

# Peer-Reviewed Protocol – The contract by which we conduct consistent testing across the contractor configurations



- Protocol includes inputs from multiple stakeholders
  - NextSTEP
  - FCT
  - AES
  - Crew Office
  - HRP
  - Human Health and Performance
  - Operations/MCC
  - ....
- Clearly defined objectives, hypotheses, metrics, procedures, flight rules, and data analysis
- These ground tests and analyses will initially be conducted on a minimum of two, NASA developed configurations in order to train the test teams, and refine data collection and evaluation methods during FY18.
- This protocol will be customized for each specific contractor DSG configuration. The level of detail of these tests and analyses will be a function of the fidelity of the individual contractor deliverables.





#### Investigators

Principal Investigator (Org.):

Michael L. Gernhardt (SK/ER) michael.gernhardt@nasa.gov

Co-Investigators (Org.):

Steven P. Chappell (SK) steven.p.chappell@nasa.gov

Omar S. Bekdash (SK)

omar.s.bekdash@nasa.gov

Harry L. Litaker (SF) harry.l.litaker@nasa.gov

Alexandra M. Whitmire (SK) alexandra.m.whitmire@nasa.gov

Kara H. Beaton (SK)

kara.h.beaton@nasa.gov

Andrew F. J. Abercromby (SK)

andrew.f.abercromby@nasa.gov

Robert L. Howard (SF) robert.l.howard@nasa.gov

- Contraction of the Contraction

#### Ground Test Team & Subject Matter Experts (Org.):

Autonomy: Jeremy D. Frank (ARC-TI)

Avionics & Software: James E. Ratliff (EV), Daniel B. Carrejo (EA), Larry N. Townsend (ER)

Communication: Adam M. Schlesinger (XS)

Environ. Control & Life Support: Daniel J. Barta (EC), Miriam J. Sargusingh (EC), Imelda

Stambaugh (EC)

Exercise: Bobbie Gail Swan (SA), Darby Vicker (EG), Darby F. Magruder (ER)

 $\underline{Extravehicular\,Activity} : \mathsf{Amy}\,\,\mathsf{L}.\,\, \mathsf{Ellison}\,(\mathsf{EC}),\,\, \mathsf{David}\,\,\mathsf{Coan}\,(\mathsf{XX}), \mathsf{Natalie}\,\,\mathsf{Mary}\,\,(\mathsf{XX}), \mathsf{Marc}$ 

Ciupitu (XX)

Exploration Medical: Michael A. Canga (SF), Jennifer A. Mindock (SA)

<u>Vehicle Systems and Design:</u> Nathan Howard (ER), Fernando Zumbado (ER), Robert Trevino (EC),

Human Factors, Behavioral Performance: Alexandra Whitmire (SK)

<u>Human Factors, Habitability</u>: Robert L. Howard (SF), Kriss J. Kennedy (SF), Harry L. Litaker (SF), Canaan Martin (SF)

Guidance, Navigation, & Control: William L. Othon (EG)

Lighting: James Maida (SF), Toni A. Clark (SF)

<u>Logistics</u>: James L. Broyan (EC), Michael K. Ewert (EC), Kandyce E. Goodliff (LARC-E402), Harry L. Litaker (SF)

<u>Mission Control Center</u>: Dina E. Contella (CA), Christopher K. Bellant (CO), Tobin R. Melroy (CO), Paul W. Gramm (CO), Jackelynne P. Silva-Martinez (CO), Steven R. Hillenius (ARC-

TH), Jessica J. Marquez (ARC-TH)

Power: James F. Soeder (GRC-LE), Karin E. Bozak (GRC-LEMO)

Radiation: Martha S. Clowdsley (LARC-D309)

Robotics: Myron Diftler (ER), Phillip S. Callen (ER), Darby F. Magruder (ER)

Requirements Development: Howard A. Wagner (ER), Svetlana Hanson (ER)

Safety & Mission Assurance: Hellen Vaccaro (NE)

Science: Samuel Lawrence (XI)

Simulation: Edwin Z. Crues (ER), Paul Bielski (ER)

Structures: Jason L. Raboin (ES)

Test Objectives Development: Jason E. Poffenberger (XM)

Thermal: Katy M. Hurlbert (EC), Christopher J. Massina (EC), Bruce Conger (EC), Imelda

Stambaugh (EC)

<u>Trash Management</u>: Michael K. Ewert (EC) <u>Vehicle Health</u>: Adam M. Schlesinger (XS)

#### Approvals

Douglas A. Craig 2/13/2018

Douglas A. Craig (HQ)

NextSTEP Habitation BAA Lead

Onouthun

Patrick A. Troutman (LARC-E402) Integrated Analysis Team (IAT) Lead

Michael L. Gernhardt (ER) Principal Investigator

JSC Division Chiefs/Directors

CLIFF FARMER FARMER Date: 2018.02.02 13:23:38-06'00'

Robert O. Ambrose (ER)

Software, Robotics, & Simulation Division Chief

Scott A. Swan (EC)

Crew & Thermal Systems Division Chief

Christopher P. Hansen (XX) Extravehicular Activity Office Chief 16 /11. Gra 12-21-17

Kim M. ESS (XM

NextSTEP Habitation BAA Deputy Lead Exploration Mission Planning Chief

William L. Othon (EG)

NextSTEP Habitation BAA Ground Test Lead

Jennifer L. Rochlis (SF)

Human Systems Engineering & Development Division Deputy Chief

JUDITH HAYES Digitally signed by JUDITH HAYES Date: 2018.02.01 18.28.08.0600

Judith Hayes (SK)

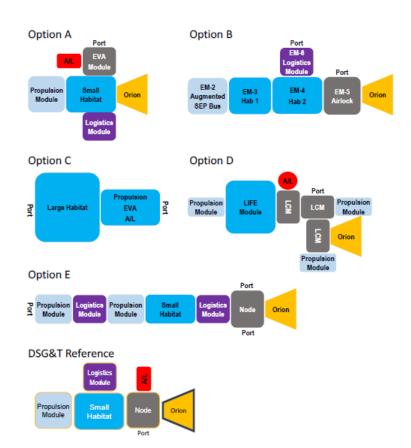
Biomedical Research & Environmental

Sciences Division Chief

### **Five Different Contractor Options**



- The Phase 2 RFP focused on getting contractor ideas for what a DSG should be
  - No Specific Requirements
- It is critically important for a consistent evaluation that the same core mission is conducted in each of the five contractor habitats
  - If we do 5 completely different missions in 5 completely different habitats there will be absolutely no basis for effective comparison
- The purpose of this test and analysis program is not to pick a "winner" but through the testing and analysis define what we like and don't like.
  - Data is used to inform requirements for Phase 3.



# **Acceptability Ratings**



#### **DSG Architectural Configuration Acceptability Ratings**

Unacceptable	10
Borderline	5
Acceptable	1

	Α	В	С	D	Е	
Robotic arm ops	2	8	9	3	9	
EVA prep	6	10	2	6	1	
EVA	7	3	6	1	8	
Meal prep	9	10	6	9	1	
Hygiene	1	2	7	6	7	
WCS ops	5	4	7	3	2	
Suit Stowage	3	3	7	4	8	
Sleeping	5	6	2	8	9	
Docking and berthing	10	5	2	6	5	Acceptability
Logistics/Trash Stowage	7	6	7	5	10	Ratings < 4
Simulated contingencies	4	9	1	4	2	
Experimental science	6	6	4	5	8	
House keeping	2	5	2	3	5	
Routine maintenance	2	7	1	4	9	
IFM	5	8	7	10	6	
Exercise	4	5	10	5	8	
PAO	3	10	5	3	10	
Medical	7	9	2	5	2	

Acceptable	Most Acceptable		
Configurations	Configuration		
A, D	Α		
C,E	E		
B,D	D		
E	Е		
A,B	Α		
B,D,E	E		
A,B,D	A or B		
C C	C		
С	С		
None	None		
A,C,D,E	С		
С	С		
A,C, D	A or C		
A,C,D	С		
None	None		
Α	Α		
A,D	A or D		
C,E	C or E		

Totally Acceptable		Accep	table	Borde	erline	Unacce	eptable	Totally Unacceptable		
A. S. 10 / Wood To - C.	ovements ssary	Minor improvements desired		PENNINE 200 00 10 10	Improvements warranted		Improvements required		Major improvements required	
1	2	3	4	5	6	7	8	9	10	

# **HITL Test Conditions**



The baseline DSG stack configuration is assumed to be a habitat, airlock, Orion, and logistics module.

- ♦ In FY18 preliminary testing at JSC, two conditions: "Habitat-Centric Function Allocation" and a "Distributed Function Allocation", will be executed to evaluate the allocation of DSG functions across those elements.
- ◆ Each condition includes four crewmembers, with the differences among conditions reflecting different strategies for distributing the required DSG functions, systems, and subsystems across available elements.
- Habitat-Centric Function Allocation
  - Assume all required DSG functions (e.g. robotic workstation, exercise, science, meals) are co-located in a single small habitat that includes a dedicated equipment lock (E/L)/crew lock (C/L).
- Distributed Function Allocation
  - Spread the required DSG functions across available elements; functions, such as exercise, meal preparation, robotic workstation, and science, may be performed in a separate multifunction equipment lock/crew lock element, with the remaining functions in a small habitat

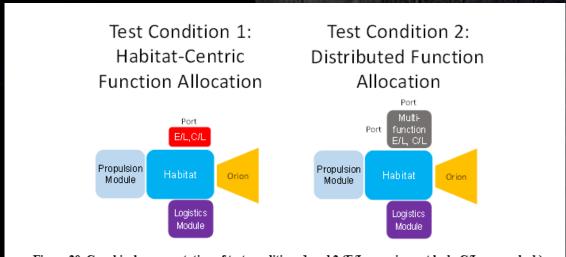
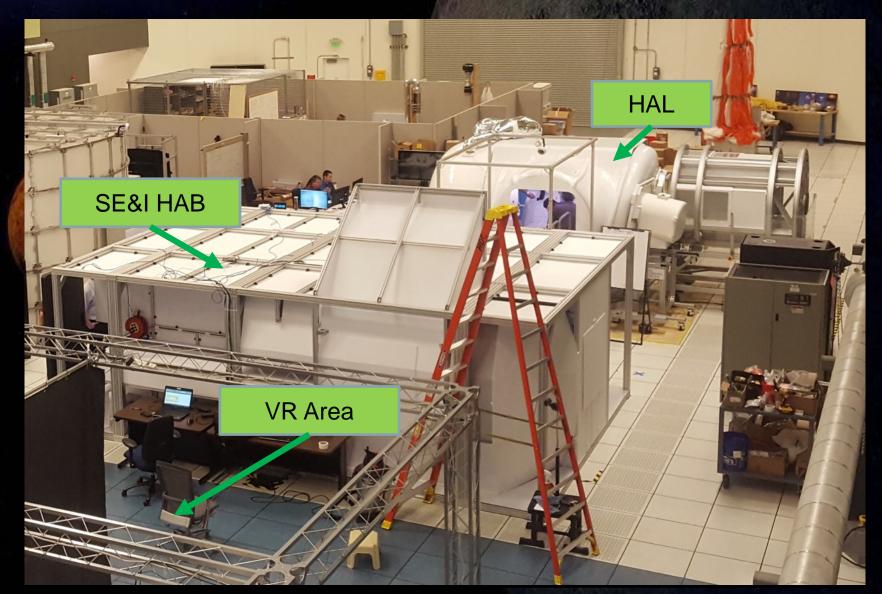


Figure 20. Graphical representation of test conditions 1 and 2 (E/L = equipment lock, C/L = crew lock).

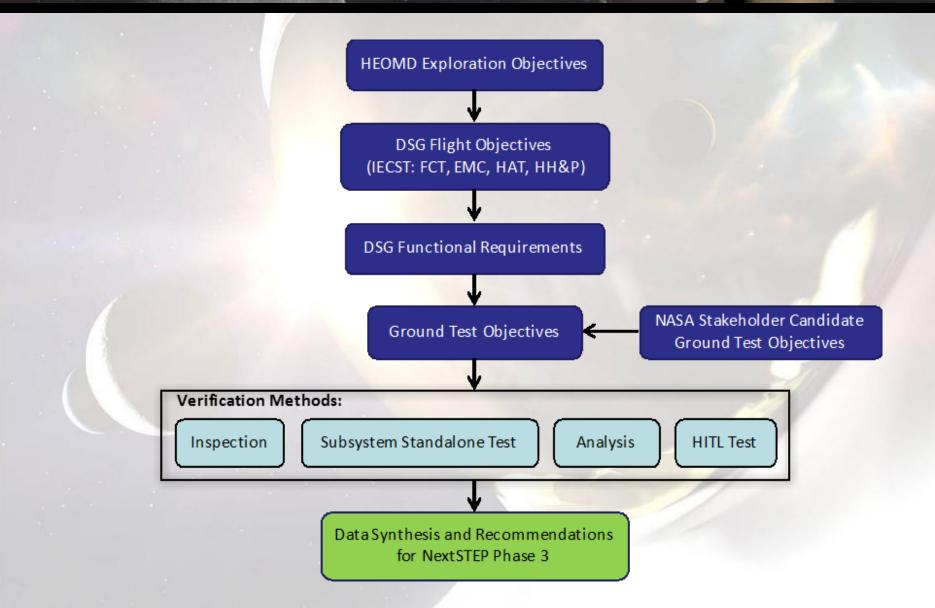
# Picture of iPAS Setup in Building 29/JSC





# **BAA Ground Test and Analysis Protocol Development Process**

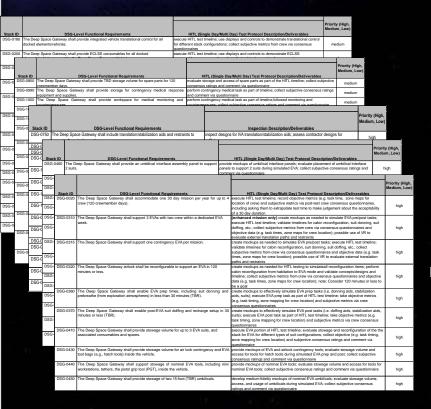




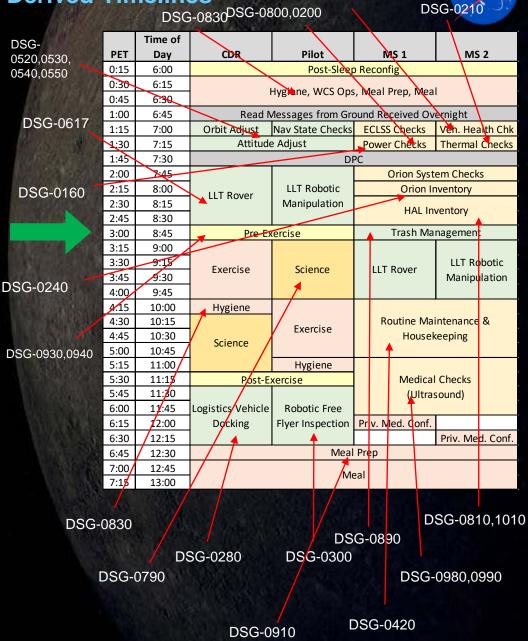
# **DSG Draft Functional Requirements Derived Timelines**

DSG-0240

NASA DSG-0210



HITL test timeline directly maps to draft DSG functional requirements and stakeholder ground test objectives.

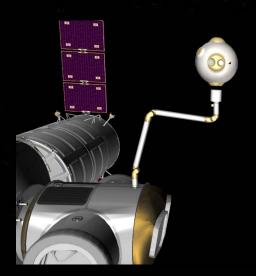


## **Example Timeline Task –TeleRobotics**



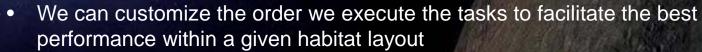
- Strategic Question 12: What robotic assets are needed to support DSG task categories, including, but not limited to, logistics handling, dormancy maintenance, sample return, experiment deploy/recover, EVA support, and aggregation of the DST?
  - ...To understand the requirements for robotic workstations (human factors design, number/location of stations, etc.), specific representative tasks including lunar rover teleoperations and sample return simulations will be performed with HITL testing. The NASA in-house and contractor tests will include different numbers, types, and locations of robotic workstations all used to execute a common representative mission timeline.

DSG ID	Primary Functional Requirements Domain	DSG-Level Draft Functional Requirements	Ground Test Objectives		
DSG-0290		sample return.	Demonstrate robotic arm displays and controls for capture and berthing of sample return capsules; simulate capture and berthing of sample return capsules		
DSG-0617	robotic operations and communication	The Deep Space Gateway shall communicate with the Moon.	simulate and evaluate Deep Space Gateway communicating with the Moon		
DSG-0300	ropotic operations	The Deep Space Gateway shall provide robotic operations of free-flyers.	Demonstrate robotic free-flyer displays and controls; simulate robotic free-flyer operations		









NASA

- In addition there are blocks (in blue) in the timeline which are variables where contractor unique mission content can be incorporated.
- It is critically important for a consistent evaluation that the same core mission is conducted in each of the five contractor habitats
  - If we do 5 completely different missions in 5 completely different habitats there will be absolutely no basis for effective comparison

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					Time					
					of					
CDR	Pilot	MS 1	MS 2	PET	Day	CDR	Pilot	MS 1	MS 2	
				7:45	13:45			Pre-Exercise F	rep and Set-up	
				8:00	14:00	IIT Da	ver Sim			
	Post-S	Sleep		8:15	14:15	LLI NO	ver sim	Exercise	Standalone	
(H	lygiene, WCS Ops, Meal	Prep, Meal, Prep for DPC	.)	8:30	14:30			Exercise	Assessments	
				8:45	14:45					
				9:00	15:00	Mar	dical			
GNC Checks Hab Systems & Consumables Checks				9:15	15:15	ivie	aicai	Standalone	Exercise	
(Nav State, Orbit &	Attitude Adjusts)	(ECLSS, Power, Therr	mal, Vehicle Health)	9:30	15:30			Assessments	Exercise	
	DF	c		9:45	15:45					
		Orion Systems & Co	onsumables Checks	10:00	16:00	C.i.	ence	Post-Exercise Clea	an-up and Reconfig	
LLT Rover Sim	LLT Robotic	HAL Systems & Co	nsumables Checks	10:15	16:15	Scie	ence			
LLI Kover Sim	Manipulation Sim			10:30	16:30				LLT Robotic	
		Logi	STICS	10:45	16:45	:45 Priv. Med. Conf.		LLT Rover Sim	Manipulation Sim	
Pre-Exercise Pre	ep and Set-up	Trash Management		11:00	17:00		Priv. Med. Conf.			
				11:15	17:15					
Exercise	Science	LLT Rover Sim	LLT Robotic	11:30	17:30	Standalone	Standalone	84-	.d:1	
Exercise	Science	LLI KOVET SIM	Manipulation Sim	11:45	17:45	Assessments	Assessments	Medical		
				12:00	18:00					
				12:15	18:15		Mea	Prep		
Science	Exercise	Scie		12:30	18:30	Meal				
Science	Exercise	Scie	nce	12:45	18:45		IVI	eal		
				13:00	19:00	BAO		Event		
Post-Exercise Clear	-up and Reconfig	Priv. Med. Conf.		13:15	19:15		PAU	event		
	Meal Prep		Priv. Med. Conf.	13:30	19:30		D	PC		
Meal				13:45	19:45					
Meal				14:00	20:00					
				14:15	20:15	D.	ili. Uakisasian Osi	mainer and Matrice Deti		
LLT Robotic				14:30	20:30	Da	aily Habitation Question	naires and Metrics Kati	ngs	
Manipulation Sim	LLT Rover Sim	Routine Maintenan	ce & Housekeeping		20:45					
					21:00					
						The Royal Co.	A STREET, STRE			

# **May Test – Engineering Day 1 (Habitat Only)**

	7		1
N	A	A	
12			

	Time of								
PET	Day	CDR	Pilot	MS 1	MS 2				
0:15	6:15								
0:30	6:30								
0:45	6:45		Post-	Sleep					
1:00	7:00		(Hygiene, WCS Ops, Meal	Prep, Meal, Prep for DPC)					
1:15	7:15								
1:30	7:30								
1:45	7:45	GNC C	Checks	Hab Systems & Co	nsumables Checks				
2:00	8:00	(Nav State, Orbit 8	& Attitude Adjusts)	·	mal, Vehicle Health)				
2:15	8:15	(1111		PC	,				
2:30	8:30			Orion Systems & C	onsumables Checks				
2:45	8:45			-	nagement				
3:00	9:00	LLT Rover Sim	LLT Robotic Manipulation Sim						
3:15	9:15			Logistics	Reconfig				
3:30	9:30	Pre-Exercise P	rep and Set-up						
3:45	9:45			Lunar Traverse and	Sample Collection				
4:00	10:00	Exercise	Telescope Observations						
4:15	10:15								
4:30	10:30	Post-Exercise Clean-up		Radiation Ve	st Assessment				
4:45	10:45		Exercise						
5:00	11:00	IFM							
5:15	11:15		Post-Exercise Clean-up and Reconfig						
5:30	11:30			Prep					
5:45	11:45								
6:00	12:00		IVI	eal					
6:15	12:15	Comple Box	o' PAG	Imagery/Charge Reminder	Personal Health Checkout				
6:30	12:30	Sample Kett	urn Sim RMS	Pre-Exercise Prep and Set-up	Priv. Med. Conf.				
6:45	12:45	Personal Health Checkout	Imagery/Charge Reminder		Pre-Exercise Prep and Set-up				
7:00	13:00	Priv. Med. Conf.	Personal Health Checkout	Exercise					
7:15	13:15	Imagery/Charge Reminder	Priv. Med. Conf.		VR Task				
7:30	13:30		Airlock Ops	Post-Exercise Clean-up					
7:45	13:45	HAD Science	: Alliock Ops						
8:00	14:00			VR Task	Exercise				
8:15	14:15	UPP Soinger (Mr.	uscle Ultrasound)						
8:30	14:30	nnr science (IVI	uscle oldasound)	Personal Health Checkout	Post-Exercise Clean-up and Reconfig				
8:45	14:45			Priv. Med. Conf.	Imagery/Charge Reminder				
9:00	15:00		PAO Eve	nt Setup					
9:15	15:15		P/	AO					
9:30	15:30		D	PC					
9:45	15:45		Mea	l Prep					
10:00	16:00		M	eal					
10:15	16:15	Niedi							
10:30	16:30								
10:45	16:45								
11:00	17:00		Daily Habitation Question	naires and Metrics Ratings					
11:15	17:15		Daily Habitation Question	man es and metrics hattings					
11:30	17:30								
11:45	17:45								

# May Test – Engineering Day 2 (HAL-Hab Distributed)

N	A	Α
1		35

	Time of			Control of the Contro						
PET	Day	CDR	Pilot	MS 1	MS 2					
0:15	6:15	- CON	1 1100	2						
0:30	6:30									
0:45	6:45		Post-Slee	ep (HAL)						
1:00	7:00			Prep, Meal, Prep for DPC)						
1:15	7:15	(**)6 ,								
1:30	7:30									
1:45	7:45	GNC Che	GNC Checks (HAL)  Hab Systems & Consumables Checks (Hab)							
2:00	8:00		& Attitude Adjusts)	-	mal, Vehicle Health)					
2:15	8:15		DPC	(HAL)						
2:30	8:30			Orion Systems & Cons	umables Checks (Hab)					
2:45	8:45	LLT Davies Sim (HAL)	LLT Robotic Manipulation Sim	HAL Systems & Consu	ımables Checks (Hab)					
3:00	9:00	LLT Rover Sim (HAL)	(HAL)	Trash Manageme	nt (Hab and HAL)					
3:15	9:15			Logistics Posonf	ig (Hab and HAL)					
3:30	9:30	Pre-Exercise P	rep and Set-up	Logistics Recomi	g (Has alla HAE)					
3:45	9:45	Exercise (HAL GRC Ergo)	Exercise (Hab HOPPER)	Lunar Traverse and Sa	mple Collection (HAL)					
4:00	10:00	Exercise (Hab HOPPER)	Exercise (HAL GRC Ergo)	Editar Traverse and Sa						
4:15	10:15	Post-Exercise Clea	n-up and Reconfig	Sample Return and Habitat So	ience Airlock Operation (HAL)					
4:30	10:30				, , , , , , , , , , , , , , , , , , , ,					
4:45	10:45	Radiation Vest A	Assessment (HAL)							
5:00	11:00		HRP Science (Muscle Ultrasound) (Hab)							
5:15	11:15	Imagery (H	AL and Hab)	5 111 11 61 1 1 1/1161	D. Life H. C. L. (1981)					
5:30 5:45	11:30 11:45	IFM - Filter a	nd RCA (HAL)	Personal Health Checkout (HAL)	Personal Health Checkout (HAL)					
6:00	12:00		Moal Pr	Priv. Med. Conf. (HAL) ep (HAL)	Priv. Med. Conf. (HAL)					
6:15	12:15		Weart	ep (line)						
6:30	12:30		Meal	(HAL)						
6:45	12:45	Personal Health Checkout (HAL)	Imagery/Charge Reminder							
7:00	13:00	Priv. Med. Conf.(HAL)	Personal Health Checkout(HAL)	Housekeeping	(HAL and Hab)					
7:15	13:15		Priv. Med. Conf.(HAL)	Pre-Exercise P	rep and Set-up					
7:30	13:30			Exercise (HAL GRC Ergo)	Exercise (Hab HOPPER)					
7:45	13:45		Telescope and Observations (Hab)	Exercise (Hab HOPPER)	Exercise (HAL GRC Ergo)					
8:00	14:00	na: : Data (II-1)		` '	n-up and Reconfig					
8:15	14:15	Mini-DNA (Hab)								
8:30	14:30		HRP Science (Vein Ultrasound	VR Task (H	AL or Hab)					
8:45	14:45		Simulation) (Hab or HAL)							
9:00	15:00			PAO Eve	nt Setup					
9:15	15:15			40						
9:30	15:30		DI	PC						
9:45	15:45		Meal	Prep						
10:00	16:00	Meal								
10:15	16:15									
10:30	16:30									
10:45	16:45									
11:00	17:00		Daily Habitation Question	naires and Metrics Ratings						
11:15	17:15			•						
11:30	17:30									
11:45	17:45									

# May Test – Engineering Day 3 (Habitat and EVA)

NAS	A

			1/4(5)		A PROBLEM DESCRIPTION					
	Time of									
PET	Day	CDR	Pilot	MS 1	MS 2					
0:15	6:15									
0:30	6:30									
0:45	6:45	Post-Sleep (HAL)								
1:00	7:00		(Hygiene, WCS Ops, Meal	Prep, Meal, Prep for DPC)						
1:15	7:15									
1:30	7:30									
1:45	7:45	GNC Chec	cks (HAL)	Hab Systems & Consu	mables Checks (Hab)					
2:00	8:00	(Nav State, Orbit 8		(ECLSS, Power, Then	mal, Vehicle Health)					
2:15	8:15			(Hab)						
2:30	8:30		umables Checks (Hab)							
2:45	8:45	HAL Systems & Consu		Reconfigure	HAL for EVA					
3:00	9:00	Pre-Exercise Prep	and Set-up (Hab)							
3:15	9:15	Francisc (Units)		SCU Install a	nd Checkout					
3:30 3:45	9:30 9:45	Exercise (Hab)	LLT Rover Sim (Hab)	Airloc	Prop					
4:00	10:00	Post-Exercise Clean-up (Hab)		Airlock (	•					
4:00	10:00	i ost-exercise clean-up (nab)		EVA Teathe	•					
4:30	10:30		Exercise (Hab)							
4:45	10:45	LLT Robotic Manipulation Sim (Hab)	2	EVA Tool Config						
5:00	11:00		Post-Exercise Clean-up and Reconfig	EVA Prep and Purge						
5:15	11:15			Crewlock Depress						
5:30	11:30	Trash Management an	d Housekeeping (Hab)	Crewlock Repress						
5:45	11:45	Meal Pre	ep (Hab)	EVA PostOps						
6:00	12:00			SCU Uninstall						
6:15	12:15	Meal	(Hab)	Reconfigure HAL for Habitation						
6:30	12:30									
6:45	12:45	Reconfigure	HAL for EVA	Meal Prep (Hab)						
7:00	13:00			Meal (Hab)						
7:15	13:15	SCU Install a	nd Checkout							
7:30	13:30			· IFM (Hab)	VR Task (Hab)					
7:45	13:45		k Prep	` '	` '					
8:00	14:00		Campout	Pre-Exercise Pr	ep and Set-up					
8:15	14:15		r Inspection							
8:30	14:30	EVA Too	Ol Contig	Exercise (Hab)	LLT Rover Sim (Hab)					
8:45	14:45	EVA Prep and Purge (inc	clude last minute items)	Dark Francisco Classic						
9:00	15:00	6II	. D	Post-Exercise Clean-up						
9:15 9:30	15:15 15:30	Crewlock	Depress		Exercise (Hab)					
9:30	15:30	EVA Po	•	LLT Robotic Manipulation Sim (Hab)	Exercise (Hab)					
10:00	16:00	SCU Ur	•		Post-Exercise Clean-up and Reconfig					
10:00	16:15				·					
10:30	16:30	Reconfigure HA	L for Habitation	Meal Pro	ep (Hab)					
10:45	16:45									
11:00	17:00		Meal (Hab)							
11:15	17:15		DPC							
11:30	17:30									
11:45	17:45									
12:00	18:00									
12:15	18:15		Crew Consensus Questionnaires							
12:30	18:30									
12:45	18:45									
13:00	19:00									

# NASA-Developed Procedures and Mission Content Available For Incorporation into Contractor Testing



#### Software Tools

- Playbook Timeline Control
- ProX Procedures

#### **♦** Subsystem Simulation Procedures

- GNC Systems Checks
- Hab Systems and Consumables Checks
- HAL Systems and Consumables Checks
- Orion Systems and Consumables Checks

#### ◆ Exercise

- MED2 Installation and General Ops
- GRC Ergometer Setup and Exercise
- HOPPER Setup and Exercise

#### ◆ Science

- Telepresence Lunar Rover Traverse v5
- Telescope Observations v4
- MiniDNA Sequencer Procedure

#### **◆ EVA**

- Airlock Prep
- Airlock Campout Initialization
- EVA Tether Inspection
- EVA Tool Config
- EVA Prep and Purge
- Airlock Depress
- Airlock Repress
- EVA Post Ops

#### ♦ Robotics

- LLT Rover Simulation Procedures
- LLT Manipulation Simulation
- DSG RMS Sample Return Transfer

#### ♦ Medical

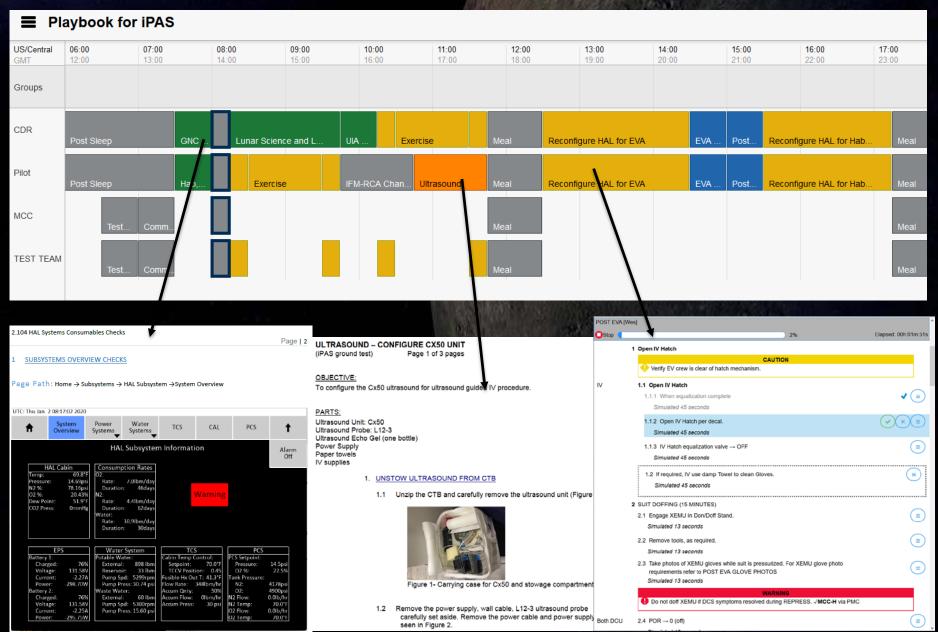
- Medical Contingency Ultrasound guided
   IV intravenous access
- SPRINT Thigh Muscle Ultrasound Assessment

### ♦ In-Flight Maintenance (IFM)

ECLSS Component Replacement

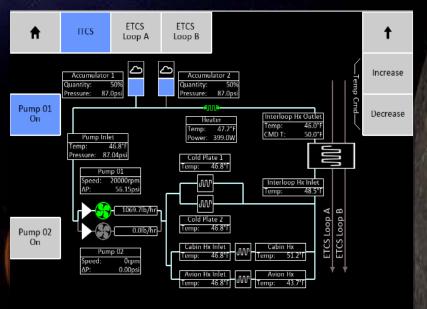
### **Timeline And Procedure Control Utilizing Playbook**

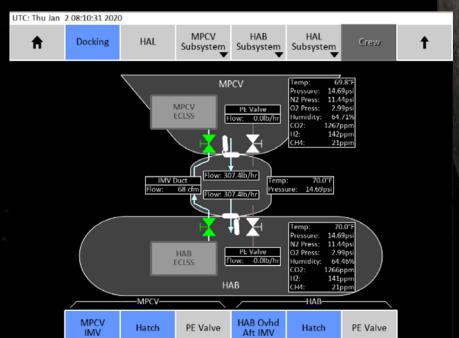


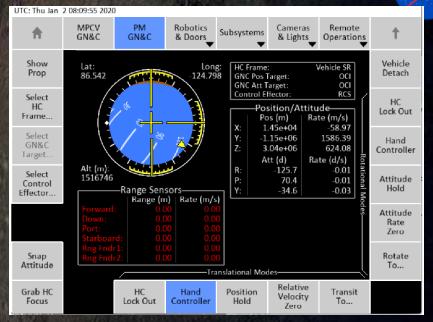


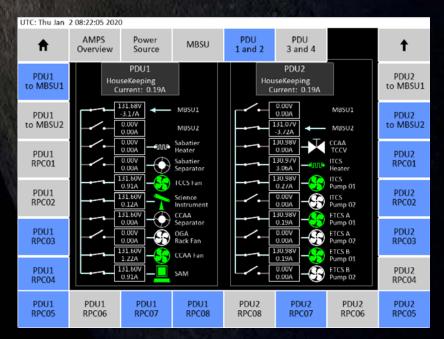
### **High Fidelity Subsystem Models of HAL and Hab Systems**







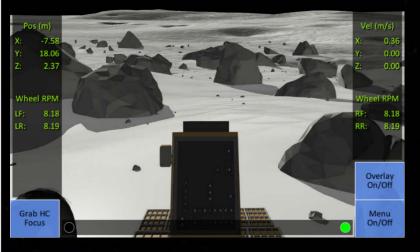


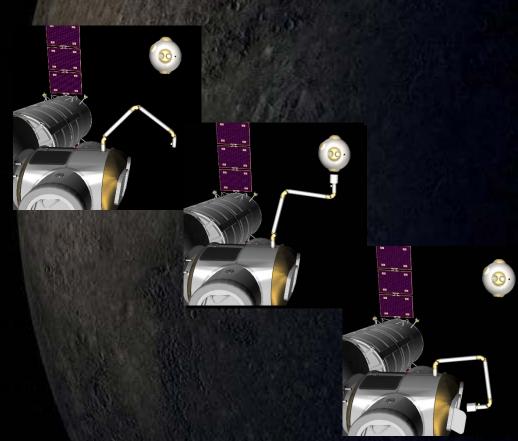


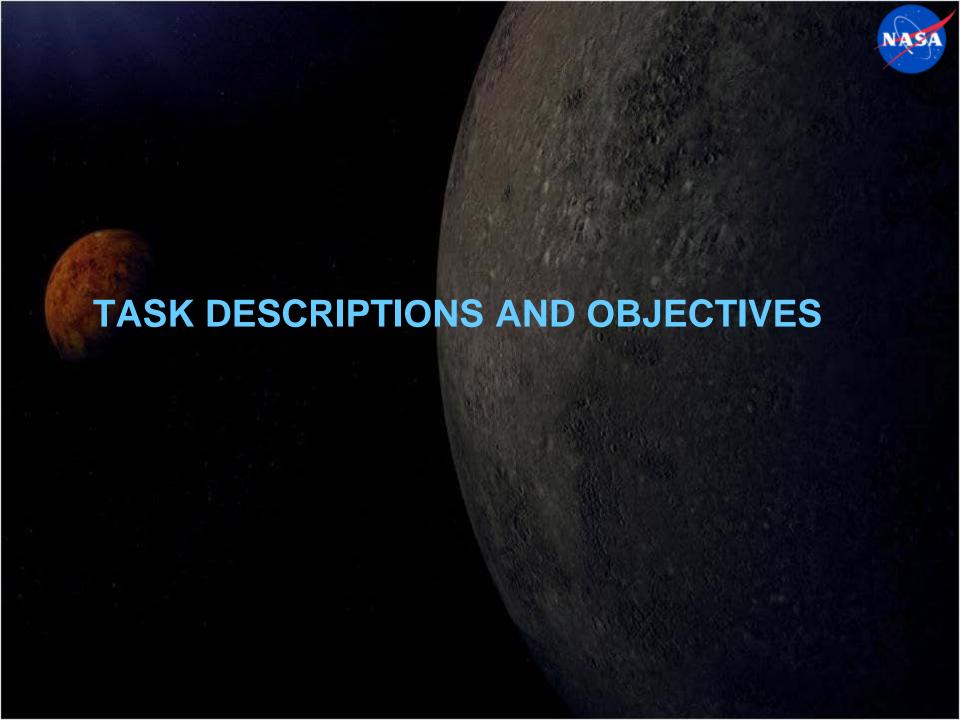
# **LLT Rover and Robotic Sample Return Simulations**











# **Big Picture**



- ◆ This test configuration represents the assembly complete of the Gateway.
- ◆ This test includes a habitat and a multifunction airlock. Although not mocked up the Orion and at least one logistics module will be part of the stack.
- ◆ The mission timeline was developed to exercise all functional requirements of the gateway and we hope represents a realistic set of tasks with a flight-like ops tempo, communications, and procedures.
- ◆ As a subject evaluator you should take the point of view that you are an astronaut that will be utilizing this gateway for 30 day missions in the future.
  - This is your opportunity to provide inputs into the design features and capabilities that you like and don't like.
  - Keep in mind the gateway is time and budget constrained and only the first step toward future lunar and Mars missions.
    - This is not the Deep Space Transport system or a long mission duration space station.
- ◆ The goal of this evaluation is to evaluate the design and layout of the habitation system. It is not to evaluate the task that you are doing.
  - At the end of the mission we will ask you to evaluate the fidelity and quality of the tasks so we can improve the tasks for subsequent tests if warranted.
  - Please do not conflate a good or bad task with a good or bad habitation design/ layout

## Limitations



The ground test and analysis protocol for the DSG has a number of limitations, including, but not limited to:

#### ♦ Number, Type, and Fidelity of DSG Contractor Mockups:

Due to budget, schedule, and 1-g limitations the NextSTEP BAA testing will not include mockups of the Orion or logistics module. The contributions of Orion and the logistics module will be assessed through a combination of analyses, VR, and standalone testing rather than fully integrated HITL testing. The fidelity of DSG contractor habitation and EVA modules could vary widely, and for this reason, our simulation quality scale will be used to discriminate which data will be used for tests of the hypotheses and forward DSG recommendations.

#### ◆ 1-g Test Environment:

The DSG will be implemented in micro-gravity which is not possible to fully simulate in 1-g environment. However
previous testing has shown that 1-g mockups which contain features required for microgravity operations (e.g.
handholds, foot loops, Velcro, etc.) combined with the expertise of experienced astronauts can result in meaningful
assessments. VR can also be used to address some aspects of microgravity, such as full utilization of the habitation
volume (e.g. exercise on ceiling versus floor) which would not be possible in a 1-g test.

#### ♦ HITL Study Design:

• The NextSTEP BAA will result in five different habitation configurations. At this time, the details of each individual DSG contractor configuration with respect to the number and type of modules and distribution of habitation, science, and EVA functions, are not known. Also, since each contractor will provide their own designs, we do not have the control to systematically vary the independent and dependent variables. For this reason, multiple specific hypotheses could not be prospectively developed. Instead, two high-level hypotheses are proposed that provide the framework to guide the HITL testing and evaluation. The results of the HITL testing across all five configurations will be assimilated, analyzed, and used to inform future requirements and design recommendations for the DSG. In this type of HITL testing (using the targeted population of astronauts as test subjects), it is not possible to execute the studies with large numbers of subjects (e.g. limited number of astronauts, scheduling constraints). Therefore, although individual data will be collected, the crew's consensus evaluation will be used to test the hypotheses and to identify the actionable results.

# Flight Rules



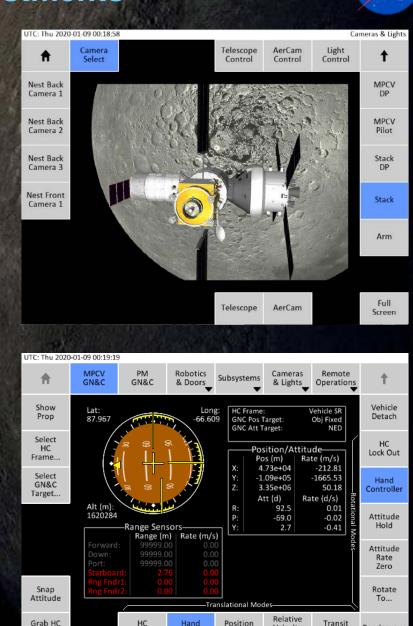
- ◆ Space-to-ground communication troubleshooting: Communication team can spend up to 5 min troubleshooting communication network. After 5 mins, all space-to-ground communication will be relayed through open hatch doors until communication is restored; if communication between B30 MCC and B29 Test Support is functioning operate in single person bent pipe mode through B29 Sim Sup until such time as communication is restored.
  - If B30 MCC <> B29 Test Support communication goes down, B30 CapCom calls crew cell phone inside Hab/Hal (CapCom will call whichever pair they were working with when comm went down) and MCC continues from B30.
  - If communication between MCC and B29 is disconnected for more than 30 min, MCC/SME talks to B29 Capcom via cell phone (bent pipe mode).
- ◆ Physical hardware troubleshooting: Up to two individuals can enter vehicle to conduct troubleshooting for up to two hours. If there is a complete hardware failure that takes more than 5 min to resolve the crew should move to the next timeline task that doesn't involve that hardware, or as instructed by MCC.
- ◆ Simulation troubleshooting: Simulation team can spend up to 5 min troubleshooting. If simulation cannot be fixed in 5 min and timeline allows, crew will move to the next simulation on their timeline. If no simulations are working, crew will move the next functioning timeline task. If crew begins a new timeline task and they are less than 10 min in when the original simulation task is recovered, they should switch back to the original simulation task; if they are more than 10 min in to the new task, they should finish the new task.

# **GNC Checks and Attitude Adjustments**



#### Task Description

- This is a simple task to check prop quantities on the PPM and the Orion, check and verify the nav state, input targets and initiate a maneuver to a new attitude for observations later in the day.
- When you complete this task you be asked to evaluate the multipurpose workstation usability for this task.



Hand

Controller

Lock Out

Focus

Position

Hold

Velocity

Transit

To...

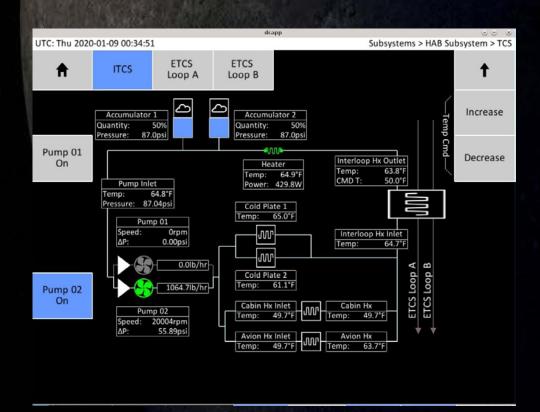
Rendezvous

# **Habitat and Orion Consumables Checks**



#### ◆ Task Description

- Simple task to look at the current consumables quantities (e.g. O2, N2, H2O) for the habitat and Orion, and perform a pump swap activity
- Evaluate the multipurpose workstation layout and design for this task.



# **LLT Lunar Rover Simulation**

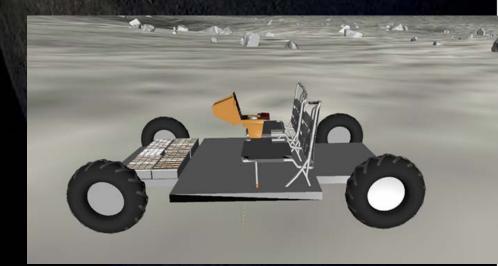
# ◆ Task Description

- This task involves driving a lunar rover through a congested rock field with the goal of reaching a sample return ascent vehicle.
- There are multiple randomized runs with different latency times (this is for data collection to look at LLT rover operations)
- The simulation has a high fidelity physics rover and contact model and you can run over or get stuck on rocks.
  - If you get stuck on a rock end the run and start the next one
- When complete you will be asked to evaluate the layout of the multipurpose workstation and hand controller for performing this task.



Focus

On/Off



# **Lunar Traverse and Sample Collection Simulation**



### ◆ Task Description

- Similar task to the Lunar Rover however two crew work together using a map to locate targeted rocks marked with a blue or green dot in a boulder field
- When complete crew will be asked to evaluate the location, usability, and layout of the multipurpose workstation for two person robotics operations.

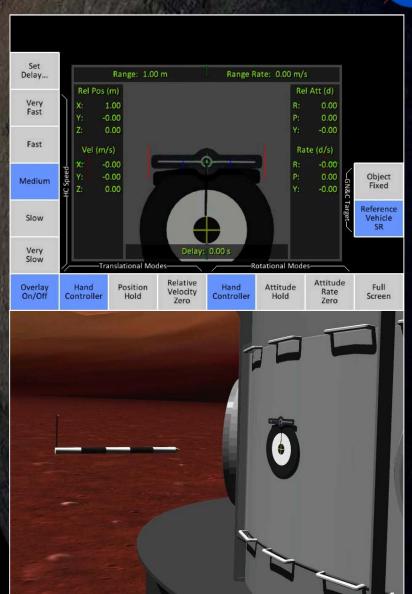


# **LLT Manipulation Simulation**



### Task Description

- This task is a standalone study to evaluate human teleoperation rotational and translational accuracy as an input to the design of future low latency tele-robots and tasks.
- The latency times range from 0, 250ms, 500ms, 750ms, and 1s
- In the context of this mission you can think
  of this as manipulation to place a rock
  sample on the sample return spacecraft.
- When complete you will be asked to evaluate the multipurpose workstation and hand controller for performing this task.

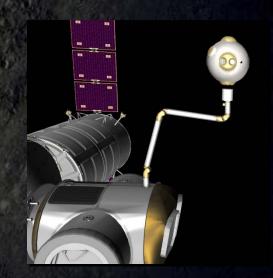


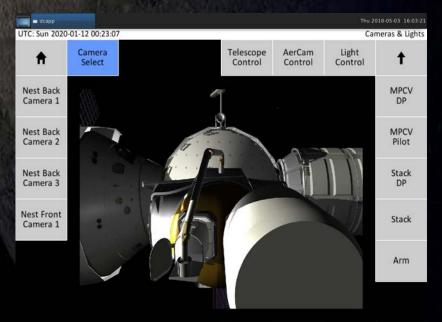
# Sample Return RMS Ops Simulation



### ◆ Task Description

- This task involves magnetically grappling a sample return spacecraft with a ferrous plate on the sample return canister.
- The space craft is then commanded to release the canister and the RMS is then used to position the canister in a science airlock secondary containment vessel.
- The procedure involves operating both the RMS and the science airlock and results in the sample being brought inside the spacecraft.
- Evaluate the location, layout, and usability of the multipurpose workstation in this habitation element layout for performing this task.





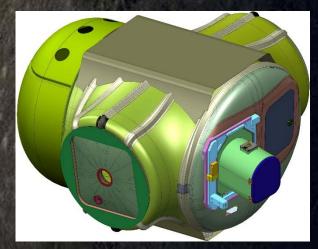
# Science Glove Box / HAL Science Airlock



### ◆ Task Description

- This is a very simple task that involves either

   opening the HAL science airlock and
   bringing in the secondary containment vessel
   and simulating taking it to the Orion. Or 2) the
   sample will magically appear in the habitat and
   you will place it in the glove box and manually
   put it in a secondary containment vessel.
- Habitat Evaluate the location and volume necessary to perform glove box science in this habitation layout.
- HAL Evaluate the location, design, and capability enhancement of the HAL Science Airlock.

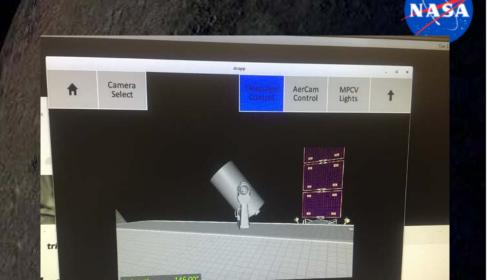


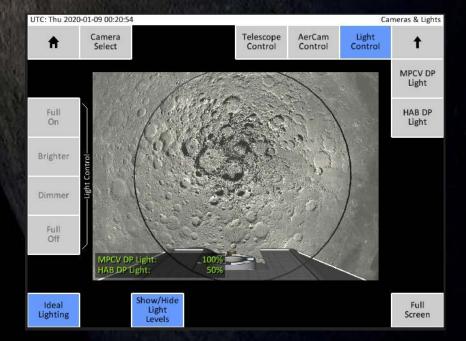


# **Telescope Observations**

### Task Description

- This procedure is currently under revision but today you will get the big picture skills.
- Basically involves pointing the telescope at targets on the earth, moon, and sun and taking pictures.
- Evaluate the multipurpose workstation for performing this task in both the habitat and the HAL.





# **Exercise – Hopper and GRC Ergometer**

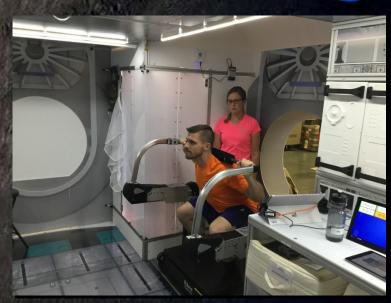


### ◆ Task Description

- Hopper: Perform exercise using the Hopper, a representative resistive exercise device.
  - Task involves setting up the device, exercising and stowing

#### Note:

- Exercise equipment for this test is a prototype device and does not include all the planned capabilities for a Gateway device (e.g. rowing); however the equipment has been put into place for operational volume assessments.
- GRC Ergometer: Task involves setting up a small combination ergometer and resistive exercise device in the HAL. Performing exercise and breaking down and stowing the device.
- You will be asked to evaluate the acceptability of the location, exercise volume, noise levels, setup, breakdown, and any interferences of exercise with the other crewmembers.





# **Ultrasound - Muscle**

### Task Description

- This is a simple task that involves setting up an ultrasound machine following a procedure. Once set up the ground will talk you through performing a guided ultrasound scan of the leg muscles using a colored and number coded keypad.
- This procedure is a reduced version of the flight procedure completed by crew onboard ISS during the S.P.R.I.N.T Study however the fidelity is nearly identical to that performed in flight.
  - NO ULTRASOUND OR MEDICAL DATA IS COLLECTED DURING THIS PROCEDURE EVALUATION!
- Evaluate the layout, associated volume, privacy, and interference associated while performing such exams.





# **Ultrasound – Guided IV Catheter Simulator**



### Task Description

- This task involves inserting an IV into the vein of an arm phantom using ultrasound to guide the insertion.
- Assess the associated volume and surfaces necessary to perform the task including temp stowage, restraint locations, and any task interferences with other crewmembers.
- Arm phantom used in this task should be placed to reflect the total volume an actual crewmember would require.



### **Habitation Tasks – Galley, Hygiene, Housekeeping**



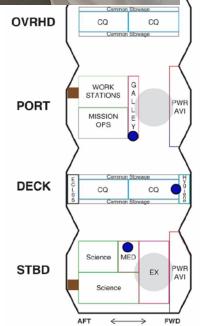
### **♦ Task Descriptions:**

- Perform basic habitation tasks including housekeeping, meal prep, WCS Ops, hygiene, trash management, sleep prep and post.
- Also a PAO event will be staged.
- Crew will move through cabin and perform these routine habitation functions to understand vehicle volume, layout, and any resulting task interferences that may exist.



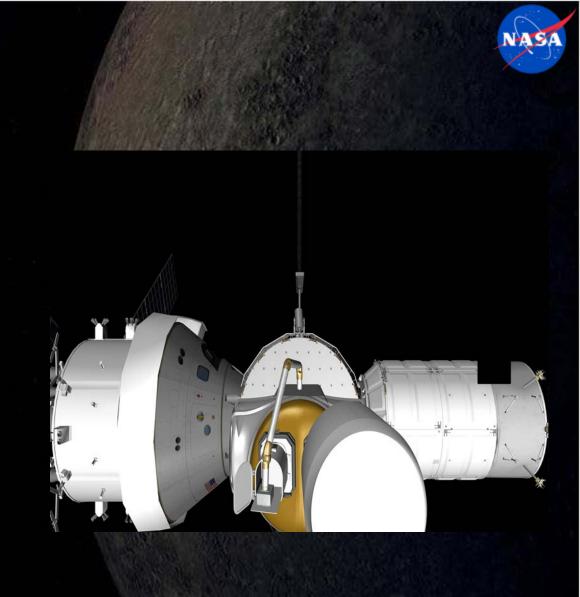


	Symbol	Item to be Cleaned	Instructions
7.	•	SDS Sample Probe	Vacuum, notify MCC-H if blockage observed.
8.		Bacteria Filters	Notify MCC-H to deactivate Area Smoke Detectors before cleaning. Vacuum Bacteria Filters and surface clean Area Smoke Detectors. Notify MCC-H ready for Area Smoke Detector activation.
9.	8	Area Smoke Detectors	
10.		IMV Grilles	Vacuum, disinfect.
11.		TCCS Inlet	Without opening rack door, clean, disinfect.
12.		Supply Diffusers	Vacuum, disinfect.
13.		Ku-Band Power Supply	Inspect and clean vents as required.



# **Trash Management**

- Basic task where crew gathers up temp stow, wet, dry trash from around the cabin and collects into a trash CTB.
- Trash is then ejected from the science airlock using a simulation procedure.
- Crew will assess location and accessibility of trash stowage and evaluate the science airlock for trash ejection.



# **Personal Health Checks and PMCs**



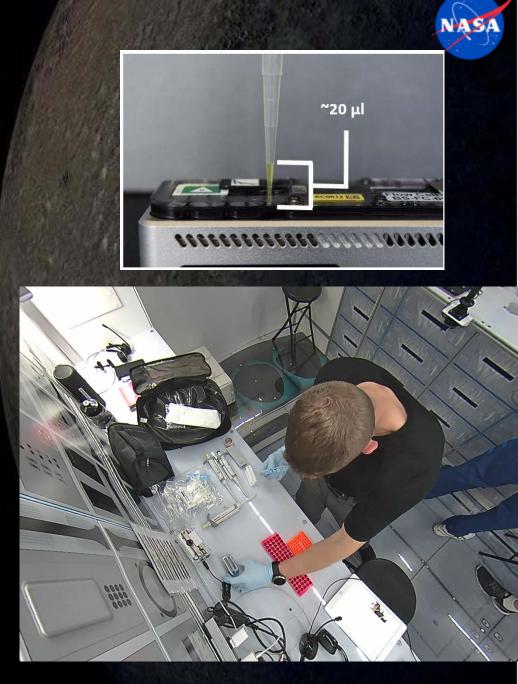
### ◆ Task Descriptions

- Crewmembers will perform a basic health status assessment measuring temperature, Pulse Oximetry, BP, and HR. Followed by a PMC with a flight surgeon.
- Crewmembers will evaluate the ability of the habitation element layout and design to provide private areas for personal use. This includes assessments of design features to enable privacy (e.g. curtains).



# **Mini-DNA Sequencer**

- This is a long and complicated task that is representative science currently being performed on space station to collect environmental samples, extract bacterial DNA the MiniDNA Sequencer device.
- Execute a representative long duration science task requiring a stationary workstation. Examine the volume necessary to complete the task, work surface layout, and potential interference with other crewmembers performing separate activities.



# **Radiation Vest Assessment**

- The radiation vest is prototype personal protective equipment designed at NASA LARC for protection of crew from SPE and other radiation events.
- Crew will don the vest to determine whether the radiation vest will hinder basic movement and task performance during a critical radiation event.
- Crewmembers will evaluate the volume and stowage accessibility necessary to quickly access and don the protective equipment.





## **IFM**

- Crewmembers will perform three separate IFM tasks that include 1) changing out an MBSU card and a science pallet in the habitat; 2) replacement of a filter on the UIA panel in the HAL; 3) replacing an RCA swing bed with a spare in the HAL
- Tasks involve steps for power down as well as the actual IFM itself using 3D printed components
- Evaluate the acceptability of the layout of the habitat or HAL for access to the failed components and execution of the IFM.
- Taking into account the location, volume, restraints, and temp stowage available to perform repairs.





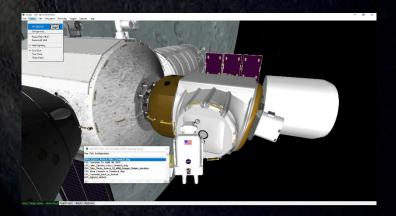


# Virtual Reality Training for EVA

- Crew will set up a VR headset, hand controllers, and laptop to perform a virtual walk around the DSG stack to train for an upcoming EVA.
- The VR simulation will provide a helmet and god's eye view
- Crewmembers will evaluate the volume and location necessary to perform this type of VR training and also comment on crewmember interferences.

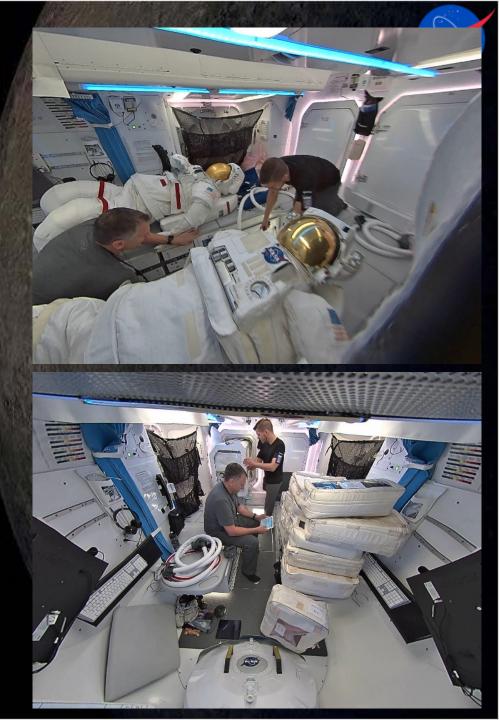


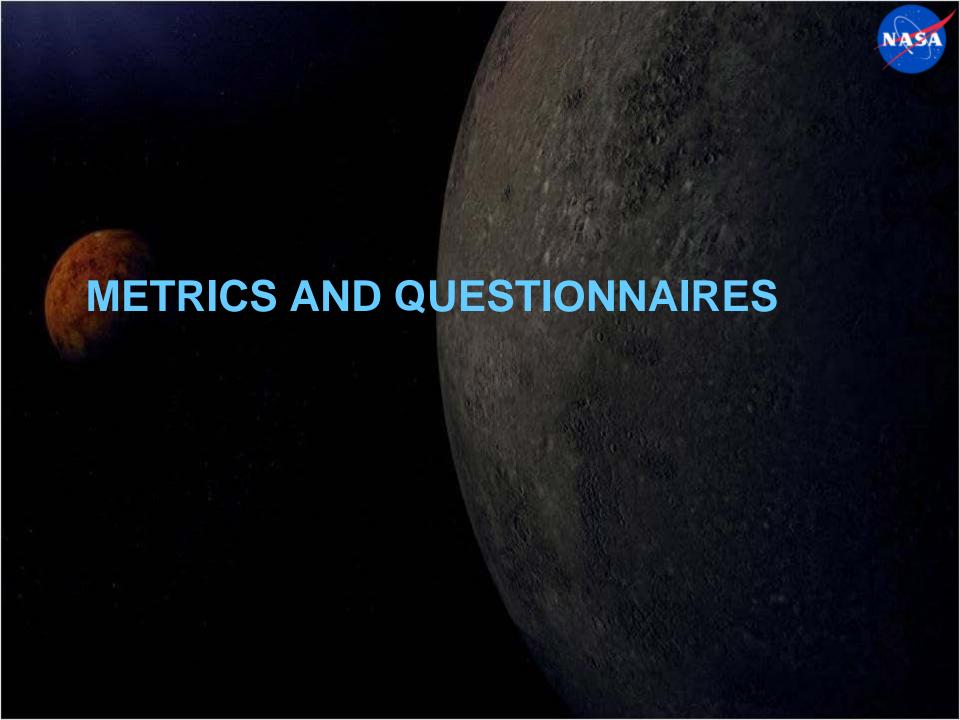




# **EVA Prep and Post**

- This task will move crew through a full day of EVA preparation and post-EVA activities.
- Crewmembers will configure the HAL to act as an airlock, simulate preparation of two EVA suits, followed by reconfiguration of the HAL as a habitation element.
- Crewmembers will evaluate the volume and layout of the HAL as a multifunction airlock for performing EVA prep and post activities.
- Crewmembers are asked to consider volume and locations to route umbilicals, access to EVA tools and equipment, and stowage locations and methods.
- Crewmembers are asked to consider 0g constraints related to don/doffing, temp stowage locations for tools and equipment, and volume necessary for access to the HAL PRS and logistics.





# **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).

 Conditions in which simulation quality was rated by test subjects as 4 or 5 would not be included in hypothesis testing.

## Metrics



- Ratings made by consensus of all 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

Categorical Difference

Acceptability

Totally Ac	ceptable	Ассер	otable	Borde	erline	Unacce	eptable	Totally Unacceptable					
No impro neces		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	rovements ired		rements anted	5	ements iired	Major improvements required					
1	2	3	4	5	6	7	8	9	10				

No Categorical Difference

## **Capability Assessment**

Categorical Difference

Essential	Enabling	Signifi Enha	cantly ncing	1	rately ncing		inally ncing	Little or No Enhancement					
Impossible inadvisable mission capal	to perform without	enhance or	ficantly	one or more aspects of the mission or ore significantly enhance useful only on very		useful ui reaso forese	es are not nder any nable eeable stances						
1	2	3	4	5 6		7	8	9	10				

Na Oatamaniaal Diffananaa

# Crew Performance Metrics (Collected Morning, Noon, and Night)



## Workload Ratings

- Crewmembers ability to maintain maximum possible task performance in a given environment, test condition, task overlap or interference from other crewmembers performing their own tasks.
- While this does not directly provide insight into the distribution of functions across the DSG configuration it does provide data into task and overall habitation system design. For example, workload may be rated high during setup of exercise equipment if the vehicle interfaces, accessibility, and procedures are complex.

Insigni Work		Light W	orkload		erate doad	_	ficant cload	Maximum Workload					
Insignificar effort – Sig spare ca remai	gnificant pacity	Light ment Desirab capacity r	•		e mental ough spare emaining	effort – \ spare c	nt mental /ery little apacity iining	Maximum mental effort – No space capacity remaining					
1	2	3	4	5	6	7	8	9	10				

## Fatigue Ratings

No Fa	tigue	Minor	Fatigue		erate igue		ficant gue	Extreme	e Fatigue			
No Fat perform compre	ance not	perform	atigue – ance not omised	perform likel compro	e Fatigue – nance will ly be omised if inued	perforr	t Fatigue – nance is omised	Extreme Fatigue unable to contin with adequate performance				
1	2	3	4	5 6		7	8	9	10			

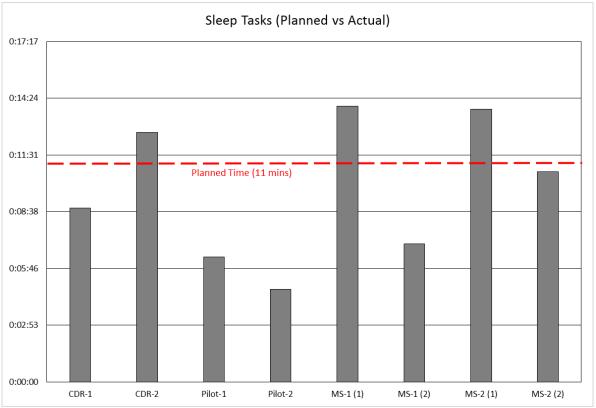
## **Crew Performance Metrics**



## Planned versus Actual Timeline Execution

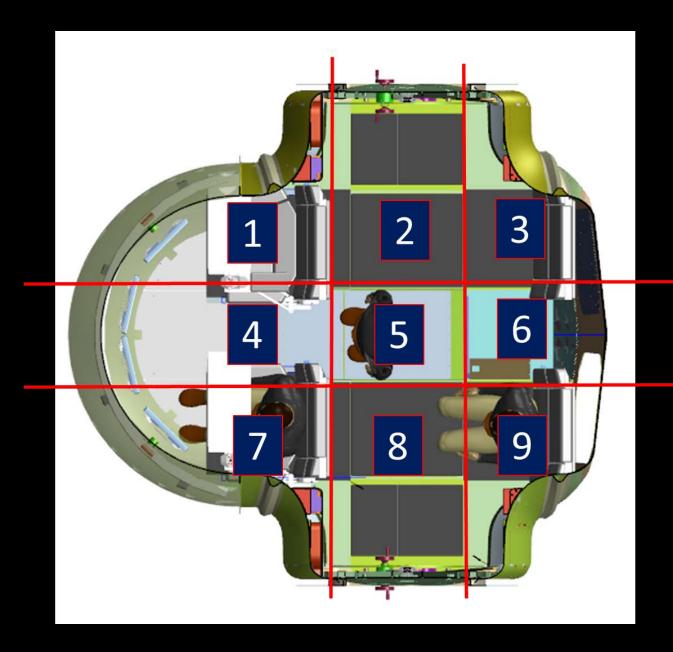
- Overall timeline and individual task durations will be collected and compared to the planned times to provide contextual understanding of other crew performance metrics.
- The actual time to perform tasks on the mission timeline will be compared to the planned times and the
  results will be presented along with insight as to what may have caused the differences, such as conflicts for
  use of the same habitable volume, simulation quality effects, crew training for test, etc.

 Additionally, crewmember wait times and number of interrupts will be considered to evaluate DSG function layout.



# **Example of Zone Definition**

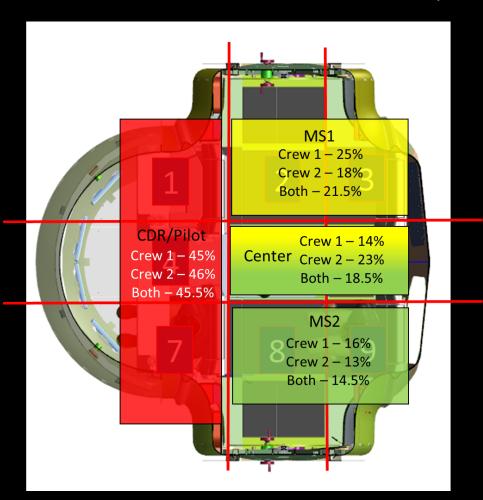




# **Crew Time Frequency Map Results**



# MAV Sectional Heat Map in Percentage



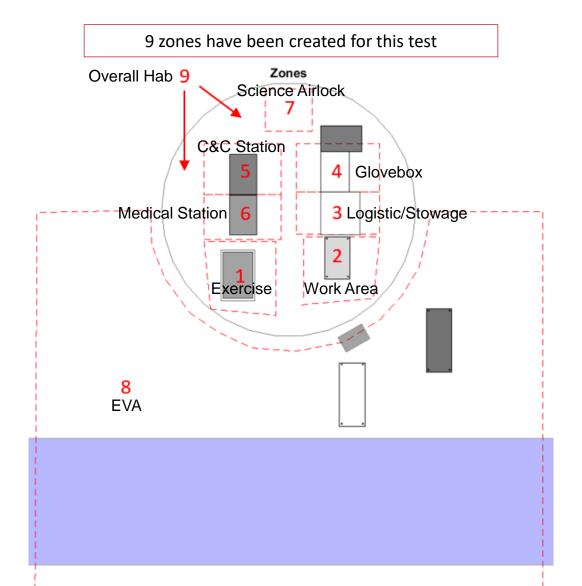
Frequency of time spent in each area consisted of actual task completion times and task discussion

Total Time = 819 minutes

# **ALLTRAQ**



## Movement Zones

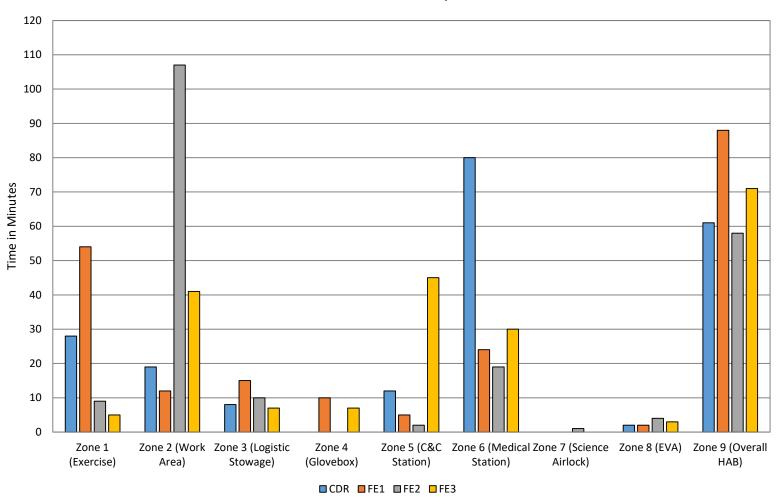


# **ALLTRAQ**



## Overall crew time spent in zones

## Crew Time in ALLTRAQ Zones



# Example Acceptability Questionnaire - Exercise



	Rate	the sim quality and	accep	tability	of the	follow	ing hal	oitati	ion c	hara	cteri	stics	for t	his v	/ehic	le:		
1.	Accessibility - The quality of being able to be easily reached or obtained for use. Functionality - The purpose that something is designed or expected to fulfill the design. Usability - The degree to which something is able or fit to be used by the operator.																	
			S	IM QU	JALITY	RATIN	G	I	AC	CEPT	ABIL	ITY F	RATII	VG				Comments (REQUIRED IF SIM > 3 OR
			1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	ACCEPTABILITY ≥ 4)
	a.	Ability to access and locate the HAB exercise equipment																
	b.	Setup of HAB exercise equipment														{		
	c.	Volume to perform aerobic exercise											195			M		
	d.	Volume to perform resistive exercise						>	<b>(</b>	)					<b>&gt;</b>			
	e.	Accessibility to non- exercising crew member to other areas within the HAB					7	) d ~~		6/	)							
	f.	Exercise equipment breakdown and stowage within HAB				14/												
	g.	Overall acceptability of exercise within HAB																

# Example Acceptability Questionnaire – Multi-Purpose Workstations

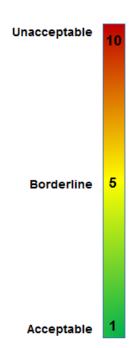


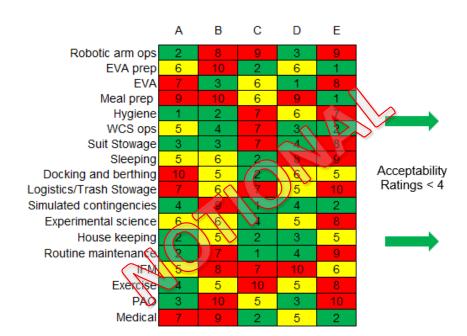
	Rate	the sim quality and	accept	ability	of the	e follov	ving ha	bitat	ion (	hara	cter	istics	for	this	vehic	:le:		
1.	Ope Acce Fund	nitions to consider w rability - The design i essibility - The quality tionality - The purpo ility - The degree to	is ready of bei	y for u ng abl t some	se suc le to b ething	e easily is desi	reach gned o	ed o r exp	r obt	aine d to	fulfil	l the	des	ign.				
			1	IM QU	JALITY 3	RATIN 4	G 5	1	AC 2	CEP1	ABII	LITY 5	RATI	NG 7	8	9	10	Comments (REQUIRED IF SIM ≥ 3 OR ACCEPTABILITY > 4)
	a.	Physical location of workstation																ACCEPTABLETT 24)
	b.	Overall work volume of the workstation																
	c.	Accessibility to the workstation's displays and controls														ㅁ (		
	d.	Usability of the workstation's displays and controls												/ / /	74 2	6		
	e.	Accessibility to the workstation's display edge keys							~			7		<b>)</b> )	)   			
	f.	Adjustability of the display(s)							Ø	9	6	79						
	g.	Lighting within the workstation				<	9		R	A	4	4						
	h.	Accessibility to hand controllers				P	4			A								
	i.	Accessibility of horizontal work surfaces for the workstation (e.g. keyboard tray)			Y			<u></u>										
	j.	Workstation setup																
	k.	Acceptability of the mulit-purpose workstation																

# **Acceptability Ratings**



#### **DSG Architectural Configuration Acceptability Ratings**





Acceptable	Most Acceptable
Configurations	Configuration
A, D	Α
C,E	E
B,D	D
Е	Е
A,B	Α
B,D,E	E
A,B,D	A or B
C C	С
С	С
None	None
A,C,D,E	С
С	С
A,C, D	A or C
A,C,D	С
None	None
Α	Α
A,D	A or D
C,E	C or E

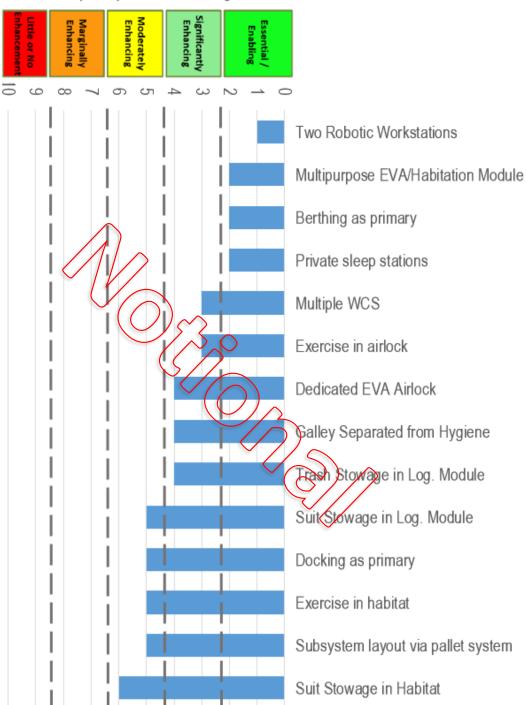
# **Example Capability Questionnaire**



Sim quality should be provided first before considering capability. If simulation quality is inadequate to meaningfully evaluate the aspect, a sim quality rating of 4 or 5 should be provided and comments must be added that indicate the reason for the inadequate sim quality. If the sim quality is adequate for evaluation (i.e. 1-3), provide an capability rating for that aspect. If an aspect is rated anything but essential/enabling (i.e. if a rating of 3-10 is given), comments must be provided that indicate the level of significance enhancment. Comments SIM QUALITY RATING CAPABILITY RATING (REQUIRED IF SIM > 3 OR CAPABILITY > 8 9 10 5 A WCS in a different module from the galley An additional WCS separate from Orion An additional c. galley separate from Orion Trash ejection on a per mission basis Trash ejection on a per weekly basis Multiple, dedicated temp stow areas for trash Separate wet and dry trash stowage Two multiipurpose workstations A dedicated medical area A dedicated science module A hardwired multipuprose station for critical commanding Two exercise stations A permanently m. installed exercise

# pabi lities **Assessments**

## **Capability Assessment Rating**



# **Analytical Hierarchy**



Instructions:

For each of the listed capabilities, assign an "X" to indicate which capability in a row is more important than the capability in the column for the specific test condition (i.e. HAB-HAL). You can have more than one "X" per row.

			WCS			Trash Management		Workstation	Medical	Science	Command & Control	Exercise			Sleep Station		Logistics	Lighting	Windows
"X" Indi	Selection Criteria cates Row more Important Than Column	A WCS in a different module from the galley	An additional WCS Separate from Orion	An additional galley separate from Orion	Trash ejection on a per mission basis	Multiple, dedicated temp stow areas for trash	Separate wet and dry trash stowage	Two multi-purpose workstations	A dedicated medical area	A dedicated science module	A hardwired multi-purpose station for critical commanding	Two exercise stations	A permanently installed exercise station	Exercise station in separate module from the main habitat	Private sleep stations	A dedicated logistics module A logistics module sized for a single	Mission A deterministic logistics stowage system (i.e. labeled lockers)	Circadian cycle lighting system	A viewing window (not a virtual window)
wcs	A WCS in a different module from the galley					) )													
	An additional WCS Separate from Orion																		
Galley	An additional galley separate from Orion		$\sim$																
	Trash ejection on a per mission basis				<u> </u>														
Trash Mangement	Trash ejection on a per weekly basis			$\langle \vee \rangle$															
	Separate wet and dry trash stowage			)															
Workstation	Two multi-purpose workstations																		
Medical	A dedicated medical area																1		
Science	A dedicated science module	7														$\vdash$	+		
Command & Control	A hardwired multi-purpose station for critical commanding																		
	Two exercise stations																		
Exercise	A permanently installed exercise station																		
LACIOIDO"	Exercise station in separate module from the main habitat																		
Sleep Station	Private sleep stations																		
	A dedicated logistics module																		
Logistics	A deterministic logistics stowage system vs CTBs (i.e. labeled lockers)																		
Lighiting	Circadian cycle lighting system																		
Windows	A viewing window (not a virtual window)																		

# **May Ground Test Early Lessons Learned**



- ♦ It is a lot of work to put together all the mission content and ground support infrastructure to support an integrated test.
  - We have been working on preparations for this single test for 8 months and are still not quite ready
- **♦** The importance of performing a dry "engineering run" before the formal crew run.
- Some of the stakeholder mission content does not fit well within the constraints of the timeline and potentially adversely affects the evaluation of the habitats.
  - Understanding of priorities with regards to core ground test objectives and not overpromising stakeholders.
- ♦ Based on December test and multiple reviews we have significantly refined/revised the questionnaires and capability assessment ratings.
- ◆ To develop flight-like procedures and mission content takes far more time than most people understand.
- ♦ We need to maintain flexibility to work with crew office scheduling
- ♦ We are behind the curve with respect to developing the contractor specific timelines, questionnaires, and test plans.
  - Recommend within 1-month we develop draft timelines for each contractor that incorporate as much of our core mission content that has already been developed as possible, while leaving the flexibility to arrange the sequence of tasks and allowing for some contractor unique content.





