

Extravehicular Activity Testing in Analog Environments: Evaluating the Effects of Center of Gravity and Environment on Human Performance

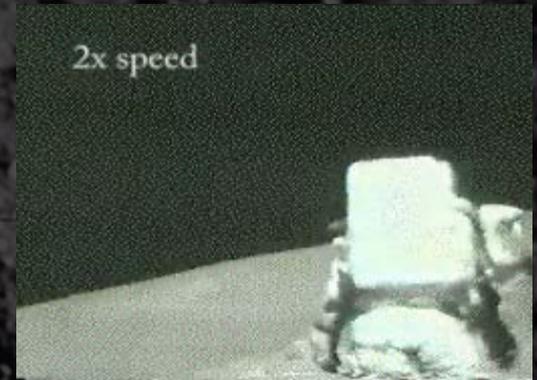
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Background

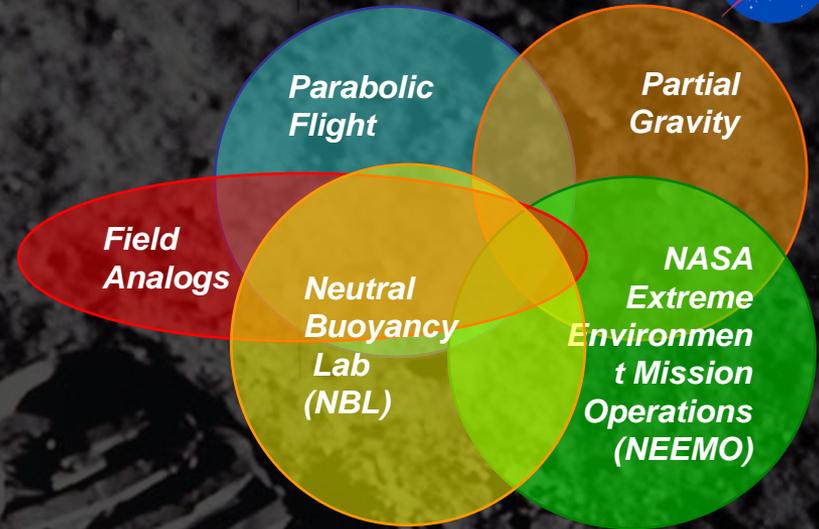
- Background:
 - Center of Gravity (CG) is likely to be an important variable in astronaut performance during partial gravity EVA
 - The Apollo Lunar EVA experience revealed challenges with suit stability and control
 - Likely a combination of mobility and center of gravity factors
 - The EVA Physiology, Systems and Performance Project (EPSP) in conjunction with the Constellation EVA Systems Project Office have developed plans to systematically understand the role of suit weight, CG and suit pressure on astronaut performance in partial gravity environments
- CG Study Objectives
 - To understand the impact of a varied CG on human performance in lunar gravity



Simulation Environments & Studies

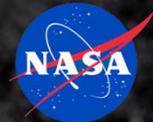


- Test series
 - EVA Walkback Test (EWT)
 - Integrated Suit Test 1 (IST-1)
 - Integrated Suit Test 2 (IST-2)
 - Haughton Mars Project (HMP) Walkback Test
 - Integrated Suit Test 3 (IST-3)
 - NBL CG
 - NEEMO 9 – 13
 - Integrated Parabolic Flight Test 1
 - Integrated Parabolic Flight Test 2



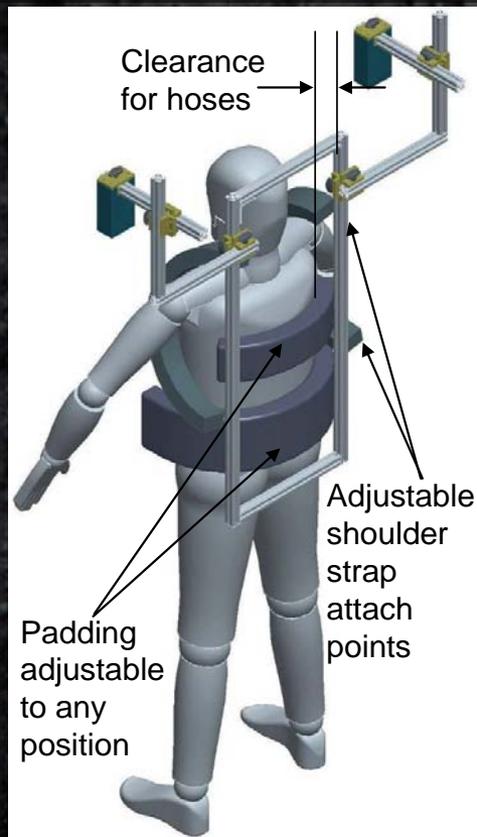
Simulation Characteristics	Simulation Environments				
	1. Parabolic flight	2. POGO Wt. relief	3. NBL	4. NEEMO	5. Field Analogs
Suit kinematics / pressure volume	+	+	+	-	+
Mass distribution / dynamics	+	-	+	+	-
Unlimited time duration	-	+	+	+	+
6 DOF motion throughout work envelope	+	-	+	+	+
True operational environment	-	-	-	+	+
Drag and buoyancy effect	+	+	-	-	+

Center of Gravity Studies – NEEMO/NBL



- Total Apollo EVA suit & PLSS earth weight - 88.6 kg (195 lb)
 - Suit 27.2 kg (60 lbs)
 - PLSS 61.2 kg (135 lbs)
- CG location based on 182.9 cm (6 ft), 81.8 kg (180 lb) male
- 21 subjects weighed to result in 1/6 g static ground reaction force (GRF)

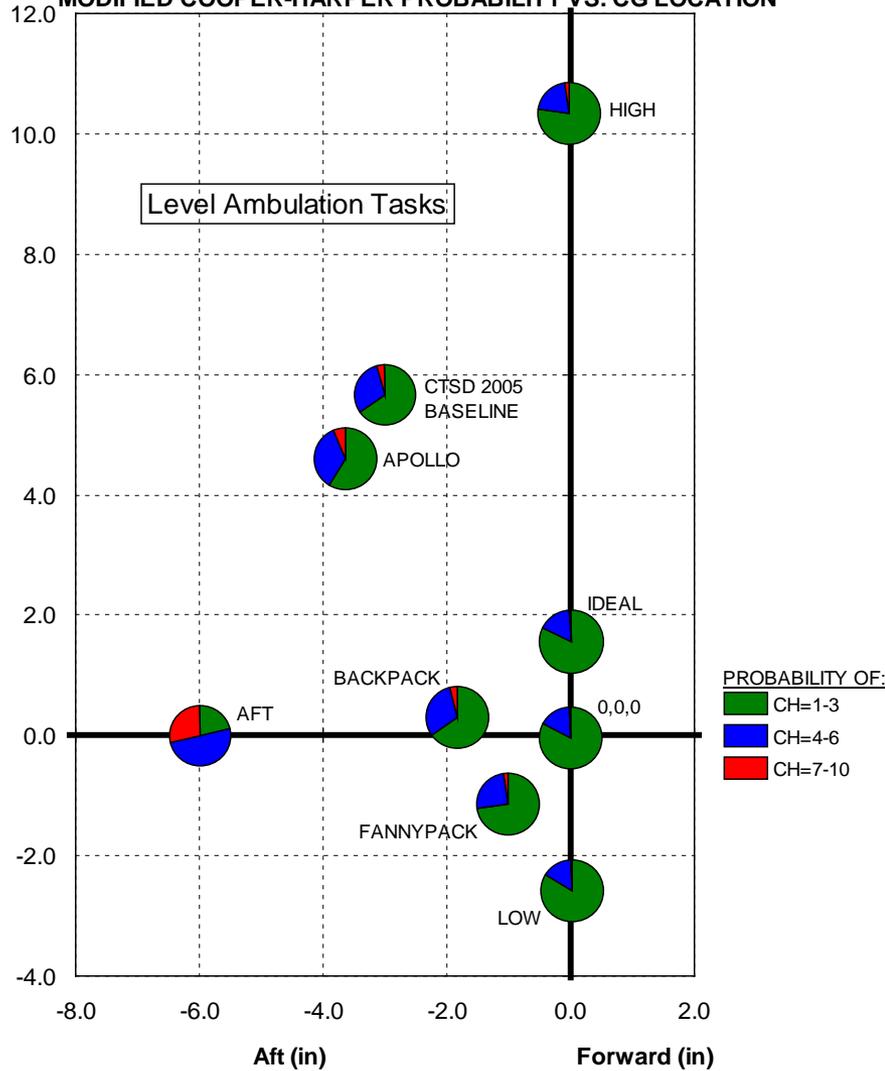
- Level walk/jog/run
 - Walk 20 feet (one foot always on the ground)
 - Jog 20 feet (slowest speed with both feet off the ground)
 - Run 20 feet
 - Preferred ambulation
- Ramp incline / decline
 - 6 CGs (ideal, low, forward, high, aft, baseline)
 - 30 , 25 , 20 , 15 , 10
- Exploration tasks
 - Kneel & recovery
 - Fall & recovery (forward)
 - Shoveling activity
 - Rock pickup
 - Ladder climb



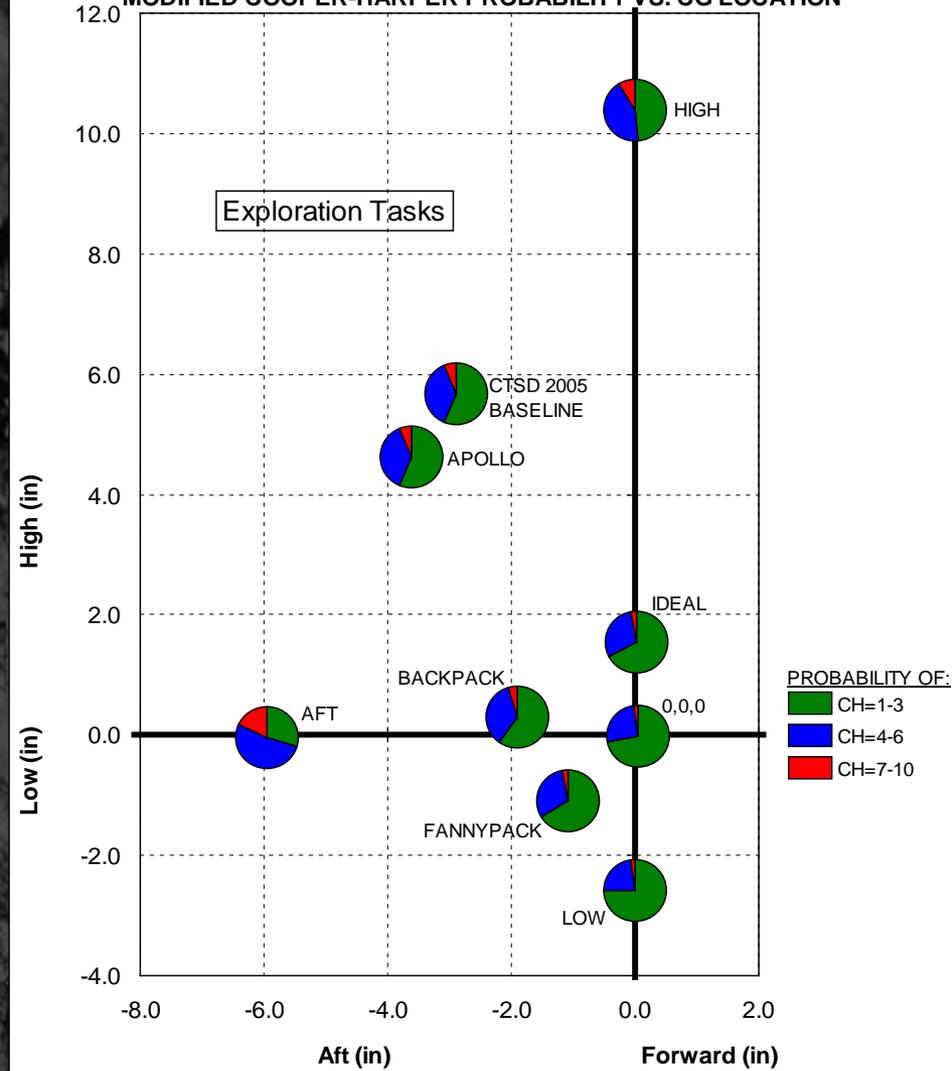
NEEMO/NBL Cooper-Harper Probabilities vs. CG Location



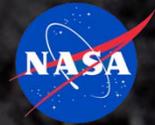
MODIFIED COOPER-HARPER PROBABILITY VS. CG LOCATION



MODIFIED COOPER-HARPER PROBABILITY VS. CG LOCATION



Recent/Ongoing Tests



- Shirt-sleeve IST-3
 - CG test on POGO to validate NEEMO/NBL results



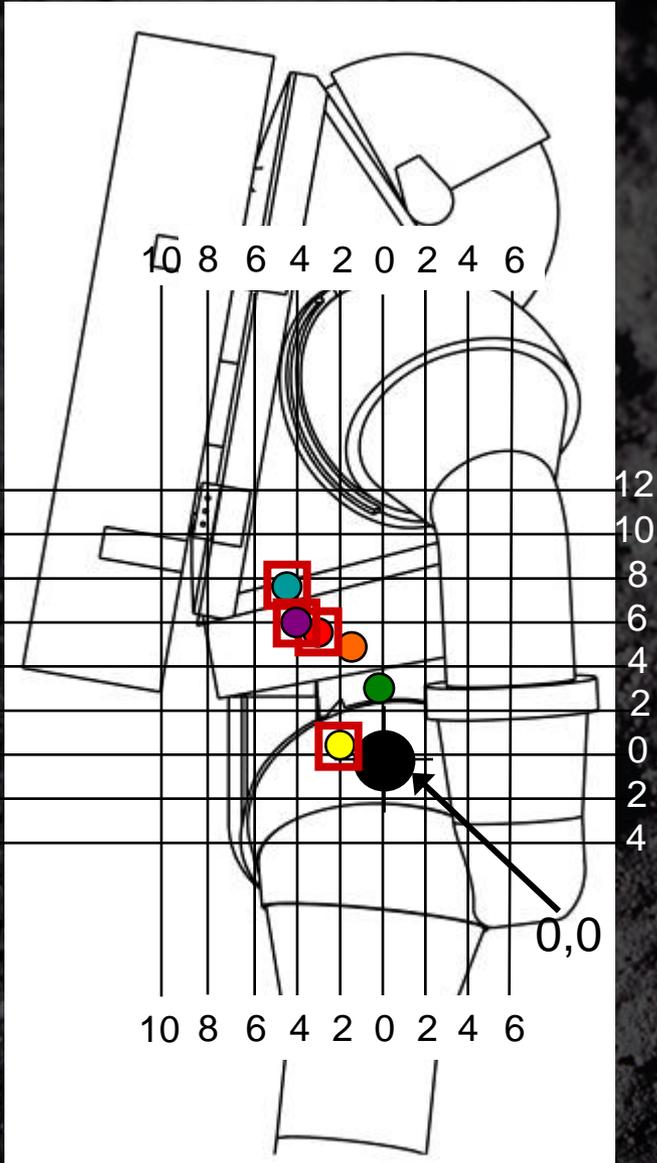
- Integrated Parabolic Flight Test 1
 - Suited MKIII test varying mass and weight for comparison to POGO results



Integrated Studies - Center of Gravity Locations



IST-3 Shirt-Sleeve rig CG locations



Previously Tested Cases at NEEMO/NBL

- 2005 Baseline 2.98" aft / 5.65" high (330, 400 lbs)
- Flex Pack Backpack 1.90" aft / 0.40" high (400 lbs)
- 0,0 0.0" aft / 0.0" high

Previously Tested Cases at EWT/IST-1

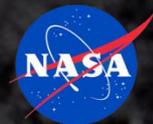
- Pogo System 4.41" aft / 7.93" high (330, 400 lbs)

Other achievable CG's:

- Mk III w/ PLSS mockup, C9 CG rig, stowed arms, no lead weights 3.53" aft / 5.84" high (265 lbs)
- Mk III (AI HUT/hatch) 0.3" aft / 2.9" high (155 lbs)
- Mk III w/ PLSS mockup 1.5" aft / 4.7" high (195 lbs)

These CG locations are being assessed in parabolic flight tests

C-9 Study Design

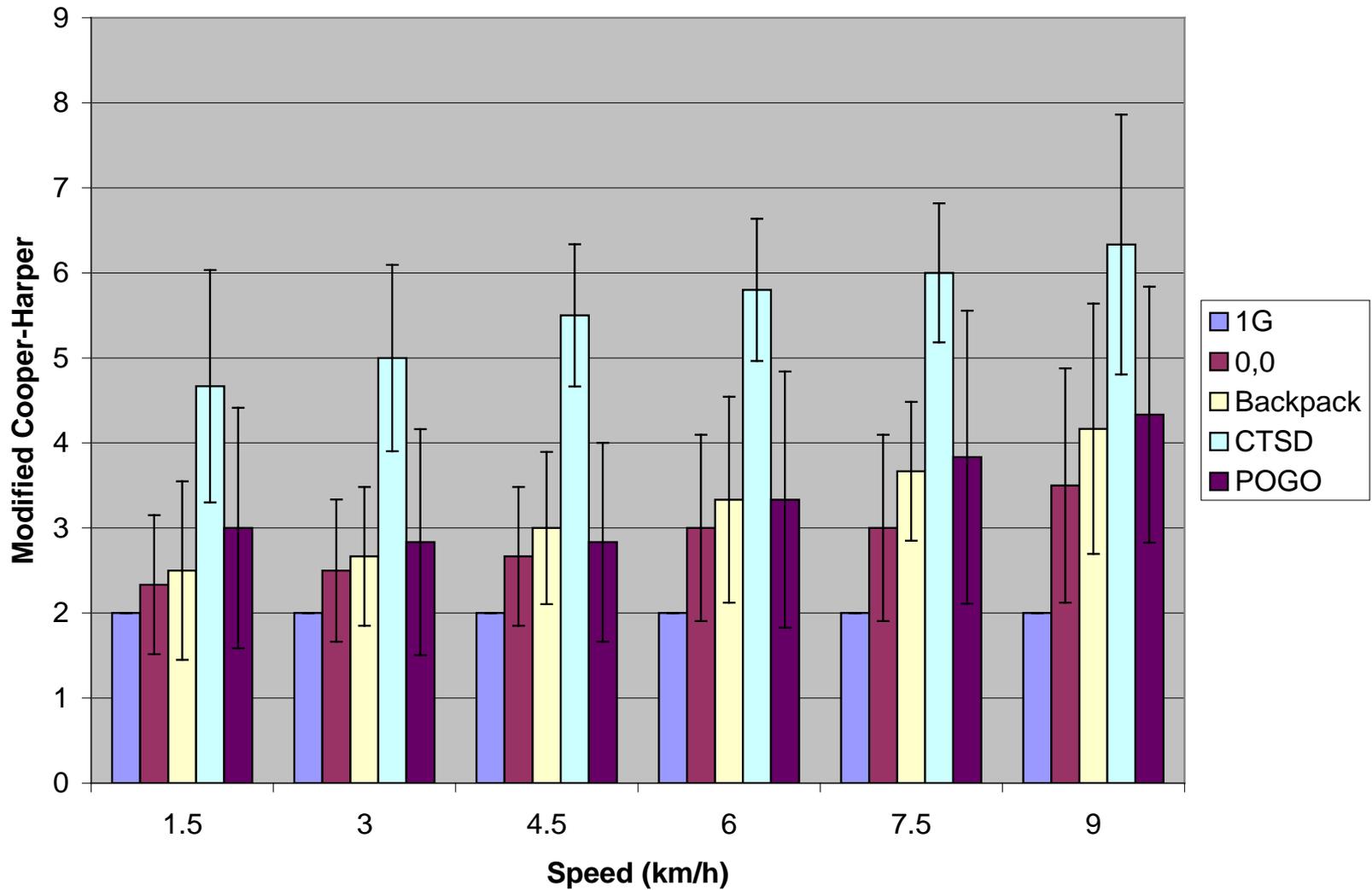


		<u>Trial 1</u>	<u>Trial 2</u>	<u>Trial 3</u>
Varied Mass Testing	Suit Mass	195 lb	265 lb	400 lb
	Gravity	0.17g	0.17g	0.17g
	1g Suit Weight	195 lb	265 lb	400 lb
	CG	CTSD (almost)	CTSD/POGO	CTSD
Varied Weight Testing	Suit Mass	265 lb	265 lb	265 lb
	Gravity	0.1g	0.17g	0.3g
	1g Suit Weight	~ 87 lb	265 lb	~ 620 lb
	CG	CTSD/POGO	CTSD/POGO	CTSD/POGO
Varied CG Testing	Suit Mass	400 lb	400 lb	400 lb
	Gravity	0.17g	0.17g	0.17g
	1g Suit Weight	400 lb	400 lb	400 lb
	CG	Backpack	CTSD	POGO



} Denotes same condition across tests

Preliminary IST-3 Shirt-Sleeve Results





Integrated Tests Next Steps

- Integrated Parabolic Flight Test 2
 - Run added mass trials w/ Mk-III
 - Perform modified CG trials
- Complete exploration trials of shirt-sleeve IST-3 on POGO
- Compare results across environments
- Other follow-on tests in planning stages
 - Rear-Entry I (REI) suit testing parabolic flight to test effects of a different suit
 - REI suit testing on POGO/ARGOS (Active Response Gravity Offload System)
 - Other suited and unsuited testing on ARGOS
 - NEEMO 14
 - Desert RATS 2009
- Make requirements recommendations for achieving desired suited performance