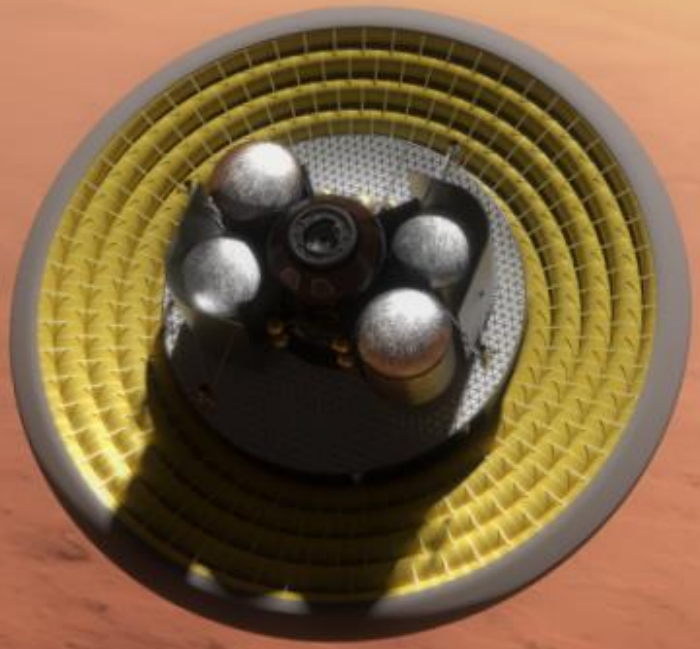
Mars Ascent Vehicle Sizing, Habitability, and Commonality in NASA's Evolvable Mars Campaign



Mike Gernhardt, Omar Bekdash, Harry Litaker, Steven Chappell, Kara Beaton, Carolyn Newton, Edwin Crues, Andrew Abercromby

Background

- The Mars Ascent Vehicle (MAV) has the largest “gear ratio” in the EMC architecture. Earth to Cis-lunar, Cis-lunar to Mars orbit, Mars orbit to surface, surface to HMO. A 500 pound reduction in mass for the MAV cabin is equivalent to 10 tons of payload in Cis Lunar space.

- Mass and volume of the MAV cabin drives requirements for the In-Situ Resource Utilization to generate propellants, which drives the surface power needs, and which also sets the Lander payload size, which drives the in-space transportation architecture, and the number of launches and time required to land humans on Mars Surface.

- No Human in the loop evaluations to generate the data necessary to inform decisions on the MAV sizing, which are critical to begin to close the various EMC architectures have been done

- This goal of this project is to provide data to define the smallest credible MAV cabin

MAV

Existing Mockup Cabin

Suited Evaluations

Functional Requirements for MAV Cabin (1 of 2)

- **Support transfer under pressure of crewmembers into/out of MAV (in space and on Mars surface)**
  - Transfer under pressure may be different in space vs. Mars surface
- **Support 4 crewmember for up to 5 days in space (worst case, suboptimal rendezvous)**
  - Best case could be 16 hours
  - This includes logistics, consumables, etc.
- **Accommodate return of 250 kg of samples**
  - Not constrained to internal stowage
- **Accommodate habitability for 4 crewmember**
  - For example sleeping, eating, personal hygiene, WCS, etc.
- **Accommodate LEA suit donning for 4 crewmembers in < 60 min (TBR)**
  - Includes connect umbilicals and suit loop
- **Accommodate LEA suit doffing**
- **Enable piloting of the vehicle during launch and rendezvous ops (suited and unsuited)**
  - Including windows and camera views
- **Enable necessary interaction with vehicle subsystems during all phases (suited and unsuited)**
- **Support command/control of local vehicles and robotic assets from the MAV**
- **Enable commanding of the MAV from the transit hab**

Functional Requirements for MAV Cabin (2 of 2)

- **Support 2 year dormancy/storage on Mars surface prior to use**
  - Consider drivers associated with minimal spares, redundant systems for required reliability and readiness
- **Support a 2 hour time from beginning of ingress to launch**
  - 2 hours could be contingency limit
  - Nominal may be for 2 crew to ready vehicle over some period of time prior to ingress of remaining crew
- **Enable incapacitated crewmember transfer and medical care using available medical resources**
  - Orion-level of care
- **The atmosphere should be controllable between 8.2psi /34% O_2 and 14.7 psi standard atmosphere**
- **Support one-at-a-time in space EVA transfer from the MAV to transit vehicle**
  - Includes necessary EVA translations paths and construction standards
- **Occupant protection during ascent**
  - In addition to LEA suits
- **Support maintainability and repair on surface and in orbit**
- **Support berthing of the MAV at the Mars transit vehicle, including enabling commanding of berthing arm and docking system on transit vehicle from MAV**
- **Integrate with descent vehicle, first stage, and remainder of second stage**
- **Accommodate multiple shifts of crewmember operations**
- **Accommodate planetary protection**

Team Derived Lander MEL – ECLSS (pg 1 of 3)

16 Hrs – page 1

			Subsystem Total		16 hour mission								
E/G/I	Sub	Part #	Dash	Common Name	Basic Mass (kg)	Quantity	Total Mass (kg)	Length (m)	Height (m)	Width (m)	Outer Diameter (m)	Volume (m^3)	Notes
CA2A	**10**	**000**	**301**	**ECLSS Top**									
CA2A	10	001	31001	**Cabin Ventilation**									
CA2A	10	002	31002	Controller, Cabin Fan	6.00	2.00	12.00	0.1	0.1	0.1		1.000E-03	ORION
CA2A	10	003	31003	Ducting, Cabin Ventilation	20.50	1.00	20.50	12			0.050	2.356E-02	ORION
CA2A	10	004	31004	Return Vent	0.10	1.00	0.10	0.03	0.03	0.03	0.030	2.700E-05	
CA2A	10	005	31005	Filter HEPA, Cabin #0001	13.30	1.00	13.30	0.2	0.05	0.2		2.000E-03	ORION
CA2A	10	006	31006	Sensor, Temperature, Cabin Ventilation #0001	0.14	2.00	0.28		0.05		0.020	1.571E-05	ORION
CA2A	10	008	31008	Muffler Pre-Fan, Cabin	5.50	2.00	11.00	0.46			0.152	8.347E-03	ORION
CA2A	10	009	31009	Fan, Cabin #0001	3.50	2.00	7.00	0.02	0.12	0.006	0.120	1.440E-05	ORION
				Check Valve	0.21	2.00	0.42						ORION
CA2A	10	010	31010	Muffler Post-Fan, Cabin	5.50	2.00	11.00	0.46			0.152	8.347E-03	OIRON
CA2A	10	012	31012	Heat Exchanger, Cabin	6.00	1.00	6.00	0.12	0.1	0.15		1.800E-03	Altair
CA2A	10	013	31013	Valve, Bypass, HXC	8.00	1.00	8.00		0.07		0.030	4.948E-05	ORION
CA2A	10	014	31014	Vent, Outlet #0001	0.10	1.00	0.10	0.03	0.03	0.03	0.030	2.700E-05	Altair
CA2A	10	015	31015	Vent, Outlet #0002	0.10	1.00	0.10	0.03	0.03	0.03	0.030	2.700E-05	Altair
				Module Total	**89.80**							**4.522E-02**	
CA2A	10	016	32001	**PLSS Umbilical Panel**									
				Drinking Water Subassembly	4.60	2.00	9.20						ORION
				Oxygen Subassembly	4.60	2.00	9.20						ORION
				LCG Cooling Water Subassmbly	3.20	1.00	3.20						ORION
CA2A	10	017	32002	Ducting, ARS	6.00	1.00	6.00	4			0.050	7.854E-03	Altair
CA2A	10	021	32006	Bed, Control, Trace Contaminant #0001	11.78	1.00	11.78		0.23		0.100	1.806E-03	ORION
CA2A	10	022	32007	Air Monitor	9.00	1.00	9.00	0.35	0.25	0.25		2.188E-02	ORION
CA2A	10	023	32008	Analyzer, Raman #0001	10.00	1.00	10.00	0.1	0.2	0.2		4.000E-03	Altair
CA2A	10	024	32009	Compressor, ARS #0001	4.00	1.00	4.00		0.08		0.050	1.571E-04	PLSS
CA2A	10	025	32010	Compressor, ARS #0002	4.00	1.00	4.00		0.08		0.050	1.571E-04	PLSS
CA2A	10	026	32011	Valve, Check, ARS #0001	0.19	1.00	0.19		0.02		0.010	1.571E-06	ORION
CA2A	10	027	32012	Valve, Check, ARS #0002	0.19	1.00	0.19		0.02		0.010	1.571E-06	ORION
CA2A	10	028	32013	Muffler, ARS	4.50	2.00	9.00	0.46			0.152	8.347E-03	ORION
CA2A	10	029	32014	Ducting, ARS Vacuum	2.40	1.00	2.40	12			0.050	2.356E-02	Altair
CA2A	10	030	32015	Sensor, Pressure, Vacuum #0001	0.30	1.00	0.30		0.076		0.030	5.372E-05	ORION
CA2A	10	031	32016	Sensor, Pressure, Vacuum #0002	0.30	1.00	0.30		0.076		0.030	5.372E-05	ORION
CA2A	10	032	32017	Valve, Vacuum, ARS #0001	5.00	2.00	10.00		0.07		0.130	9.291E-04	Altair
CA2A	10	033	32018	Valve, Vacuum, ARS #0002	5.00	2.00	10.00		0.07		0.130	9.291E-04	Altair
				Valve Assembly, Vacuum, SWME	5.00	4.00	20.00						Altair
CA2A	10	034	32019	Vent, Vacuum CO2 & H2O	0.10		1.00	0.03	0.03	0.03	0.030	2.700E-05	Altair
				Module Total	**98.16**							**6.975E-02**	
CA2A	10	035	33001	**Cabin Interfaces - Intra Module Utilities & Ventilation**									
CA2A	10	040	33006	QD, H2O IMU, Female #0001	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	041	33007	Valve, Selector, H2O IMU #0001	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	042	33008	QD, H2O IMU, Female #0002	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	043	33009	Valve, Selector, H2O IMU #0002	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	044	33010	QD, Oxygen IMU, Female #0001	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	045	33011	Valve, Selector, Oxygen IMU #0001	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	046	33012	QD, Oxygen IMU, Female #0002	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	047	33013	Valve, Selector, Oxygen IMU #0002	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	048	33014	QD, Nitrogen IMU, Female #0001	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	049	33015	Valve, Selector, Nitrogen IMU #0001	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	050	33016	QD, Nitrogen IMU, Female #0002	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	051	33017	Valve, Selector, Nitrogen IMU #0002	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	052	33018	QD, Air IMV, Female #0001	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	053	33019	Valve, Selector, Air IMV #0001	1.60				0.12		0.120	1.357E-03	Altair
CA2A	10	054	33020	QD, Air IMV, Female #0002	0.25				0.08		0.044	1.216E-04	Altair
CA2A	10	055	33021	Valve, Selector, Air IMV #0002	1.60				0.12		0.120	1.357E-03	Altair
				Module Total	**14.80**							**1.183E-02**	

Continued

Team Derived Lander MEL – ECLSS (pg 2 of 3)

16 Hrs – page 2

			Subsystem Total		16 hour mission								
E/G/I	Sub	Part #	Dash	Common Name	Basic Mass (kg)	Quantity	Total Mass (kg)	Length (m)	Height (m)	Width (m)	Outer Diameter (m)	Volume (m^3)	Notes
CA2A	10	064	34001	**Gas Storage - Nitrogen**									
CA2A	10	065	34002	Tank, Nitrogen	19.47	1.00	19.47					1.040E-01	Sized for 16 hr mission (no gas)
CA2A	10	066	34003	Tubing, Nitrogen	2.40	1.00	2.40	12			0.050	2.356E-02	
CA2A	10	067	34004	Valve, Relief, Tank, Nitrogen	1.20	1.00	1.20		0.12		0.050	2.356E-04	
CA2A	10	068	34005	Sensor, Pressure, Tank Nitrogen #0001	0.30	1.00	0.30		0.076		0.030	5.372E-05	
CA2A	10	069	34006	Valve, Isolation, Tank, Nitrogen	1.00	2.00	2.00		0.07		0.030	4.948E-05	
CA2A	10	070	34007	QD, Fill Port, Nitrogen, Female	0.25	1.00	0.25		0.08		0.044	1.216E-04	
CA2A	10	072	34009	Regulator, Tank, Nitrogen #0002	1.20	4.00	4.80		0.15		0.070	5.773E-04	
CA2A	10	073	34010	Sensor, Temperature, Tank Nitrogen	0.30	1.00	0.30		0.076		0.030	5.372E-05	
				Heater, Tank Nitrogen #0001	1.70	1.00	1.70						
				Controller, Nitrogen Introduction	4.60	1.00	4.60						
CA2A	10	074	34101	**Gas Storage - Oxygen**									
CA2A	10	075	34102	Tank, Main Oxygen	24.83	1.00	24.83					6.000E-02	Sized for 16 hr mission (no gas)
CA2A	10	078	34105	Tubing, Oxygen	2.40	1.00	2.40	12			0.050	2.356E-02	
CA2A	10	079	34106	Valve, Relief, Tank, Oxygen	1.20	1.00	1.20		0.12		0.050	2.356E-04	
CA2A	10	080	34107	Sensor, Pressure, Tank Oxygen #0001	0.30	4.00	1.20		0.076		0.030	5.372E-05	
				Sensor, Tempearture, Tank, Oxygen	0.30	1.00	0.30						
CA2A	10	081	34108	Valve, Isolation, Tank, Oxygen #0001	1.00	1.00	1.00		0.07		0.030	4.948E-05	
CA2A	10	082	34109	Valve, Isolation, Tank, Oxygen #0002	1.00	1.00	1.00		0.07		0.030	4.948E-05	
				Regulator , Tank Oxygen #0001	1.40	1.00	1.40		0.15		0.070	5.773E-04	
				Valve, Bulkhead, Oxygen	1.00	1.00	1.00						
				Valve,Introduction, Oxygen, Manual	1.00	1.00	1.00						
				Valve, Check, Oxygen	0.10	2.00	0.20						
				Heater, Tank Oxygen #0001	3.68	1.00	3.68						
				Controller Oxygen Introduction	4.60	1.00	4.60						
				Module Total	**80.83**							**2.126E-01**	
CA2A	10	084	35001	**Pressure Control - Cabin**									
CA2A	10	071	34008	Valve, Bulkhead, Nitrogen	1.60	1.00	1.60		0.12		0.120	1.357E-03	
				Valve, Introduction, Gas	1.00	4.00	4.00						
				Gas Introduction Orifice	0.10	3.00	0.30						
CA2A	10	085	35002	Valve, Isolation, Cabin Pos Pressure #0001	1.00	1.00	1.00		0.07		0.030	4.948E-05	
CA2A	10	087	35004	Valve, Relief, Cabin Pos Pressure #0001	4.00	1.00	4.00		0.12		0.050	2.356E-04	
CA2A	10	089	35006	Sensor, Cabin Pressure	0.30	1.00	0.30		0.076		0.030	5.372E-05	
CA2A	10	103	35020	Sensor, Cabin Temperature	0.30	2.00	0.60		0.15		0.070	5.773E-04	
				Sensor, Cabin Partial Pressure Oxygen	0.70	1.00	0.70						
				Module Total	**12.50**							**9.161E-04**	
CA2A	10	104	36001	**Life Support Misc Components**									
CA2A	10	105	36002	Extinguisher, Fire	4.50	1.00	4.50		0.35		0.100	2.749E-03	
CA2A	10	106	36003	Contingency Breathing Apparatus Type 1	11.00	1.00	11.00					2.750E-02	
CA2A	10	107	36004	Contingency Breathing Apparatus Type 2	11.00	1.00	11.00					2.750E-02	
CA2A	10	007	31007	Fire Detection	2.30	1.00	2.30	0.18	0.18	0.18		5.832E-03	
CA2A	10	011	31011	Combustion Gas Analyzer	4.00	1.00	4.00	0.094	0.445	0.191		7.990E-03	
				Module Total	**32.80**							**5.775E-02**	

Continued

MEL for MAV Cabin, Crew, Suits, Logistics vs. Mission Duration (kg)

	Number of Days					
Item	**0.67**	**2**	**4**	**6**	**8**	**10**
Structures	699	699	699	699	699	699
Protection	405	405	405	405	405	405
Active Thermal H/W	108	108	108	108	108	108
Propulsion	0	0	0	0	0	0
Power	97	97	97	97	97	97
Navigation/Sensors/Control	142	142	142	142	142	142
Avionics	171	171	171	171	171	171
Environment	405	643	643	643	643	643
Umbilicals & PLSS Support Structure	64	64	64	64	64	64
Other	12	12	12	12	12	12
Dry Mass w/o Growth	2103	2341	2341	2341	2341	2341
Dry Mass w/ Growth	2734	3043	3043	3043	3043	3043
Food/O2/H20	7	21	42	62	83	104
Suits/Tools/Samples	287	287	287	287	287	287
Crew (2)	164	164	164	164	164	164
Total (w/ growth & 2 crew)	3192	3515	3536	3557	3577	3598
Total w/out growth & 2 crew)	2561	2813	2834	2854	2875	2896
Total (w/ growth & 4 crew)	3356	3679	3700	3721	3741	3762
Total w/out growth & 4 crew)	2725	2977	2998	3018	3039	3060

MAV Operations Draft Timelines

PRELAUNCH

PET	CDR	Pilot	MS 1	MS 2
0:05			Viable Atmosphere Check (< 5 min)	
0:10	Ingress (15 min)			
0:15				
0:20				
0:25	Reconfigure Lander to MAV Asset (15 min)		Transfer and Stow Logistics (15 min)	
0:30				
0:35				
0:40	MAV Systems Checks (60 min)		Hatch Closure and Verification (5 min)	Transfer and Stow Samples (15 min)
0:45			Cabin Stowage and Verification (10 min)	
0:50				
0:55			Teleoperate rover to back away from MAV (30 min)	
1:00				
1:05				
1:10				
1:15				
1:20				
1:25			Seat Ingress and Restraint Configuration (10 min)	
1:30				
1:35			Umbilical Connections, Pressure Checks, Suit-leak Checks, O2 Checks (20 min)	
1:40	Engine/Gimbal Checks, FCS/RCS Checks (5 min)			
1:45	Seat Ingress and Restraint Configuration			
1:50				
1:55	Umbilical Connections, Pressure Checks, Suit-leak Checks, O2 Checks (20 min)		Health/Readiness Check of Transit Hab for Ascent and Rendezvous (15 min)	
2:00				
2:05				
2:10			Weather Updates (5 min)	
2:15	Communications Checks with Ground (25 min)			
2:20				
2:25				
2:30				
2:35				
2:40	Launch Commit Criteria from Ground (5 min)			

MAV Operations Draft Timelines

LAUNCH

Time	CDR	Pilot	MS 1	MS 2
0:05	Ignition and Ascent (10 min)			
0:10				
0:15	Monitoring/Piloting Systems, Including Preparation for Manual Staging (if needed) (10 min)			
0:20				

POST-INSERTION

Time	CDR	Pilot	MS 1	MS 2
0:05	Status Checks with Ground (15 min)			
0:10				
0:15				
0:20	Reconfigure Propulsion & GNC Systems for Orbit Operations (30 min)		Reconfigure Systems and Software for Orbit Operations (30 min)	
0:25				
0:30				
0:35				
0:40				
0:45				
0:50	Health/Readiness Checks of Transit Hab Propulsion & GNC Systems for Rendezvous (15 min)		Health/Readiness Checks of Transit Hab Systems for Rendezvous (15 min)	
0:55				
1:00				
1:05	Egress seats (5 min)			
1:10	Egress suits (10 min)			
1:15				
1:20	WCS Activation and Ops (20 min)		Stow Suits (15 min)	Stow Umbilicals (10 min)
1:25				
1:30				
1:35			WCS Ops (15 min)	
1:40	Deployment, Activation, Check-out of Rendezvous Tools (20 min)			
1:45				
1:50			Reconfigure Cabin, as needed (20 min)	
1:55				
2:00	Activation and Check-out of Docking System on Hab (20 min)			
2:05				
2:10				
2:15				

MAV Operations Draft Timelines

CRUISE AND RENDEZVOUS

Time	CDR		MS 1	Pilot		MS 2
0:00	Post-Sleep Activities (Hygiene, WCS ops, Meal)			Status checks with ground, etc. (3 hr)		Mission Science (1 hr)
1:00	Status Checks with Ground, Systems Monitoring, Health/Readiness Checks of Transit Hab for Rendezvous, Trajectory Burns (14 hrs)		Mission Science (5 hr)		Meal (1 hr)	Meal (1 hr)
2:00		Exercise (2 hr)				
3:00				Pre-Sleep Activities (Hygiene, WCS ops) (1 hr)		
4:00				Sleep (8 hr)		
5:00						
6:00		Meal (1 hr)	Exercise (2 hr)			
7:00						
8:00		PAO (1 hr)	Meal (1 hr)			
9:00						
10:00			Mission Science (3 hr)			
11:00						
12:00				Post-Sleep Activities (Hygiene, WCS ops, Meal) (1 hr)		
13:00		Meal (1 hr)	Meal (1 hr)	Status Checks with Ground, Systems Monitoring, Health/Readiness Checks of Transit Hab for Rendezvous, Trajectory Burns (11 hrs)		Mission Science (5 hr)
14:00					Exercise (2 hr)	
15:00	Pre-Sleep Activities (Hygiene, WCS ops) (1 hr)					
16:00	Sleep (8 hr)					
17:00						
18:00					Meal (1 hr)	Exercise (2 hr)
19:00						
20:00					PAO (1 hr)	Meal (1 hr)
21:00						
22:00						Mission Science (2 hr)
23:00						

MAV Operations Draft Timelines

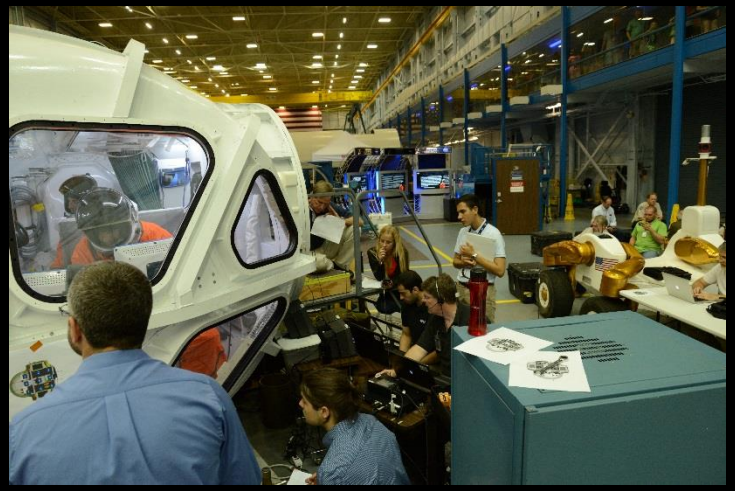
FINAL APPROACH & DOCKING

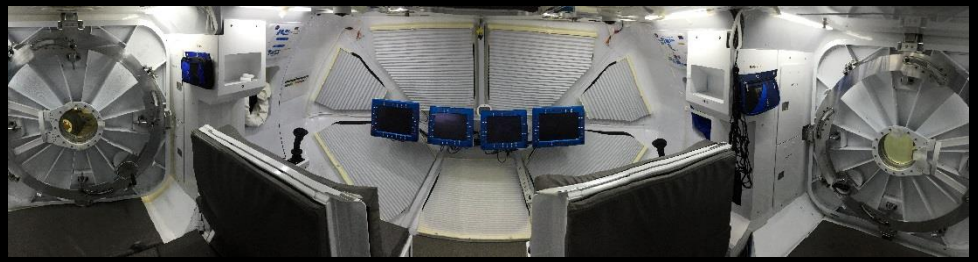
Time	CDR	Pilot	MS 1	MS 2
0:05	Fly-arounds/External Inspection of Transit Habitat (60 min)		Systems Monitoring of MAV and Transit Vehicle (150 min)	
0:10				
0:15				
0:20				
0:25				
0:30				
0:35				
0:40				
0:45				
0:50				
0:55				
1:00				
1:05	Berthing/Docking (60 min)			
1:10				
1:15				
1:20				
1:25				
1:30				
1:35				
1:40				
1:45				
1:50				
1:55				
2:00				
2:05	Pressure Equalization (10 min)			
2:10				
2:15	Vestibule Leak Check (15min)			
2:20				
2:25				
2:30	Hatch Openings (5 min)			
2:35	Crew Transfer to Transit Hab (5 min)			

Time	CDR	Pilot	MS 1	MS 2
2:40	Checkout transit hab + activate apppropriate systems (160 min)		Transfer of Samples (10 min)	
2:45				
2:50			Transfer Suits and Umbilicals to Transit Hab (20 min)	
2:55				
3:00				
3:05				
3:10			Transfer of Logistics (10 min)	
3:15				
3:20			Transfer of Necessary Usable HW, from MAV to Transit Hab (60 min)	
3:25				
3:30				
3:35				
3:40				
3:45				
3:50				
3:55				
4:00				
4:05				
4:10				
4:15				
4:20			Transfer Trash and Leftover Consumables from Transit Hab to MAV (60 min)	
4:25				
4:30				
4:35				
4:40				
4:45				
4:50				
4:55				
5:00				
5:05				
5:10				
5:15				
5:20			Final Inspection of MAV (10 min)	
5:25				
5:30	Unberth/Undock from MAV (30 min)			
5:35				
5:40				
5:45				
5:50				
5:55				
6:00	Teleoperate MAV Away from Transit Hab for TBD Future Use (10 min)			
6:05				

Human in the Loop Testing Objectives

- Configure Generation (GEN) 2A
  - Determine the minimum MAV cabin volume for:
    - A crew of four to don/doff suits
    - For crew to exercise using the GRC ergometer
    - For a crew of four habitation
  - Identify changes to the GEN 2A common cabin interior configuration to address MAV specific interior configuration for maximum commonality

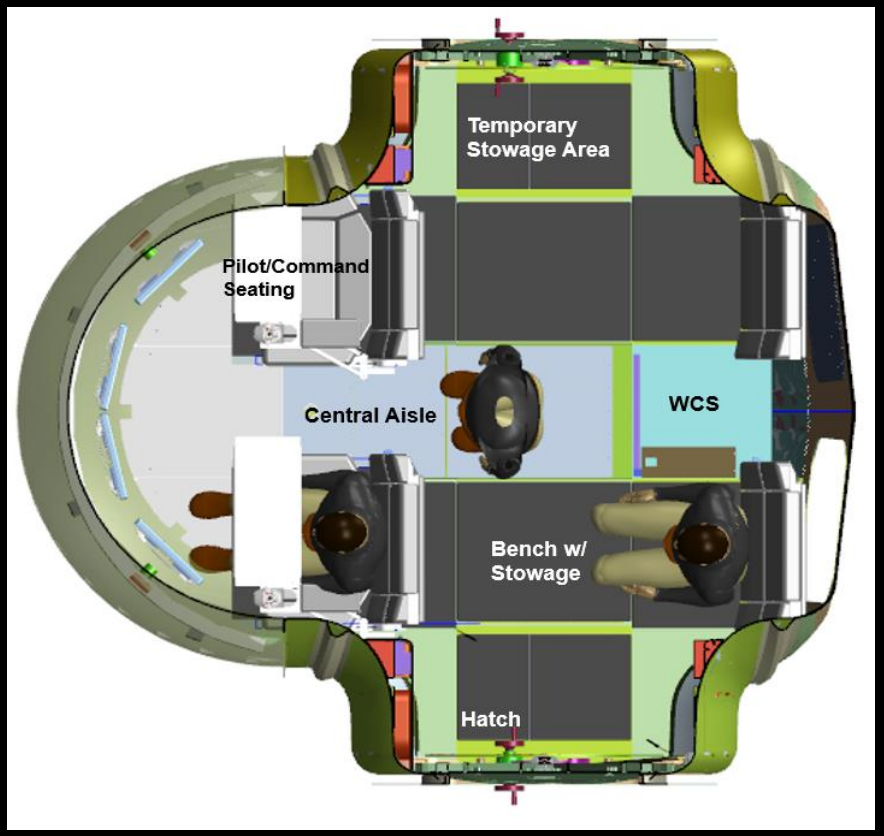




Equipment (Generation (GEN) 2A Mockup)

- A medium-fidelity mockup based on the Multiple Mission Space Exploration Vehicle (MMSEV) design
- Located at JSC in the Space Vehicle Mockup Facility (SVMF)
- Mockup consist of three major sections:
  - Nose Section
  - Cabin Section
  - Aft Deck Section
- Mockup measurements:
  - Length = 130 inches (3.3 meters)
  - Width = 140 inches (3.56 meters)
  - Height = 100 inches (2.54 meters)
  - Estimated internal volume of 469.7 feet^3 (13.3 meters^3)

MAV Cabin 2A Stowage



Location	ITEM	Quanity	STATUS
SBHFL-1B ↓ (PILOT)	Small Face Towels (Green Bag)	2	

Location	ITEM	Quanity	STATUS
PHFL-1B (CMDR)	Small Face Towels (Green Bag)	2	

Location	ITEM	Quanity	STATUS
SBHFL-1B ↓ (PILOT)	Small Face Towels (Green Bag)	2	

Location	ITEM	Quanity	STATUS
PHFL-1B ↓ (CMDR)	Small Face Towels (Green Bag)	2	
	Medium Hand Towels (Green Bag)	2	
	Large Crew Clothing Bag (Blue)	1	
	Crew Pref, Socks, X-Static, Crew (Navy) (Pair)	2	
	Athlete, Shorts, Nylon (Navy, Running)	2	
	Crew Pref, Shirt, X-Static (Navy)	2	
	Athlete, Headbands (Dark Blue)	1	
	Athletic, Wrist Band (Red) (Pair)	1	
	Crew Pref, Shorts, Briefs (White)	4	
PHFlr-2B ↓	Exercise Equipment: (Includes Ergometer Base Plate (1), Ergometer Exercise Unit (1), Pedal Arm w/Pedal (2), Bodylastics Padded Handle (1), Rectangular Silver Plate w/ 2 Holes on each End (1), Base Plate Bolts (5), Base Plate Bolts, Long (4), Base Plate Nuts (6), Carabineer (1), Polar Heart Monitor (1))		
	Critical Spares-1	1	
	WCS Supplies: (Includes Wag Bags (64), Toliet Paper (2), 5oz Hand Sanitizer (2), Scott Flushable Wipes (50ct) (2), Ziploc Gallon Bags (24))	1	
	Food, Veggies #2	14	
	Food, Veggie #2	14	
PHFlr-2A ↑	Food, Chicken	14	
	Food, Snacks	28	
	Food, Veggies #1	14	
PHAL-3B ↓ (MS-1)	Small Face Towels (Green Bag)	2	
	Medium Hand Towels (Green Bag)	2	
	Large Crew Clothing Bag (Blue)	1	
	Crew Pref, Socks, X-Static, Crew (Navy) (Pair)	2	
	Athlete, Shorts, Nylon (Navy, Running)	2	
	Crew Pref, Shirt, X-Static (Navy)	2	
	Athlete, Headbands (Dark Blue)	1	
	Athletic, Wrist Band (Red) (Pair)	1	
	Crew Pref, Shorts, Briefs (White)	4	
PAL-2↓ (CMDR/MS-1)	Toilet Paper	1	
	Ziploc Gallon Bags	24	
	Poo Powder (Pint Ziplock Bag)	1	
	Scott Flushable Wipes (50ct)	1	
	5oz Hand Sanitizer	1	
	Pkg of Disposable Gloves	62	
	Wag Bags	32	

Scenarios

- Consisted of five different flight type scenarios
- Two mission versions
  - 16 hour mission
  - Multiple Day mission (5 to 8 days)
- Subjects worked through a representative and compressed timeline which covers both scenarios
- Subjects completed 30 different tasks during a 4 hour test session

Scenarios for the MAV Evaluation

Scenario	16-hour Mission	Multiple Day Mission
Pre-Launch	x	x
Launch	x	x
Post-Insertion	*x	x
Cruise	**x	x
Rendezvous/Docking	x	x

***NOTE:** For 16-hour mission crew may not need to egress suits. Would possibly stay in suits for duration of mission.

****NOTE:** For 16-hour mission, several tasks would be eliminated due to the short duration of the mission

Timeline

Task	CDR	Pilot	MS 1	MS 2
0	**Ingress Suits & Boots (20 min)** - also practice donning helmet and gloves, then doff and store in separate bag			
1	**Ingress Vehicle (2 min)**			
2	**Ingress Seats and Temp Stow Helmet & Glove Bag Near Seat Location (2 min)**		**Transfer & Stow Late Stow Items (2 CTBs) (2 min)** - MS1 enters and temp stows 2 helmet and glove bags near seat location - MS2 passes in 2 CTBs and stows in starboard hatch area	
3	**Simulate MAV Systems Checks (2 min)** - check reach to edge keys and screen visibility while stepping through menus on three monitors - check reach to overhead buttons		**Complete Cabin Stowage & Verification Using Stowage Cue Card/Checklist (3 min)**	
4	**Connect Umbilicals, Then Disconnect & Stow (1 min)**			
5	**Use Joystick to Simulate Teleoperating Rover Away from MAV (1 min)**		**Complete Hatch Closure & Verification (1 min)**	
6	**Simulate Seat Restraint Connections (1 min)**		**Ingress Seats, Simulate Seat Restraint Connections, and Connect Umbilicals, Then Disconnect & Stow (1 min)** - Assume a semi-recumbent position on the benches with knees bent and back against aft bulkhead	
7	**Don Helmets and Gloves (5 min)**			
8	**Simulate Comm Checks Internally Among all 4 Crew and Then with Ground (2 min)**			
9	**Simulate Health/Readiness Check of Transit Hab for Ascent & Rendezvous (2 min)**		**Demonstrate a fully supine launch position with knees bent (2 min)**	
10	**Simulate Launch Commit Criteria (Receive Go for Launch from Test Director) (1 min)**			
11	**Simulate Ignition & Ascent Monitoring/Piloting (1 min)**			
12	**Doff Helmet & Gloves and Stow in Bags Near Seat Locations (5 min)**			
13	**Simulate Post-Insertion Reconfiguration Commanding (1 min)**			
14	**Wait in Seats for MS Suit Doff (20 min)**		**Sequentially Egress Seats & Suits (20 min)** - Egress Seats - MS1 sits on WCS doffing station while MS2 positions feet in aisle foot restraints and assists with MS1 suit doff; repeat for MS2 suit doff - temp stow suits in port hatch	
15	**Sequentially Egress Seats & Suits (20 min)** - CDR egress seat and sits on WCS doffing station while MS1 & MS2 assist with suit doff from aisle and bunk; repeat for Pilot - temp stow suits in port hatch		**Assist with CDR/Pilot Suit Doff from Aisle and Bunk (20 min)**	

Timeline

Task	CDR	Pilot	MS 1	MS 2
16	Secure Suits in Port Hatch with Cargo Netting (1 min)			
17	Access Galley Area Under Benches and Simulate Prep of 4 Meals (2 min)		Activate WCS (2 min) - Slide side curtains forward - Hang center curtain from overhead bins	
18	Simulate Eating Meal in Seats (1 min)			
19	Discard Meal Trash in Port Trash Receptacle (1 min)			
20	Sequentially Simulate WCS Ops (10 min) - remove wag bag and simulate using - double bag wag bag, wrap with duct tape, and stow in POH-2			
21	Reconfigure Cabin for Exercise (5 min) - set up cycle ergometer in aisle			
22	CDR/MS1 Exercise on Cycle Ergometer, Pilot/MS2 Use DynaBands (5 min)			
23	Prepare for Sleep (5 min) - pull CDR & pilot seats as far forward as possible - retrieve sleeping bags: lay 2 on benches and Velcro 2 above benches at designated attachment points			
24	Simulate Sleep (1 min)			
25	Simulate System Monitoring of MAV/MTV (5 min)		Reconfigure Cabin Post-Sleep (5 min) - stow sleeping bags in overhead bins	
26	Sequentially Ingress Suits in Opposite Order of Doffing (40 min)			
27	Don Helmets and Gloves, Assume Seated Positions, Connect Umbilicals (5 min)		Don Helmets and Gloves, Assume Seated Positions, Connect Umbilicals (5 min)	
28	Simulate Berth/Docking with MTV (1 min)			
29	Simulate System Monitoring of MAV/MTV (1 min)		Open Hatch (1 min)	
30	Egress Vehicle (1 min)			
31	Collect Individual Ratings from Crew by Questionnaires			

Methodology

MAV Human Factors Data Collection Measures

Area of HF Study	Measures for Data Collections	Frequency
Planned vs. Actual Timeline Data	Planned task timelines times Actual task timelines	Pre-test time in (hh:mm:ss) Real-time collection in (hh:mm:ss)
Human Movement and Utilization of Specific Areas	Video Analysis/link analysis of human movement in pre-determined areas	Post-Test: Frequency of movement and time in area (hh:mm:ss)
Displays & Controls	Subjective Questionnaire (Acceptable Scale 1-10) includes all D&C in cockpit, monitoring stations, and work stations	Post-test on usability of D&C
Cockpit Seating	Subjective Questionnaire (Acceptable Scale 1-10)	Post-test on seat comfort, adjustability, and usability
Habitability	Subjective Questionnaire (Acceptable Scale 1-10) includes sleep, hygiene, food prep, exercise, translation paths, equipment transfer, stowage, etc.	Post-test on all habitability activities and functions
Capability of Vehicle to perform tasks efficiently and effectively	Capability Scale (1-10)	Post-test (Subject Consensus) on the overall capability of performing tasks in this vehicle configuration
Simulation Quality	Sim Quality Scale (1-10)	Post-test (Subject Consensus) on the quality of the simulation and impacts on the test data collected

Metrics

- Ratings made by consensus of all four test subjects.
- A categorical difference in consensus ratings for each rating scale was prospectively defined as being practically significant for the purposes of hypothesis testing

Acceptability

Categorical Difference

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable		No Rating
No improvements necessary		Minor improvements desired		Improvements warranted		Improvements required		Major improvements required		Unable to assess capability
1	2	3	4	5	6	7	8	9	10	NR

No Categorical Difference

Capability Assessment

Essential / Enabling		Significantly Enhancing		Moderately Enhancing		Marginally Enhancing		Little or No Enhancement		No Rating
Impossible or highly inadvisable to perform mission without capability		Capabilities are likely to significantly enhance one or more aspects of the mission		Capabilities likely to moderately enhance one or more aspects of the mission or significantly enhance the mission on rare occasions.		Capabilities are only marginally useful or useful only on very rare occasions		Capabilities are not useful under any reasonably foreseeable circumstances.		Unable to assess capability
1	2	3	4	5	6	7	8	9	10	NR

Metrics

Simulation Quality

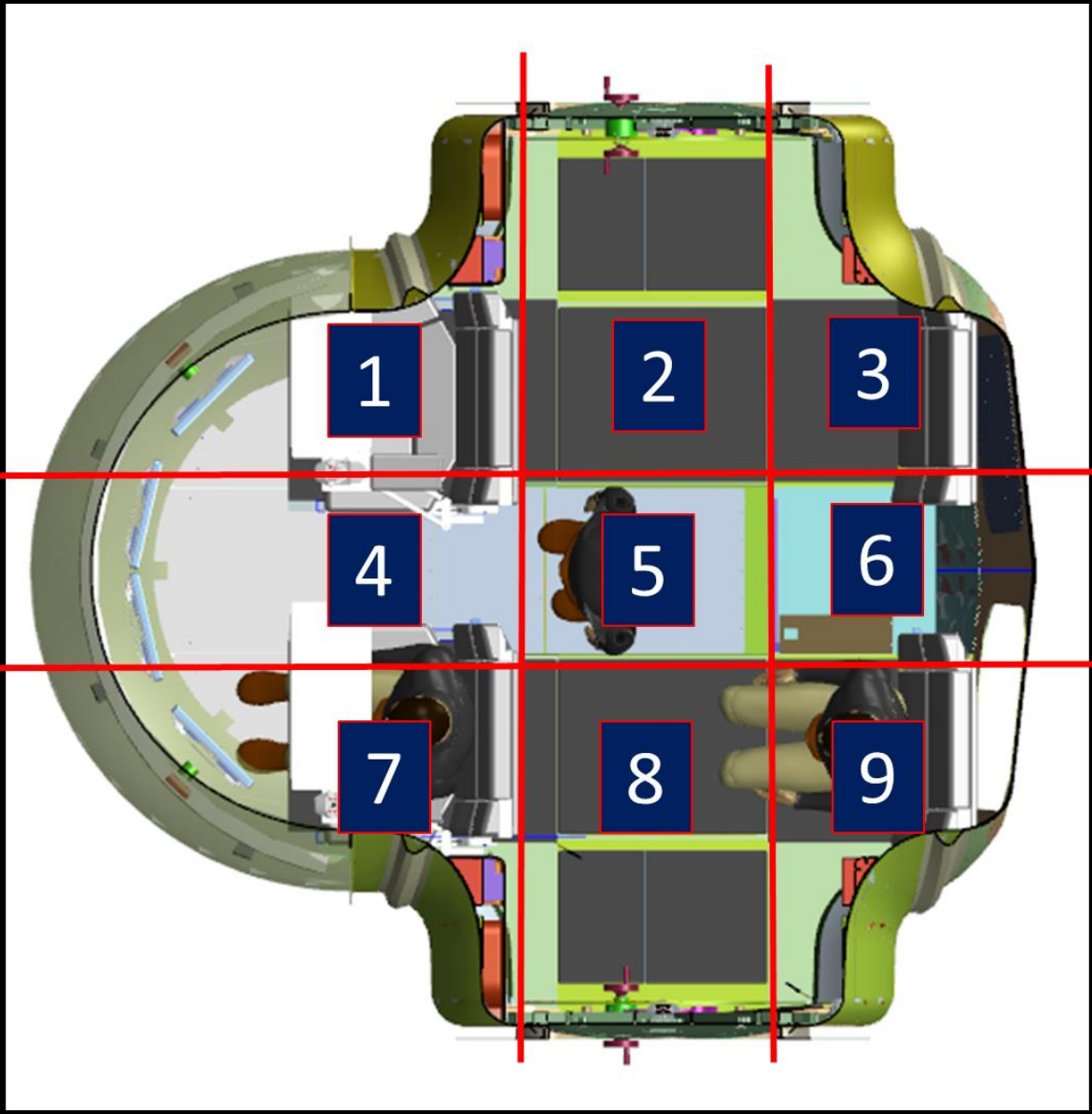
Scale Rating	Criteria
1	Simulation quality (e.g. hardware, software, procedures, comm., environment) presented either zero problems or only minor ones that had no impact to the validity of test data.
2	Some simulation limitations or anomalies encountered, but minimal impact to the validity of test data.
3	Simulation quality was adequate to provide a meaningful evaluation of most of the test objectives; simulation limitations or anomalies made test data marginally adequate to provide meaningful evaluation of test objectives (please describe).
4	Significant simulation limitations or anomalies precluded meaningful evaluation of major test objectives (please describe).
5	Major simulation limitations or anomalies precluded meaningful evaluation of all test objectives (please describe).

Participants

- Two 4-person crews participated in the test
  - 5 Males and 3 Females
  - Experience
    - Total of 559 days spaceflight experience between test crews

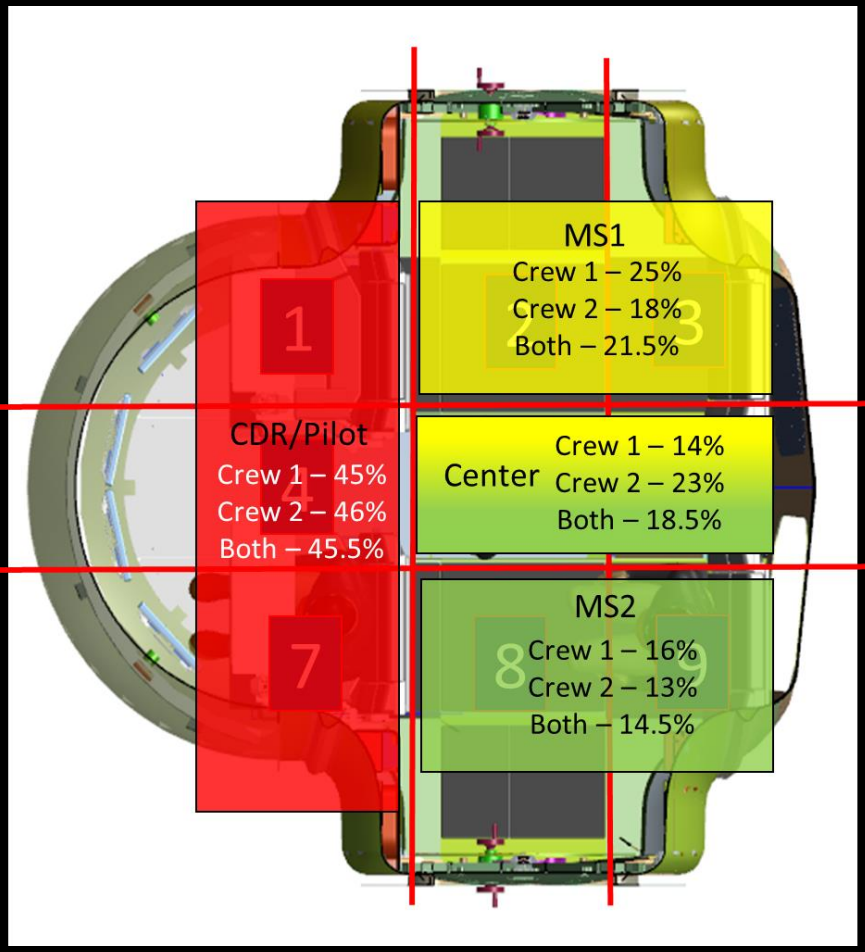
Subject	Gender	Spaceflight Experience (in days)
1	M	12
2	M	141
3	M	370
4	F	12
5	M	24
6	F	0
7	F	0
8	M	0
TOTAL		559

Original Time Frequency Map



Crew Time Frequency Map Results

MAV Sectional Heat Map in Percentage



Feasibility of Data Collection Process ONLY

Frequency of time spent in each area consisted of actual task completion times and task discussion

Total Time = 819 minutes

Heat Map Scale in Percentage

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45

Timeline Task Breakdown Results

- EVA Donning and Doffing Times

Crew	Doffing Time (in minutes)	Donning Time (in minutes)	Don/Doff Strategy
1	11:46	18:47	Done Sequentially 
2	09:15	12:17	Done in Parallel 

Timeline Task Breakdown Results

- 30 timeline tasks were broken down into 7 categories
- There is a planned and actual time for each category
- Categories:
  - General Stowage Tasks
    - Ingress seats & temp stow helmet & glove bag
    - Connect/disconnect umbilicals & stow
    - Secure suits in port hatch with cargo net
    - Complete cabin stowage
  - Suit Tasks
    - Don/doff helmets & gloves
    - Sequentially doff/don suits
    - Sequentially egress seats & stow suits
  - WCS Tasks
    - Activate WCS
    - Sequentially simulate WCS ops
  - Sleep Tasks
    - Prep cabin for sleep
    - Simulated sleep
    - Reconfigure cabin post-sleep
  - Translation Paths Tasks
    - Ingress/Egress vehicle
    - Transfer & stow late items
    - Close/Open hatch
  - Exercise Tasks
    - Reconfiguring cabin for exercise
    - Exercising on cycle ergometer
  - General Cabin Tasks
    - Flight Deck
      - Simulate MAV Systems Check
      - Use joystick to simulate tele-operations
      - Simulated seat restraint connections
      - Simulated Comm Checks
      - Simulated Health/Readiness Checks
      - Simulated Launch Commit Criteria
      - Simulated Ignition & Ascent
      - Simulated Post-Insertion Reconfiguration
      - Simulated System Monitoring
      - Simulated Berth/Docking
    - Aft Area
      - Ingress seats, simulated seat restraints, connecting umbilicals
    - Food Prep
      - Access Galley
      - Simulate eating a meal
      - Simulated discard of meal trash

Questionnaire Results

- The Acceptability Scale (1-10 scale) was used to rate the elements
  - Criteria for acceptable is a rating of ≤ 4 using median values
  - Criteria for borderline is a rating between 4.5 and 6.0 using median values
  - Criteria for unacceptable is a rating > 6.0 using median values
- Error Bars are calculated on a 1 Standard Deviation

Totally Acceptable		Acceptable		Borderline		Unacceptable		Totally Unacceptable			No Rating
No improvements necessary		Minor improvements desired		Improvements warranted		Improvements required		Major improvements required			Unable to assess capability
1	2	3	4	5	6	7	8	9	10		NR

Questionnaire Results (cont.)

- The Post-Test subjective questionnaires examined 22 volumetric tasks of the current vehicle
- These 22 tasks were broken up into 7 groups:
  - General Stowage Volume
    - Vehicle stowage
    - Suit stowage
    - Sample stowage
  - Suit Task Volume
    - Umbilical management
    - Suit donning/doffing
    - Emergency ingress/egress
  - WCS Task Volume
    - General hygiene
    - Use of WCS during sleep hours
  - Sleep Volume
    - General sleep
    - Privacy
    - Nominal unsuited operations
    - Incapacitated crew
    - Overall Vehicle Volume
  - Translation Volume
    - Equipment transfer
    - General translation paths
  - Exercise Volume
    - General exercise volume
    - One exercising while others are working
  - General Cabin Volume
    - Seats
    - Flight Control Area
    - Food Prep
    - Co-location of operations
    - Limited cross-contamination
    - Nominal unsuited operations
    - Incapacitated crew
    - Overall Vehicle Volume

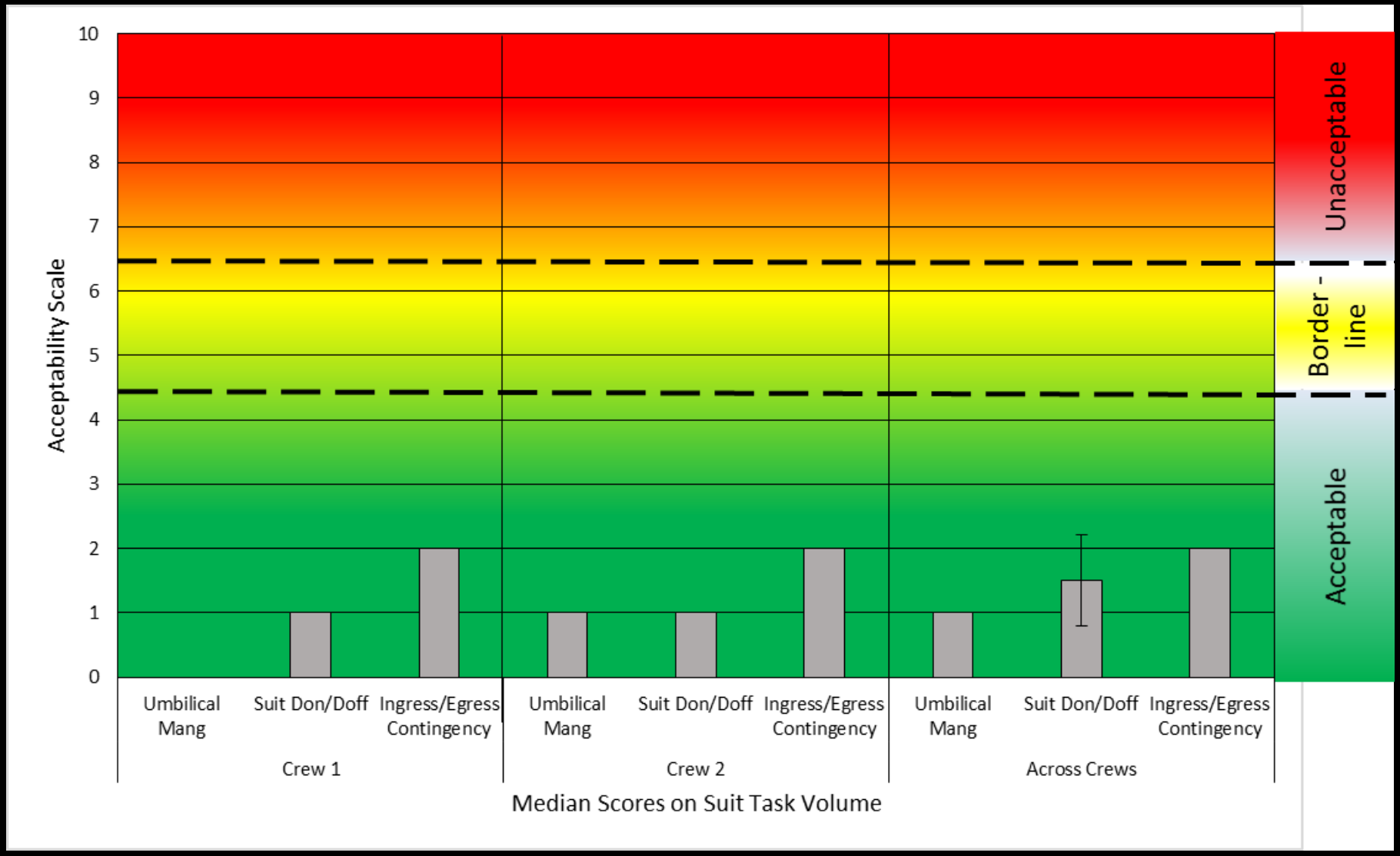
Questionnaire Results (cont.)

- General Stowage
  - General stowage volume included vehicle stowage, suit stowage, and sample stowage
  - Considered acceptable by both crews
  - Crews felt like more gear, such as personal items, computers, etc., would make its way on board and designers should plan to increase the current stowage volume
  - Suggested better net-bungee system and to consider external stowage

Questionnaire Results (cont.)

- Suit Tasks
  - Suit volume included three different areas—umbilical management, volume for suit donn/doff, volume for a contingency suit ingress/egress
  - Considered acceptable by both crews; however, some minor issues were reported
    - Umbilical interference with the joystick for the commander and pilot positions was noted
    - The same type of interference was also affecting their ability to lean over and help the other
    - Crew consensus data indicated that the simulation quality of the umbilicals was not sufficient enough at this time to make a fair assessment
  - For donning/doffing, the volume was acceptable and crews could do this task in parallel (2 in front and 2 in back)
  - Suggest designers take carefully consideration to increase the number of hand and foot holds

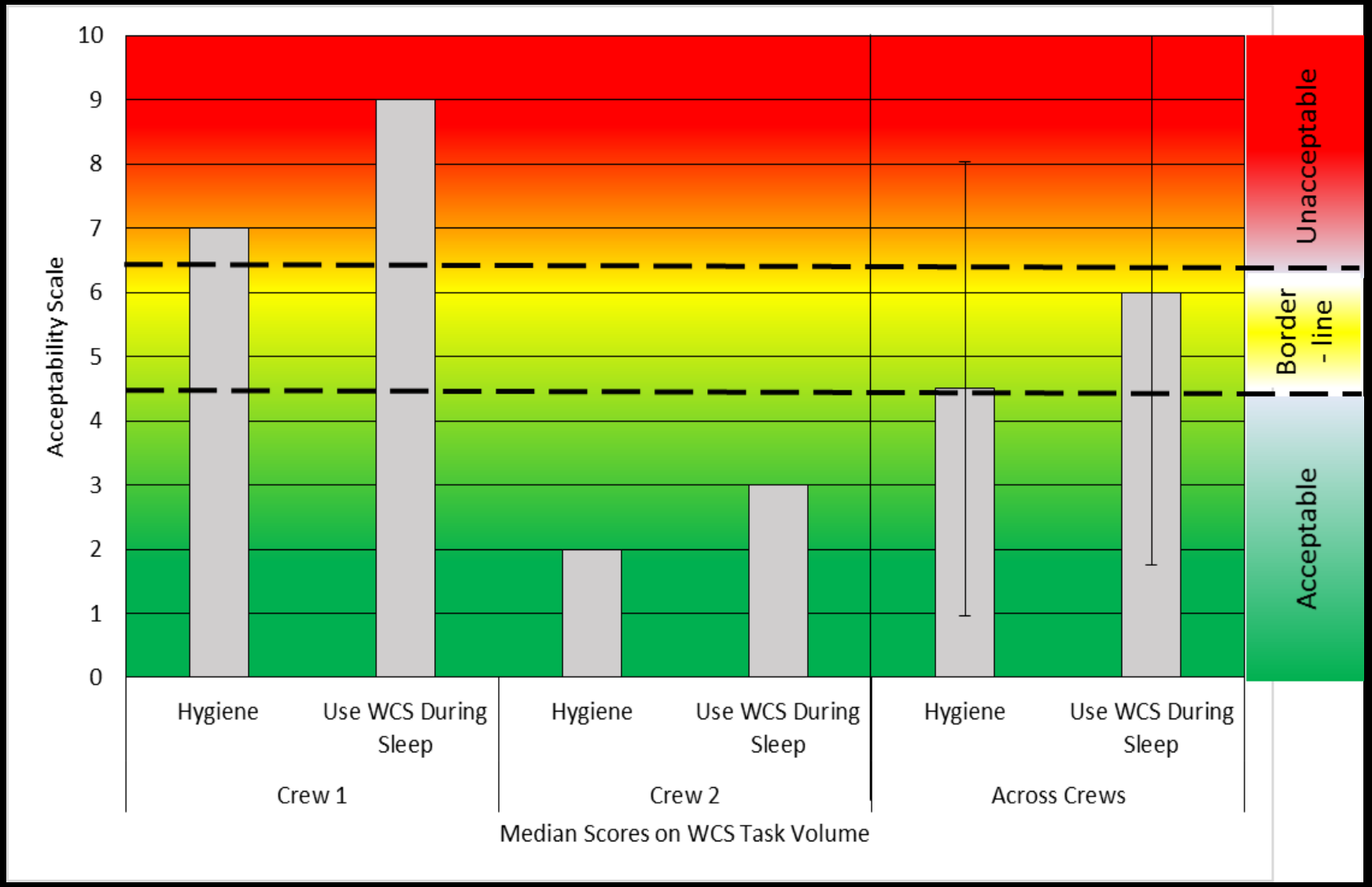
Questionnaire Results (cont.)



Questionnaire Results (cont.)

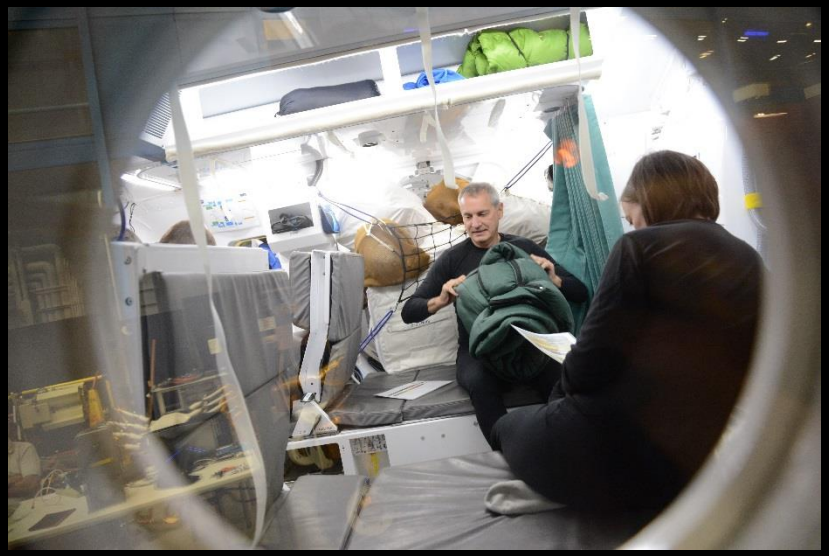
- WCS (Waste Containment System) Tasks
  - Two volume aspects were examined—Volume for personal hygiene and WCS use during sleeping hours
  - Considered general volume for hygiene as acceptable by both crews
    - However, Crew 1 consensus increased their overall rating to borderline
      - They noted the privacy curtain should not impede normal operations
      - The current curtain was inefficient and distruptive
      - Suggested a smaller curtain with enough room to stand up adjacent to the WCS
  - Volume for using the WCS during sleeping hours was deemed borderline to unacceptable by both crews
    - Crews stated, due to the small habitable volume, it would be difficult not to wake fellow crewmembers with the associated noises from WCS operations

Questionnaire Results (cont.)

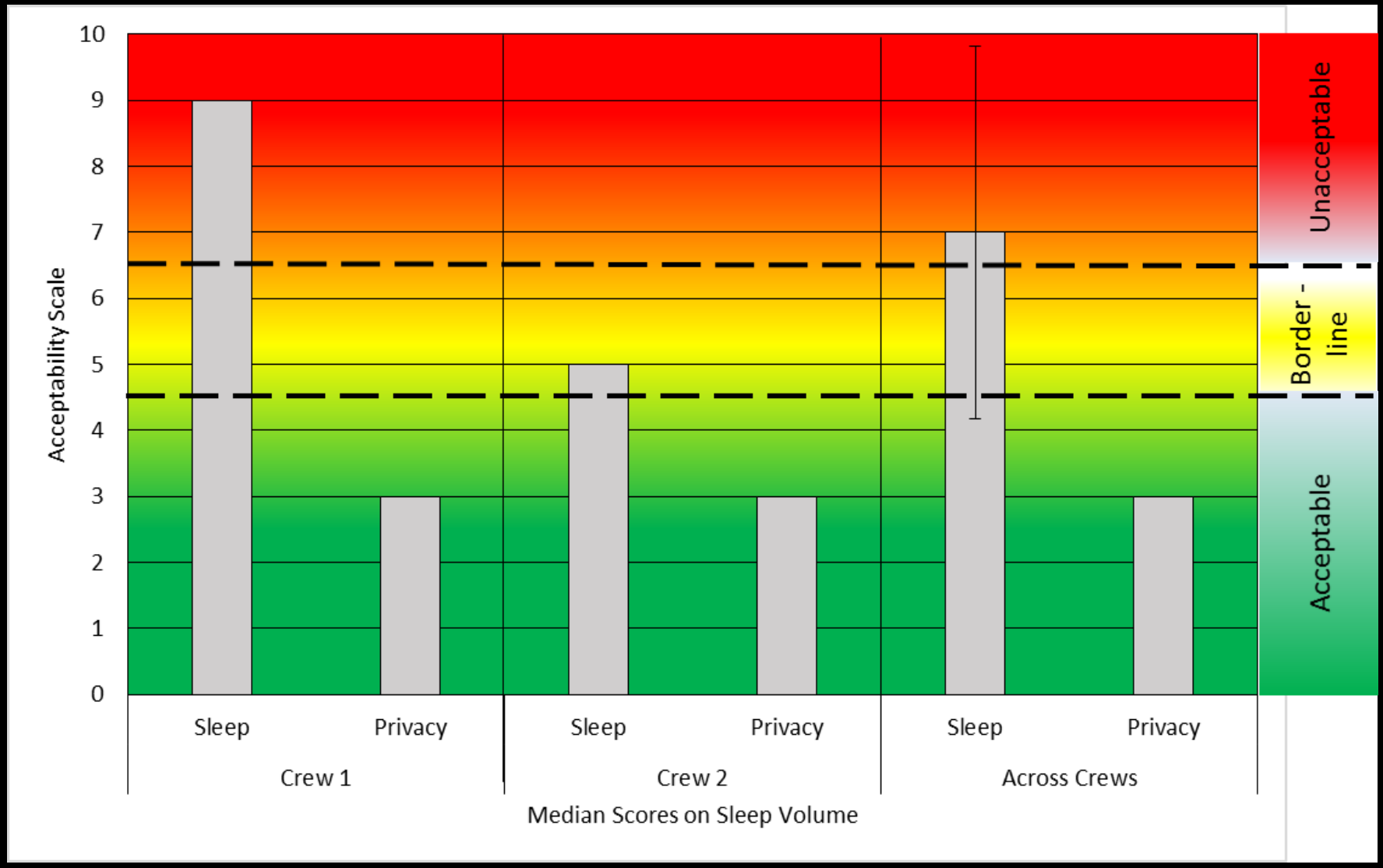


Questionnaire Results (cont.)

- Sleep Volume
  - Sleep volume included setup, breakdown and volume for sleep. Privacy was also examined
  - There were mixed ratings from the crews
    - Crew 1 rated the sleep volume (setup, breakdown) as borderline
    - Crew 1 rated privacy at acceptable
    - Crew 2 rated both sleep volume and privacy as borderline
    - Both Crew consensus showed the same mixed results as individual crew results
  - Issues with sleep volume is the proposed sleep arrangement for a crew of four
    - Having crewmembers facing each other while sleeping was considered unacceptable
    - This also affects privacy
    - Suggested more of a hammock or “shelf” arrangement with partitions for privacy between bunks
    - Air flow for the sleep bunks also needs to be addressed



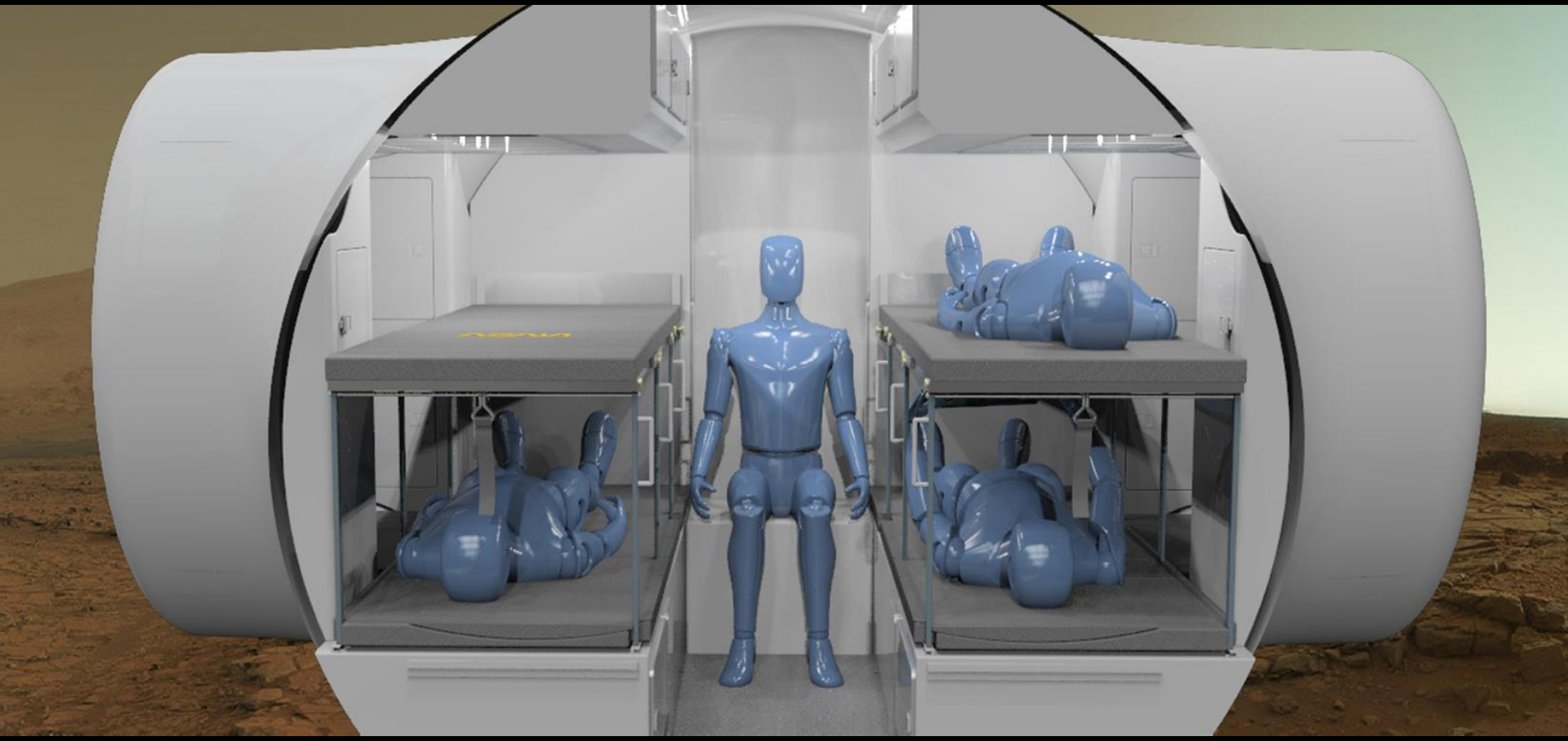
Questionnaire Results (cont.)



Questionnaire Results (cont.)

Sleeping Position: 99th Percentile Male Occupants

Front View

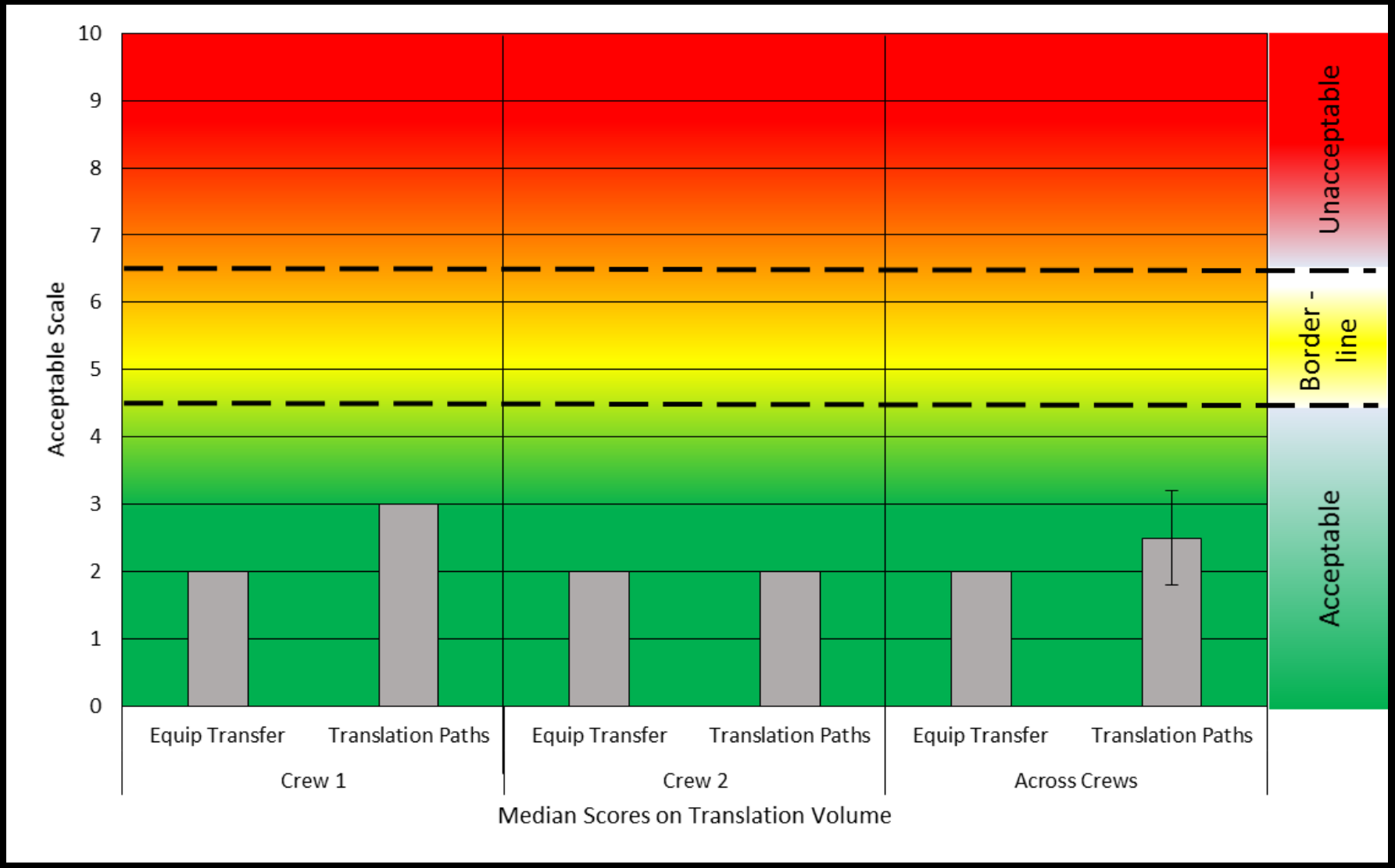


Questionnaire Results (cont.)

- Translation Volume
  - Translation paths consisted of hatchway volume for equipment transfer and aisle ways
  - Considered acceptable by both crews
  - Adding additional hand and foot holds would make translation easier

Questionnaire Results (cont.)

Crew Consensus Data on Translation Volume

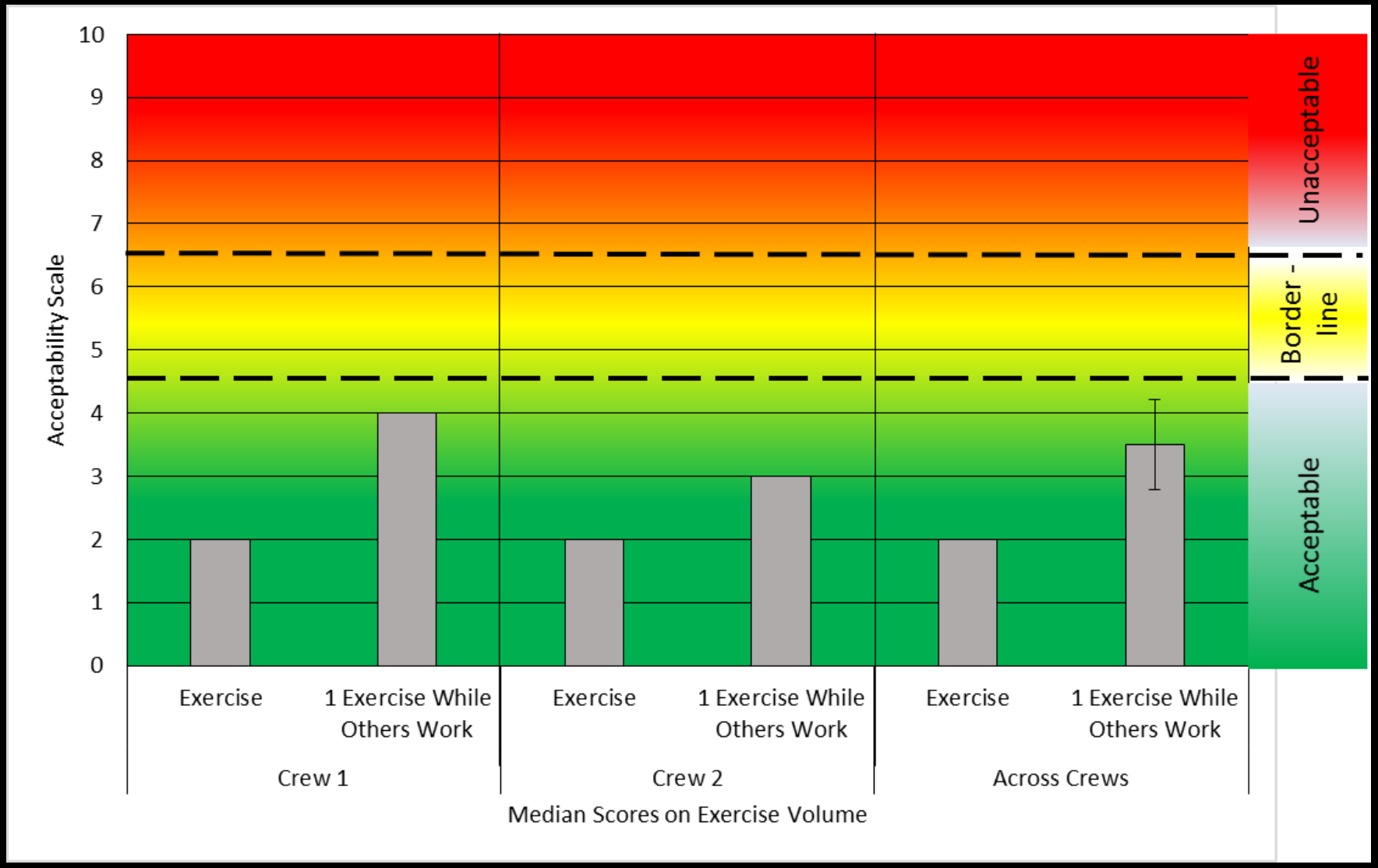


Questionnaire Results (cont.)

- Exercise Volume
  - Two volumetric areas examined were general exercise volume and the volume for one crewmember to exercise while others are working
  - Considered acceptable by both crews
  - Crews noted that having the ergometer in the aft portion of the vehicle limited the impact of others to maneuver in the vehicle
  - Activities for the non-exercising crewmembers seemed limited
  - WCS ops were also noted as being in conflict with exercise due to the exercising crewmember using the WCS seat as a ergometer seat
  - Suggested since in a 0-g environment, designers look at different locations for exercise such as the vehicle ceiling
  - Crews stated that due to the short mission duration, exercise equipment could impact other design trade-offs

Questionnaire Results (cont.)

Crew Consensus Data on Exercise Volume



Questionnaire Results (cont.)

- General Cabin Volume
  - The eight volume areas were examined by crew included seats, the flight control area, food preparation, co-located or related operations, limited cross-contamination, nominal unsuited operations, volume for an incapacitated crewmember, and the overall vehicle volume
  - Seats
    - Individual ratings score the seats as acceptable; however, the Crew 1 consensus discussion raised their score to unacceptable
      - Due to curvature on inner nose mold line citing possible discomfort to the outboard foot
      - Suggest adding a foot rest to raise feet above inner mold line
      - Rear seats need some type of structure to support body position during ascent phase

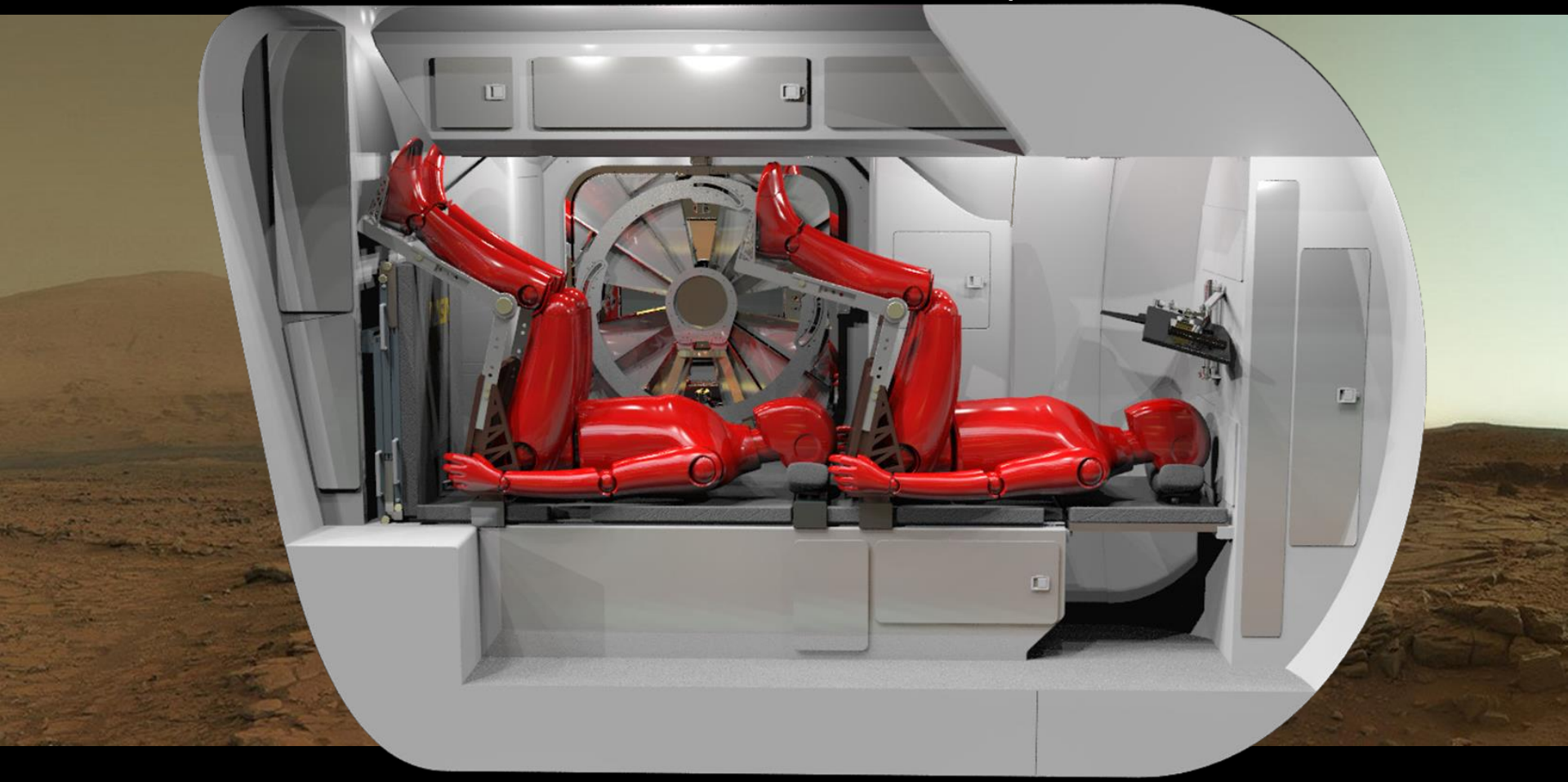
  - Flight Control
    - Considered acceptable by both crews
    - Suggest adding a forward/backward motion for joy stick

Questionnaire Results (cont.)

- Proposed Seat Design Solution
  - HDC interviewed Jacob Puttnam from KBR Wyle Occupant Protection for dimensional and safety analysis
  - Dimensional Analysis:
    - HDC utilized the MPCV Program study on Vehicle Design anthropometrics to gather critical dimensions for suited flight seat concepts
    - These data points were used to clarify the volume needed for 99th percentile astronauts in ACES flight type suits

Questionnaire Results (cont.)

Flight Position:
99th Percentile Suited Male Occupants



Due to horizontal space constraints, 99th percentile occupants have to keep their legs at different angles. Occupant Protections assured HDC that these angles would be acceptable as long as the occupants feet were secured to the footrests. This limits forces on the hips and lower back.

Questionnaire Results (cont.)

- General Cabin Volume (cont)
  - Limit cross-contamination
    - Mixed rating with individual ratings being borderline and consensus ratings being unacceptable
    - As with co-located operations, waste stowage was the biggest factor
      - Need to alleviate any waste to galley contamination
      - Suggest all waste stowage in floor
      - Suggest raise galley and water delivery system to chest height
    - Daily trash stowage was also a concern
      - Currently not enough stowage for trash, both wet/dry, for a crew of 4 over 5 days
      - Needs special attention by designers to keep trash contamination at bay
    - Sleeping area and the WCS were in very close
      - Major concern here was cloth curtain separating the two areas
        - Concern was if urine got onto curtain could easily pass through and onto sleep area
      - Suggest placing stowage between WCS and sleep area as a barrier

Questionnaire Results (cont.)

- Summary of Questionnaire Data
  - Of the 22 volumetric tasks performed in the vehicle (using the Crew Consensus Data)
    - 17 were considered acceptable (77%)
    - 3 were considered borderline (14%)
    - 2 were considered unacceptable (9%)

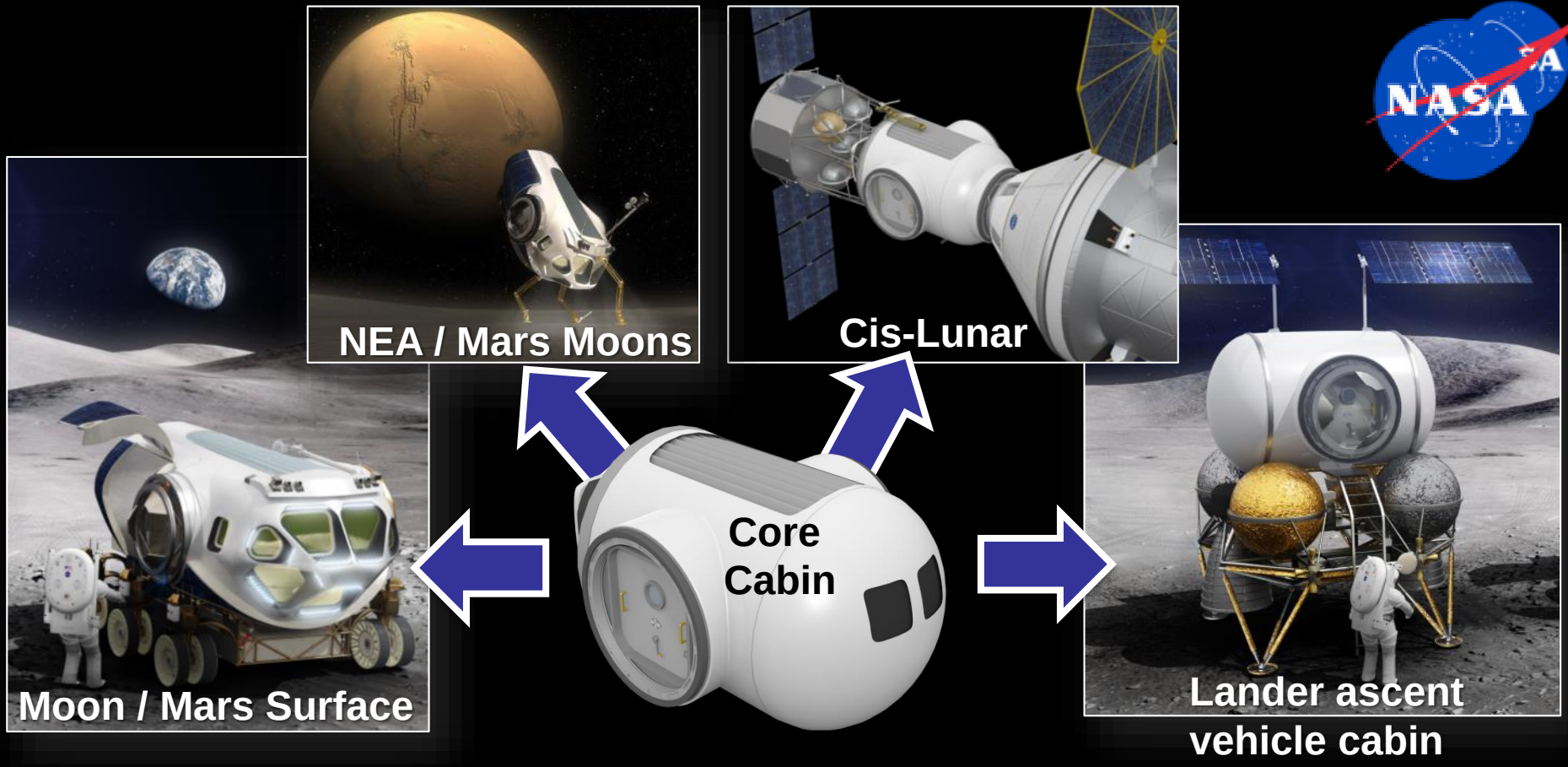
Volumetric Tasks	Crew Consensus Data		
	Crew1	Crew 2	Median
Access to MAV stowage areas			
Access to hygiene area			
Volume for crew sleep areas			
Volume for food prep and meal			
Volume for privacy			
Access to/from hatch to support equipment transfer			
Access to stow suits			
Volume for umbilical management			
Volume MAV flight control area			
Volume for donning/doffing suits			
Accessibility of translation paths			
Volume of MAV for contingency ingress/egress			
Volume of MAV for contingency with incapacitated crew			
Volume for co- located or related operations			
Volume to limit cross-contamination			
Volume for the ability of crewmember to use the WCS during sleeping hours without disrupting others			
Volume to provide adequate range of motion for a crew of 4 during nominal unsuited operations			
Volume for a crewmember to exercise			
Volume of MAV habitat to have one crew exercising while others work			
Overall volume of MAV habitat for a crew of 4			
Accessibility to the seats for a crew of 4			
Volume for sample stowage			

Conclusions

- Volumetric Conclusions (cont.)
  - WCS
    - Privacy curtain for WCS ops should not impede normal operations.
    - Due to small volume, WCS ops will wake up fellow crewmembers with associated noises from the WCS devices.
    - Need to relocate all waste and trash to floor.
    - Current trash volume is not adequate for a crew of four for five days.
    - Cross-contamination resolution between sleep area and WCS, suggest placing stowage between WCS and sleep area.
  - Sleep
    - Sleep design more hammock or “shelf” like arrangement with partitions for privacy.
    - Air flow in sleep areas needs to be addressed.
  - Translation Paths
    - Need more hand and foot holds though out vehicle.

Conclusions

- Volumetric Conclusions (cont.)
  - Exercise
    - Activities for non-exercising crewmember limited
    - Conflict with WCS ops when exercising
    - Different locations for exercise should be examined with 0-g in mind
    - Due to short mission, exercise equipment could impact other design trade-offs
  - General Cabin
    - Rear seats need structure for MS-1 and MS-2 in aft section of vehicle.
    - Add a foot rest to raise feet above mold line curvature.
    - Investigate feasibility of raising the galley/water delivery system to chest height.
    - Crew stated the GEN 2A vehicle volume was optimal and designers are “in the ballpark.” Could stay in volume for 4 to 8 days.
    - Overall interior design could be further optimized taking into account item usage frequency, item location vs time line, improvements to provide private sleep stations, WCS ops during sleep (possibly personal urine collection devices (battery powered fan).


NEA / Mars Moons
Cis-Lunar
Moon / Mars Surface
Core
Cabin
Lander ascent
vehicle cabin

Modular Exploration System

- **Through the last 5 years of engineering development, testing, and integrated analog operations, EAMD analysis, etc we have developed a modular exploration system**

Components			Mission Application	Configurations
Core Vehicle		Cabin	**Cis-Lunar Habitable Airlock:** *Habitation, Radiation Shelter, Airlock, Stowage, Trash/Logistics Mgmnt, EVA, Third docking port*	Core +9,11,12 
		Suit/Logistics Ports		
		ECLSS & Fusible Heat Sink		
		Active-Active Mating Adapter	**LLO Staging Base:** *Habitation, Radiation Shelter, Airlock, Stowage, Trash/Logistics Mgmnt, Rapid EVA*	Core +9,11 
Modules	1	Cockpit		
	2	Chassis	**Satellite Servicing:** *Habitation, Rapid EVA, Radiation Shelter, Satellite Grapple & Servicing*	Core +1,3,4,5,11 
	3	RCS Sled		
	4	Cargo Carrier	**NEA, Mars Moons:** *Habitation, Rapid EVA, Radiation Shelter, NEA Exploration, Stack Inspection & Maintenance*	Core +1,3,5,6,10,11 
	5	Robotic Arms		
	6	EVA Jetpacks		
	7	PUP / Modular Power	**Moon, Mars:** *Habitation, Rapid EVA, Radiation Shelter, Long Range Exploration, Airlock*	Core + 1,2,7,11 (+5 option) 
	8	Ascent Stage		
	9	Service Module / SEP Tug	**Lunar Lander:** *Pressurized volume for Ascent/Descent, Airlock, Ascent Stage (separate descent stage)*	Core +8 minus Suit/ Logistics Ports 
	10	Hopper Leg Module		
	11	Aft Stowage Module		
	12	Docking Port	**Mars Landing Cabin:** *Pressurized Cabin, ECLSS, Stowage, Seating for 4 crew. Duration up to 5 days*	Core 
			Mars Ascent Vehicle Cabin: *Pressurized Cabin, ECLSS, Stowage, Seating for 4 crew, duration up to 5 days*	Core 

Note: Airlock functionality provided by nominal depress of cabin, egress/ingress via side hatches

Questions