Task simulation tools for anomaly resolution and decision support under communication delays: FOD by 2031
- 6 Procedure execution guidance & requirements under communication delays: MCO, FOD by 2027 (interim), 2031
- 7 Recommendations: personalized, adaptive training regimens/platforms: BHP Ops, FOD by 2031 (interim), 2034



EIHSO – 205: Develop and validate **countermeasures** to enable **safe human-robot interaction**

- 8 Safe human robot interaction guidelines and countermeasures: FOD by 2031 (interim); 2034



LEGEND: Isolation ISS Artemis Commercial Freeflyers/PAM M2M Deliverable

TIMELINE:

1a 3a 4a 6a

2a 4b 5 6b 7a 8a

1b 2b 3b 7b 8b

2025



Risk Maps to ESDMD–1002 through 1005



2030



2034



2035

EVA Risk Approach Plan

HRR Knowledge Gap

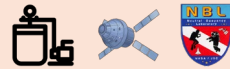
Risk Characterization / Formulation

EVA-101: Characterize **EVA preparedness** shortly post-landing on a planetary surface.



1 Days post-landing prior to initial EVA: OCHMO by 2027

EVA-102: Characterize **surface EVA performance** during exploration missions in partial gravity environments.



2a Lunar Hi-Tempo Capabilities: EHP/FOD/OCHMO by 2028

2b Martian Hi-Tempo Capabilities: EHP/FOD/OCHMO by 2029

EVA-201: Characterize impacts of **variable atmospheric conditions suits** on human health and performance, including exploration atmospheres, variable pressure suits, and alternate pre-breathe strategies.



3 Elevated Suit Pressure Trade Space (EHP/HRP): EHP/FOD by 2028

4 DCS Risk Prediction Tool: EHP/OCHMO by 2030
Initial model updates and implementation by 2027

CM Development / Evaluation

EVA-303: Identify and test **countermeasures related to exposure to variable atmospheric conditions**.



5 Integrated DCS CM (e.g. CO₂, exercise, PFO, suit pressure): EHP/HLS by 2030

CO₂-enhanced prebreathe evaluated by 2027

Exercise-enhanced prebreathe evaluated by 2027

PFO initial analysis by 2027

LEGEND: ISS CLDP Commercial Freeflyers/PAM Neutral Buoyancy Lab Atmospheric Chamber Artemis M2M Deliverable Lunar Deliverable

TIMELINE:

2025

1

2

3

4

5

DCS

2031

2035



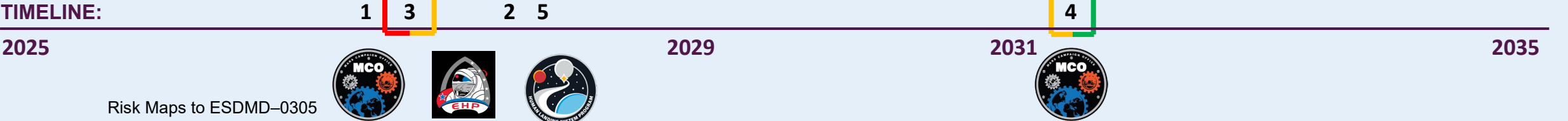
2029



Food and Nutrition Risk Approach Plan

HRR Knowledge Gap	Risk Characterization / Formulation	CM Development / Evaluation
	FN-103: Influence of temperature on the nutritional content, safety, and acceptability of the spaceflight food system. 1 Cold Storage Temperature Requirements - Mars: M2M by 2027 2 HLS Palatability and Nutrition of Food Stored at High Temps: M2M by 2028	FN-206: Using food as a countermeasure to mitigate decrements in nutritional status or DRM impacts on health and performance outcomes.  3 Restricted Food System CM (CHAPEA early trends): M2M by 2027 4 Mass Reduced Food System Evaluations: M2M by 2031 5 EVA Dietary Requirements: M2M by 2028

LEGEND:  Isolation  Neutral Buoyancy Lab  Atmospheric Chamber  M2M Deliverable



Immune Risk Approach Plan

HRR Knowledge Gap	Risk Characterization / Formulation	CM Development / Evaluation
	IM-106: Characterize the effect of the stressors associated with spaceflight (stress, microgravity, radiation, altered nutrition, circadian misalignment, hypoxia, etc.) on human immunity, determine clinical relevance and biomarkers to enable monitoring of astronauts.    1 Likelihood and Consequences of Immune Dysfunction/Infectious Disease - ISS: OCHMO by 2026 2 Health status Biomarkers Validated – Exploration Missions: M2M by 2033	IM-404: Test, optimize, and validate nutrition, pharmacological, exercise, and stress reduction techniques as preventive/mitigative countermeasures for immune dysfunction.   3 Ground Validation of Immune CMs: M2M by 2027 4 Flight Validation of Immune CMs: M2M by 2031

LEGEND:  Isolation  ISS  Neutral Buoyancy Lab  Artemis  M2M Deliverable

TIMELINE:

2025

1

3

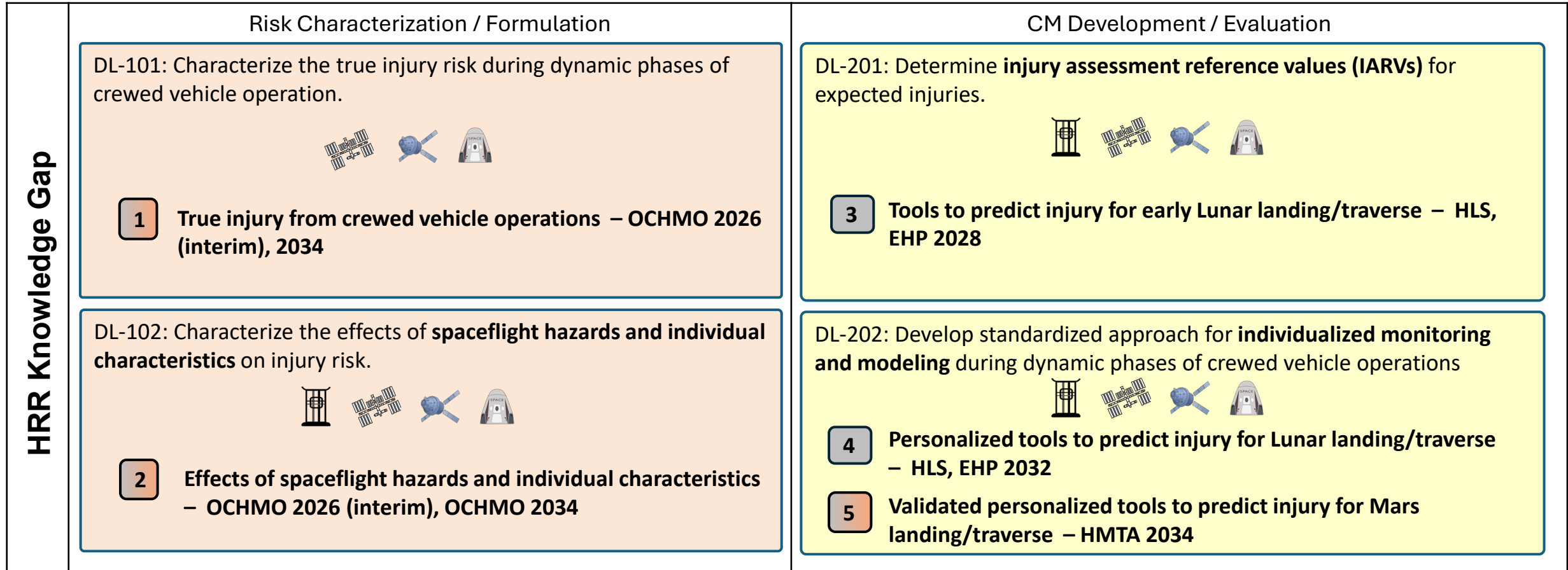
2

2030

2035



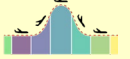
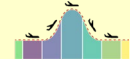
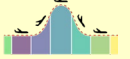
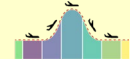
Injury Due to Dynamic Loads (DL) Risk Approach Plan

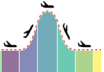


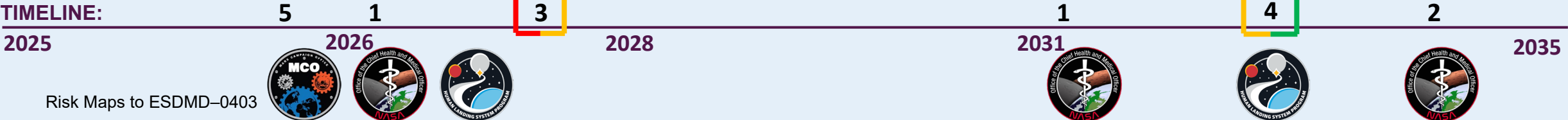
LEGEND:  ISS  Commercial Freeflyers/PAM  Artemis  Drop tower/sled  Lunar Deliverable  M2M Deliverable



SANS Risk Approach Plan

HRR Knowledge Gap	Risk Characterization / Formulation SANS-101: Characterize the temporal profile and magnitude of ocular and brain manifestations during spaceflight and recovery to inform in-mission and long-term health consequences. SANS-102: Characterize the relationship between fluid shifts-induced ocular changes and fluid shifts in the CNS, including whether elevated intracranial pressure or brain edema play a role. SANS-202: Characterize the inherent factors (for example, genetic, metabolic, anatomical, sleep) that contribute to the individual variability in the ocular and brain manifestations. SANS-203: Characterize the effects of environmental factors (for example, gravity, atmospheric conditions, radiation) during spaceflight on ocular and brain manifestations.  1 Personalized SANS Prediction Capability: OCHMO by 2031 Preliminary version to OCHMO by 2026 2 LTH Monitoring Surveillance Guidelines: OCHMO by 2036 Surveillance measures implemented 2029 <td> CM Development / Evaluation SANS-403: Develop and test candidate countermeasure(s) for SANS.  3 Personalized SANS CMs Prescription (i.e. VTC, B-Complex, GLP-1): M2M by 2031 B-Complex TTO 2028 SANS-404: Develop and test candidate monitoring technologies for SANS.  4 Ocular monitoring devices: Gateway by 2029, M2M by 2035, HRP handover to MCO </td>	CM Development / Evaluation SANS-403: Develop and test candidate countermeasure(s) for SANS.  3 Personalized SANS CMs Prescription (i.e. VTC, B-Complex, GLP-1): M2M by 2031 B-Complex TTO 2028 SANS-404: Develop and test candidate monitoring technologies for SANS.  4 Ocular monitoring devices: Gateway by 2029, M2M by 2035, HRP handover to MCO
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LEGEND:  ISS  Commercial Freeflyers/PAM  Parabolic Flight  Artemis  Bedrest  M2M Deliverable  Lunar Deliverable



Sensorimotor Risk Approach Plan

HRR Knowledge Gap

Risk Characterization / Formulation

SM-105: Characterize the effects of spaceflight on **manual control and spatial disorientation** during and after G transitions that impact vehicular control.



- 1 Manual Control Onboard Training recommendations: Analog 2027 & Flight 2033 to FOD/HLS

SM-106: Characterize the effects of spaceflight on **postural control and locomotion (gross motor control), and motion sickness** after G transitions that impact egress and early intravehicular / extravehicular activities.



- 2 Days post-landing prior to initial EVA: OCHMO by 2033

CM Development / Evaluation

SM-205: Develop and test **manual control countermeasures**, such as preflight disorientation training, onboard training and adaptive displays that impact vehicular control.



- 3 GVS for Preflight disorientation training: HLS by 2027
- 4 Manual Control Adaptive Display and Training Recommendations: HLS by 2027
- 1 Manual Control Onboard Training recommendations: Analog 2027 & Flight 2033 to FOD/HLS

SM-206: Develop and test **countermeasures for egress, early intravehicular / extravehicular activities, and motion sickness** such as inflight training, post-landing assessments and guidelines, including human factors aids.



- 5 Balance Trainer CM Validated: Bedrest 2028, Flight 2031 to M2M
- 6 Pre-EVA SM assessments: Analog 2027 Flight 2031 to SD & EHP
- 7 Head/body motion recovery guidelines: Analog 2027 & Flight 2031 to CCP & OCHMO

LEGEND: ISS Centrifuge Commercial Freeflyers/PAM Parabolic Flight Artemis Bedrest M2M Deliverable Lunar Deliverable

TIMELINE:
2025

3 4

5

2030

6

Egress

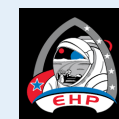
7

1

MC

2

2035



HRR Knowledge Gap

HRR Knowledge Gap



1a 2a 4a

3a 5 6 7

1b 2b 3b 4b 8



Venous Thrombosis Risk Approach Plan

HRR Knowledge Gap

Risk Characterization / Formulation

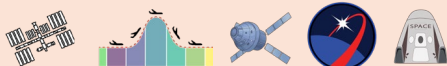
CV-104: Determine **biomarkers** relevant for development of venous thrombosis in spaceflight.

CV-105: Determine the influence of **anatomical variations** for development of venous thrombosis in spaceflight.

CV-106: Determine the influence of **genetic predispositions** for development of venous thrombosis in spaceflight.

CV-107: Determine the influence of **immune factors** for development of venous thrombosis in spaceflight.

CV-108: Determine the contribution of **flow abnormalities** to venous thrombosis risk in OG and partial-G.



1 Likelihood and Consequences (LxC) of Venous Thrombosis in 0-G: OCHMO by 2031

2 Likelihood and Consequences (LxC) of Venous Thrombosis in partial-G: OCHMO by 2033

CM Development / Evaluation

CV-202: Identify, develop, and test **monitoring strategies** for venous thrombosis in spaceflight.

CV-203: Identify, develop, and test candidate countermeasures for venous thrombosis in spaceflight.



3 Thigh Cuffs CM for Venous Thrombosis: OCHMO/M2M by 2032

4 Novel CM for Venous Thrombosis (e.g. pharmaceutical/nutraceutical): OCHMO/M2M by 2035

LEGEND: CLDP ISS Commercial Freeflyers/PAM Parabolic Flight Artemis M2M Deliverable

TIMELINE:

2025

2030

2035

Risk Maps to ESDMD-0401

