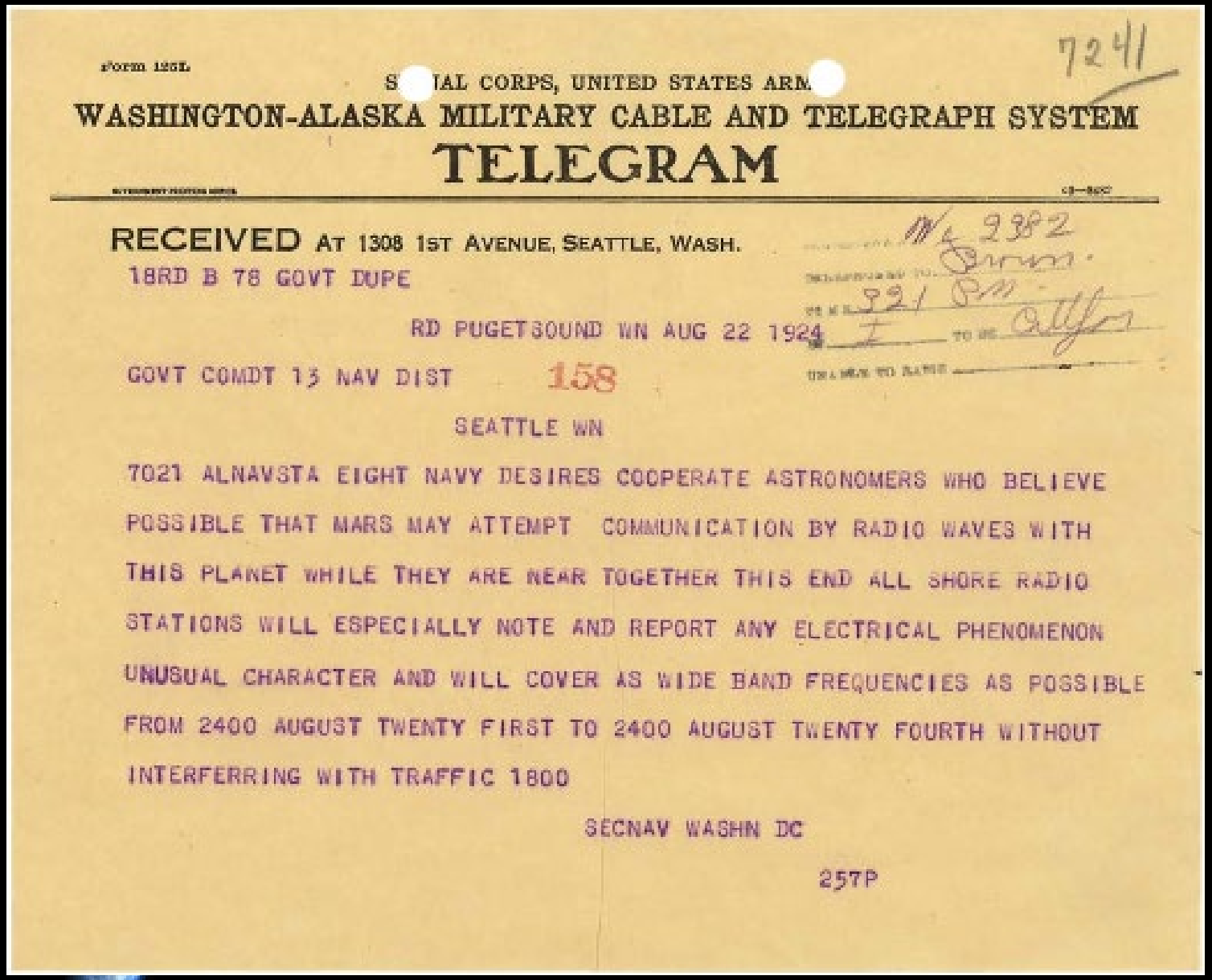
Tasks, Skills, and Abilities for the First Human Expeditions to Mars

Steering Committee for a Science Strategy for the Human Exploration of Mars

National Academies of Science, Engineering, and Medicine
Arnold and Mabel Beckman Center, Irvine, California
27 August 2024

Jack Stuster, PhD, CPE

Santa Barbara, California



Form 125L

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TELEGRAM

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7021 ALNAVSTA EIGHT NAVY DESIRES COOPERATE ASTRONOMERS WHO BELIEVE POSSIBLE THAT MARS MAY ATTEMPT COMMUNICATION BY RADIO WAVES WITH THIS PLANET WHILE THEY ARE NEAR TOGETHER THIS END ALL SHORE RADIO STATIONS WILL ESPECIALLY NOTE AND REPORT ANY ELECTRICAL PHENOMENON UNUSUAL CHARACTER AND WILL COVER AS WIDE BAND FREQUENCIES AS POSSIBLE FROM 2400 AUGUST TWENTY FIRST TO 2400 AUGUST TWENTY FOURTH WITHOUT INTERFERRING WITH TRAFFIC 1800

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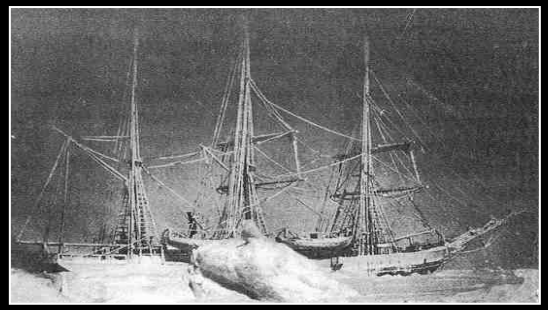
Astronomer David Todd and the “Big Listen,” 22 – 24 August 1924.

Previous Research

- Human Factors Review of Orbiter Turnaround Procedures (Rockwell International, 1982)
- Space Station Analog Study (NASA, 1985)
- HABEMSI Study Team (ESA, 1991-1992)
- Lunar/Mars Expedition Analog Study (NASA, 1996)
- Analysis of French Diaries (NASA, TAAF, ESA, 1998)
- Expedition Corps Training (NASA, 1999)
- Journals Flight Experiment (NASA, 2003 – 2019)
- Behavioral Core Measures Study (NASA, 2015 – 2023)
- Tasks/Skills/Abilities for Mars Exploration (NASA, 2015 - 2019)

Isolation and Confinement

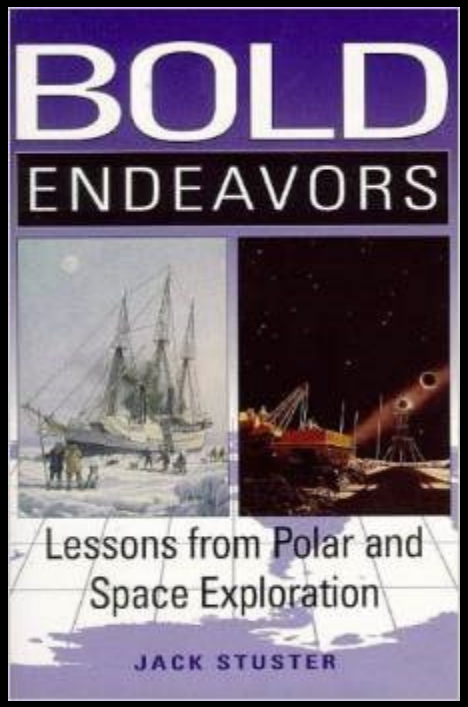


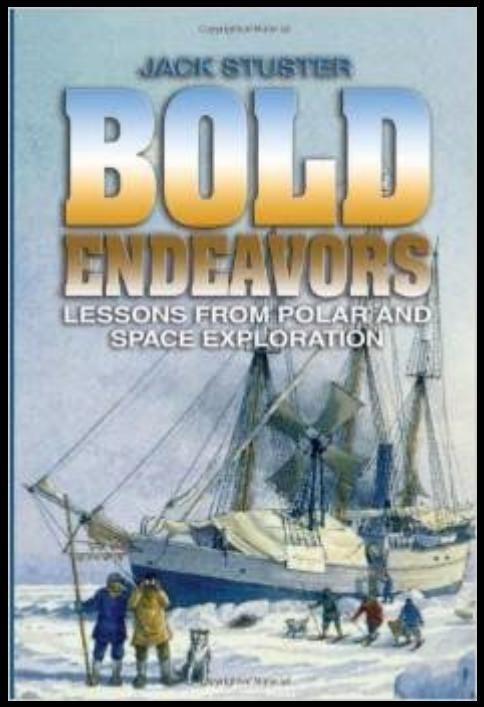
Isolation and Confinement

Expeditions and polar winter-over experiences resemble in many ways the conditions of isolation and confinement that will be experienced by future space travelers and those who will live and work at lunar and Martian outposts.

The details will be different, but most of the problems that will confront future space explorers are the same problems that troubled explorers in the past.

Isolation and Confinement





Hardcover (1997)

Paperback (2011)

Project Purpose

This study addresses the Risk of Inadequate Mission, Process, and Task Design and the Risk of Performance Errors Due to Training Deficiencies by identifying the work that will be performed during an expedition to Mars and the abilities, skills, and knowledge that will be required of crew members.

Conducted For: The Human Factors & Behavioral Performance (HFBP) Element.

Image: Earth and Moon from HiRISE near Mars.

Project Purpose

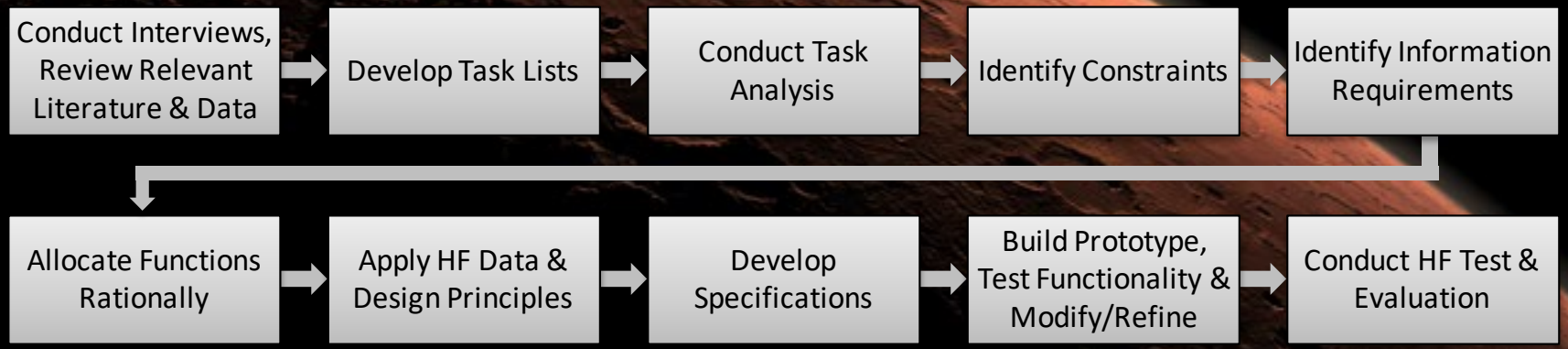
Would you design a garment without knowing under what conditions it will be worn?

Would you design a building without knowing its purpose?

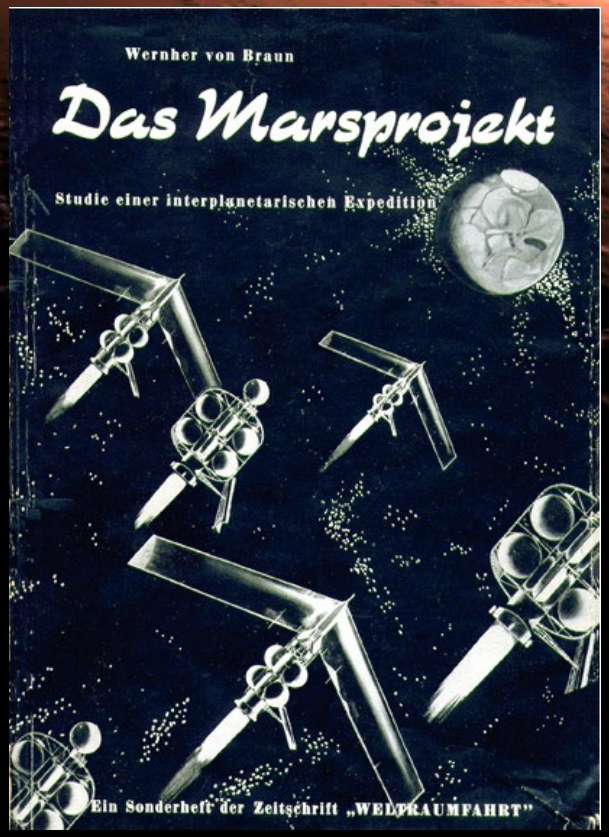
Would you select crew members without knowing the tasks they must perform?

Of course not…

Human Factors Method

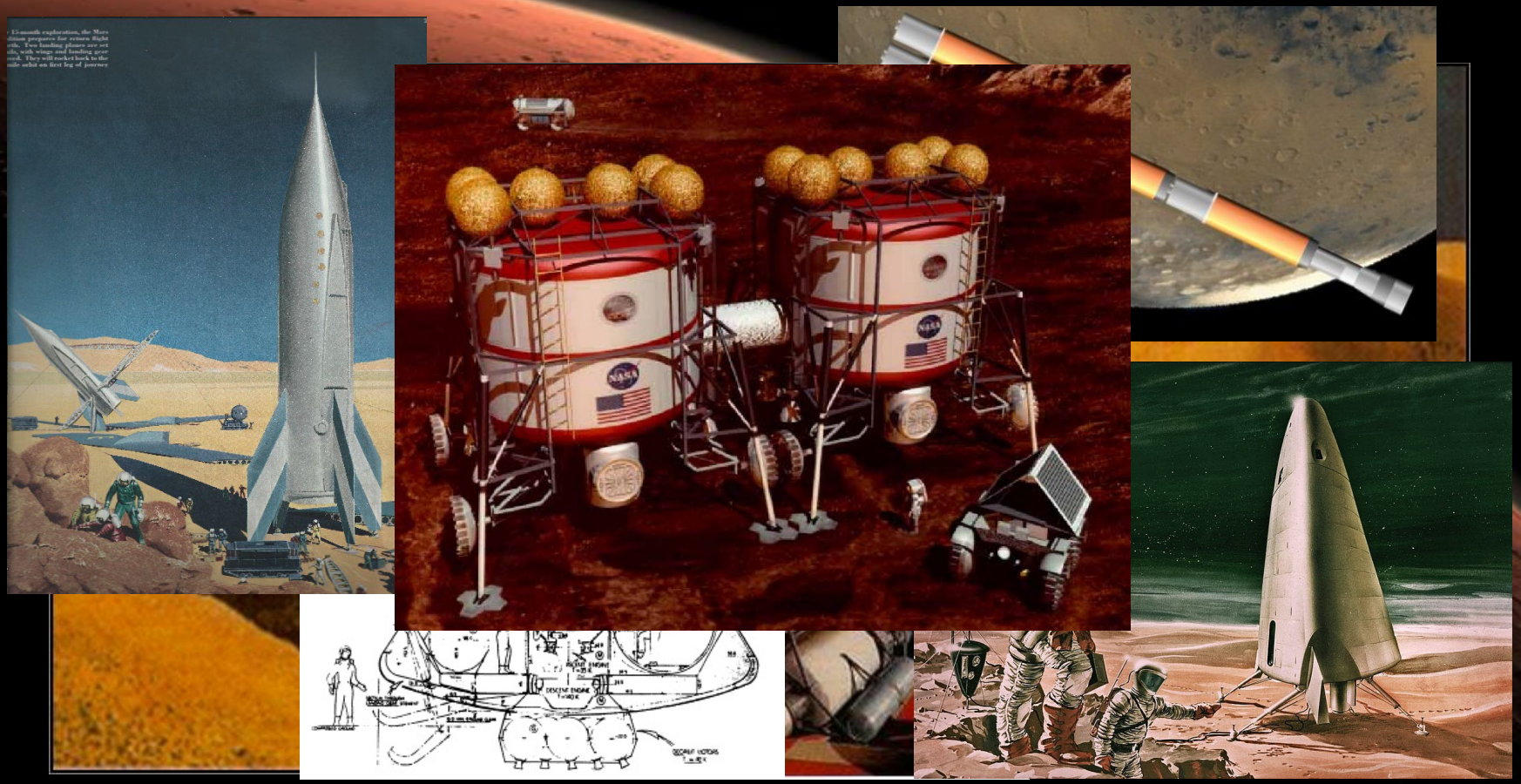


Mars Mission Plans



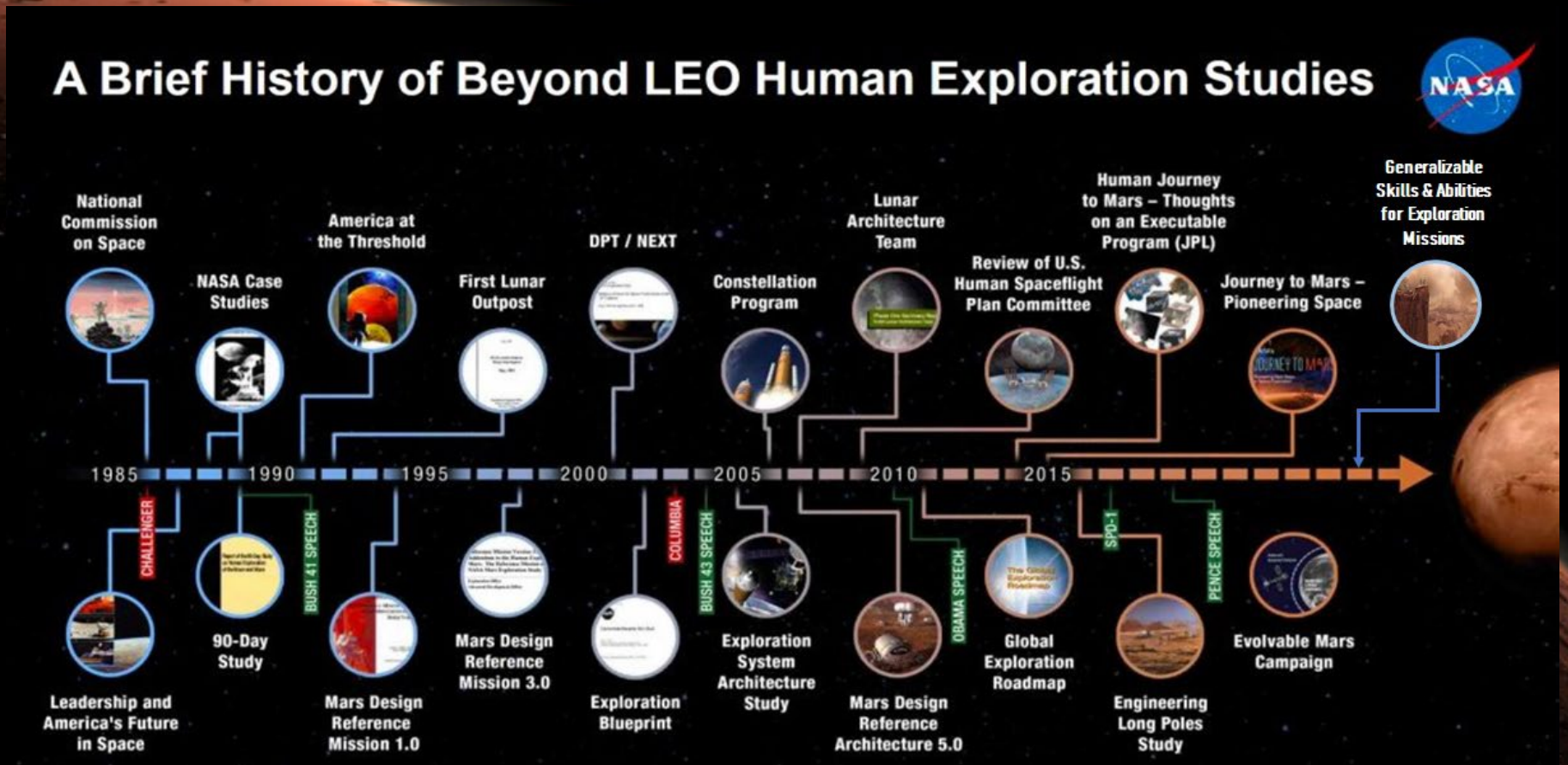
Our review began with von Braun's *The Mars Project*, 1952.

Mars Mission Plans



Review included all major mission plans, reference missions, and other sources.

Mars Mission Plans



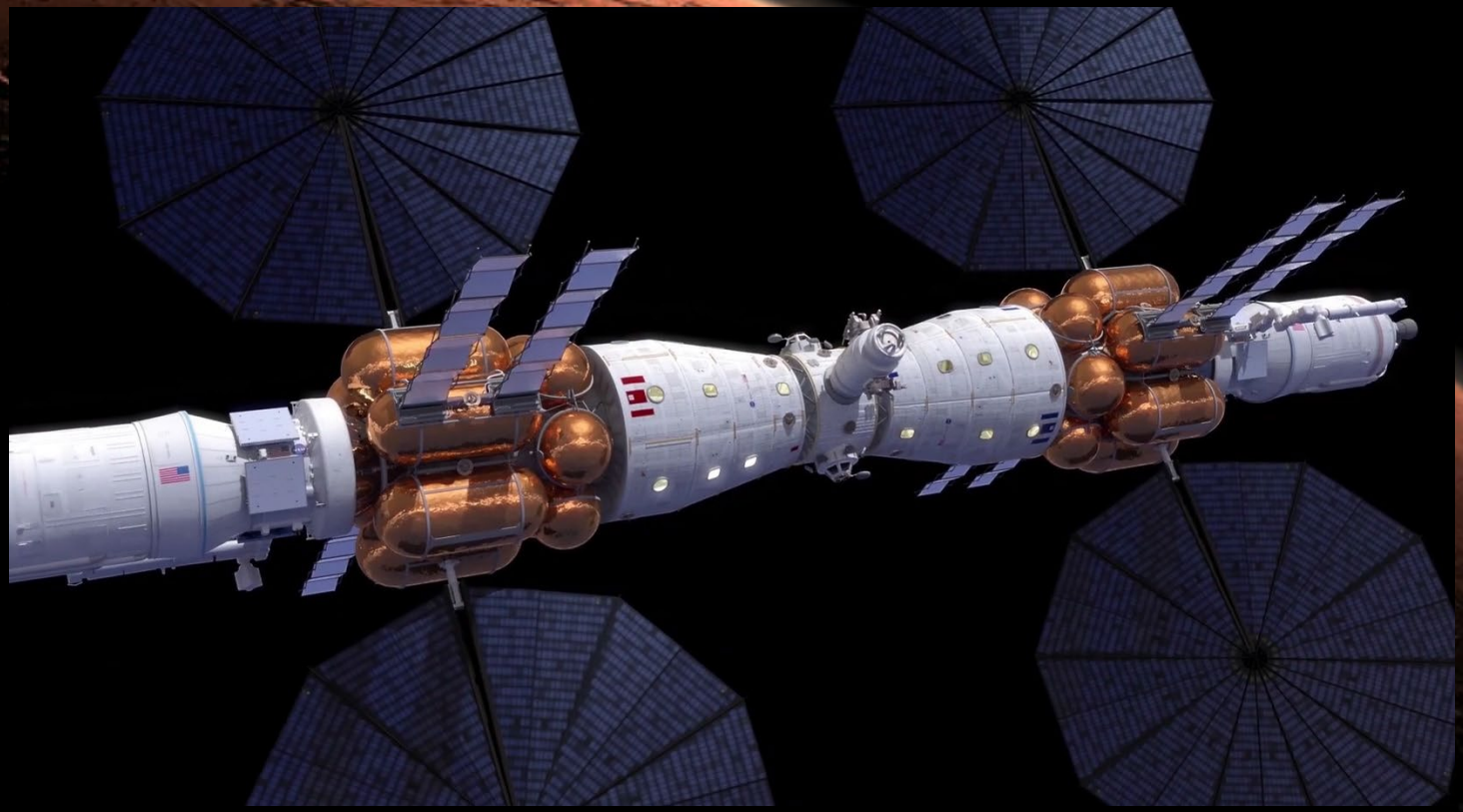
Review included all major mission plans, reference missions, and other sources.

Assumptions

- Conjunction-class;
- 12 mission phases;
- 6-month Cruise to Mars;
- 500-day Surface Operations;
- Communications Lag/Autonomous;
- 6-month Cruise to Earth followed by;
- 5-day Earth Approach and Direct Descent.

Launch
Trans-Mars Injection
Cruise to Mars
Mars Orbit Injection
Mars Orbit
Mars Surface Descent
Mars Surface Operations
Mars Surface Ascent
Trans-Earth Injection
Cruise to Earth
Earth Approach
Earth Surface Descent

Key Mission Phases



Mars Transit (Cruise)

Key Mission Phases

Mars Surface Descent

Key Mission Phases

Mars Surface Operations

Key Mission Phases

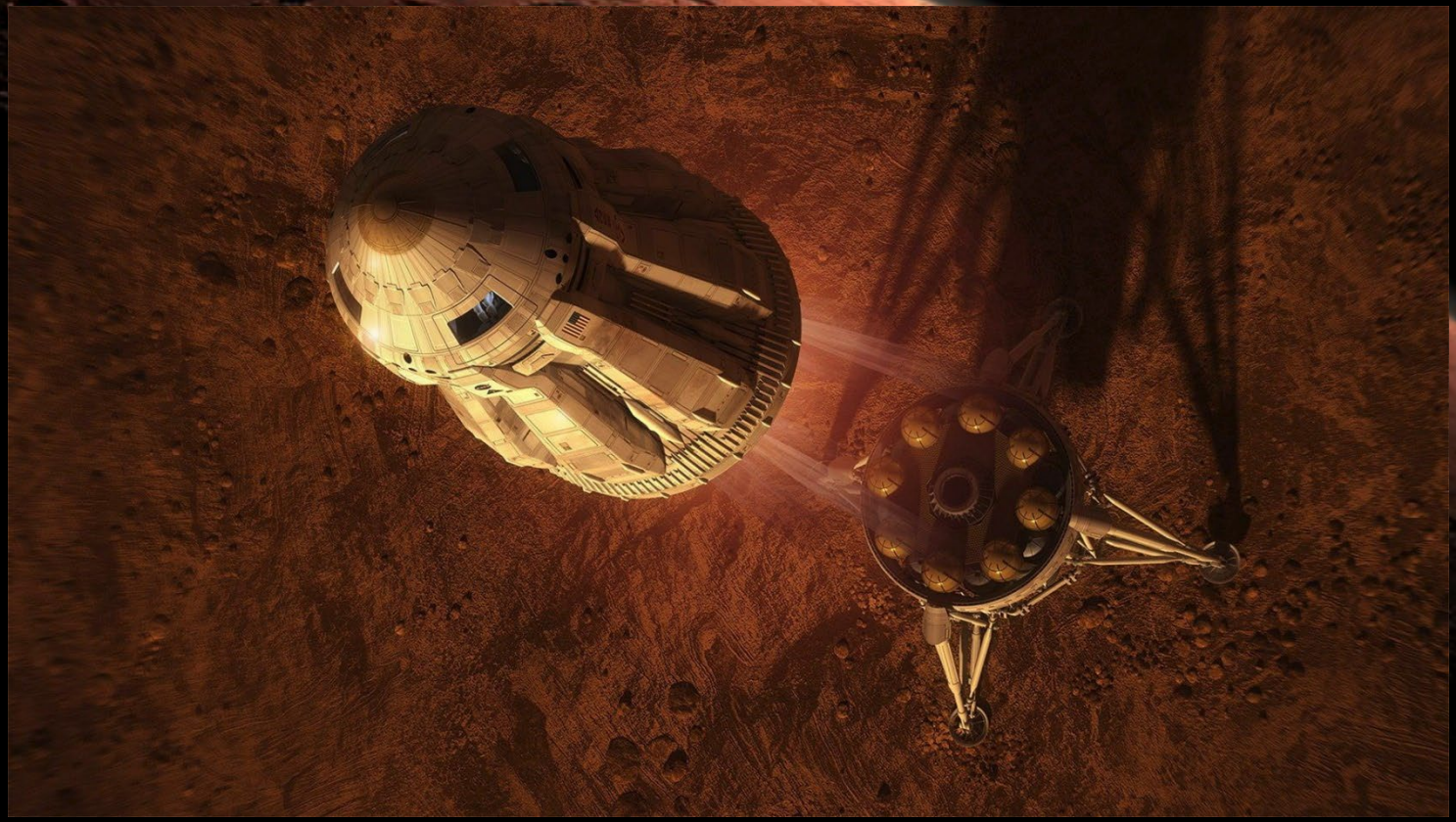
Mars Surface Operations

Key Mission Phases

"Weather affects everything." – Douglas Mawson, Explorer/Scientist

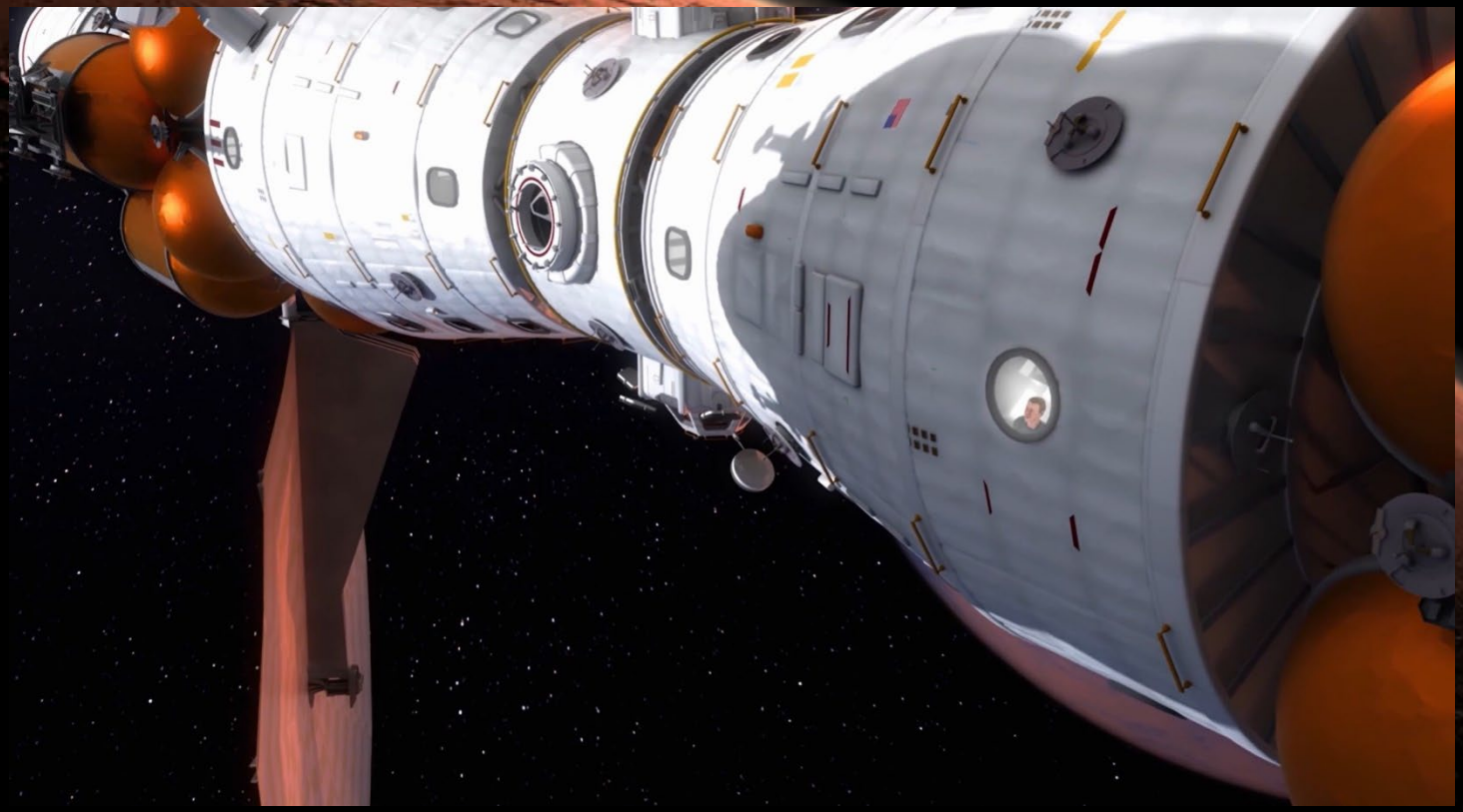
Mars Surface Operations

Key Mission Phases



Mars Surface Ascent

Key Mission Phases



Earth Transit (Cruise)

Key Mission Phases

"All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months."

- Valery Ryumin, Cosmonaut

Imagine living in a motor home with five other people for six months, followed by 18 months in a cabin on Mars. You may go outside occasionally, but must wear a space suit. Then, there is the six-month trip home in the motor home.

An expedition to Mars would be a lot like this.

Now imagine…

Key Mission Phases

		Conjunction Class (DRA-5)				
		Outbound	Surface	Return	Total Days	
	Days	180	545	180	905	Expect
	Incidence				Behavioral	In Crew of
Risk Factor/Definition	per 365 days				Risk	6
Serious Behavioral Problem	0.060	0.030	0.090	0.030	0.149	0.893
Differential	0.020	0.030	0.030	0.030	0.089	0.534

		New DRA (in progress)				
		Outbound	Surface	Return	Total Days	
	Days	350	300	350	1000	Expect
	Incidence				Behavioral	In Crew of
Risk Factor/Definition	per 365 days				Risk	6
Serious Behavioral Problem	0.060	0.058	0.049	0.058	0.164	0.986
Differential	0.020	0.058	0.016	0.058	0.132	0.789

Task Example

Adjust attitude control thrusters, manually wearing pressure suit/gloves, to dock Earth Ascent Vehicle (EAV) to space craft in LEO/CLO.

Task statements are formatted systematically to eliminate syntax as a variable.

Task Example

Walk on planetary surface while carrying hand tools and wearing surface EVA suit to conduct geological research.

Some tasks have human performance implications.

Task Example

Dig loose regolith from around surface rover wheel, manually using shovel while wearing surface EVA suit, to regain traction to proceed.

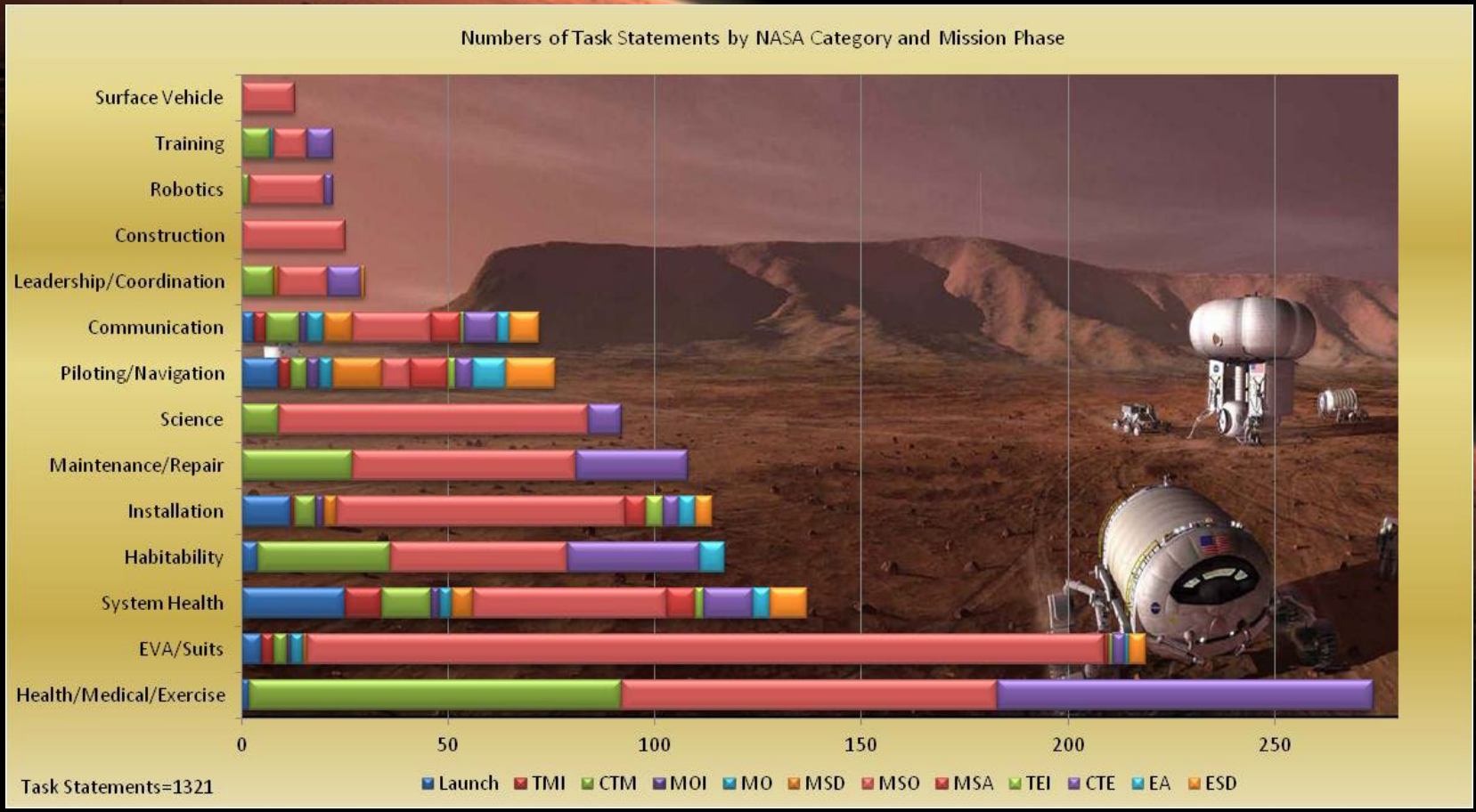
Some tasks have design implications (e.g., flexible surface EVA suits).

Task Example

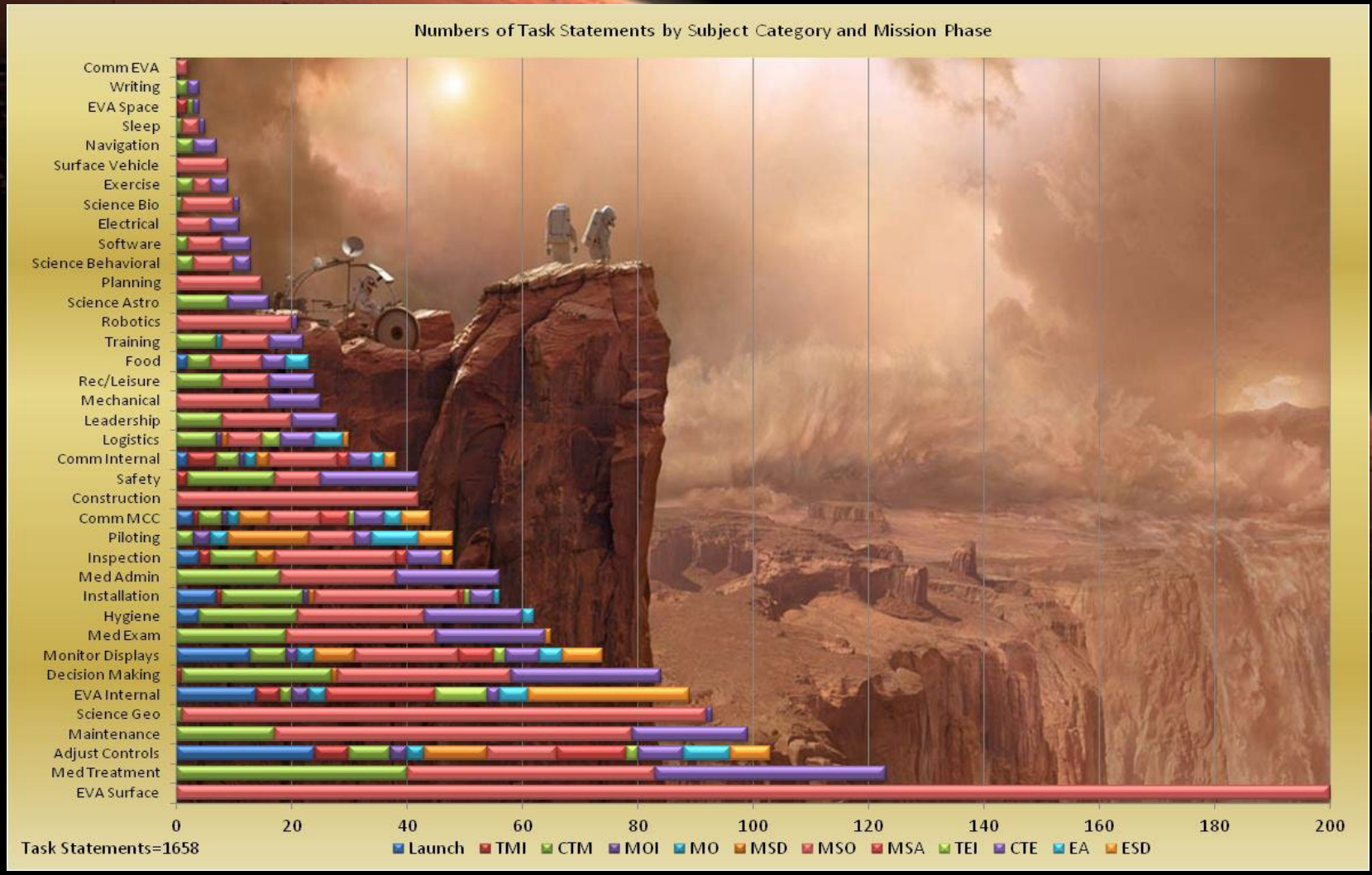
Use space craft waste management system for solid waste (i.e., toilet/bodily function).

Some tasks have procedural implications.

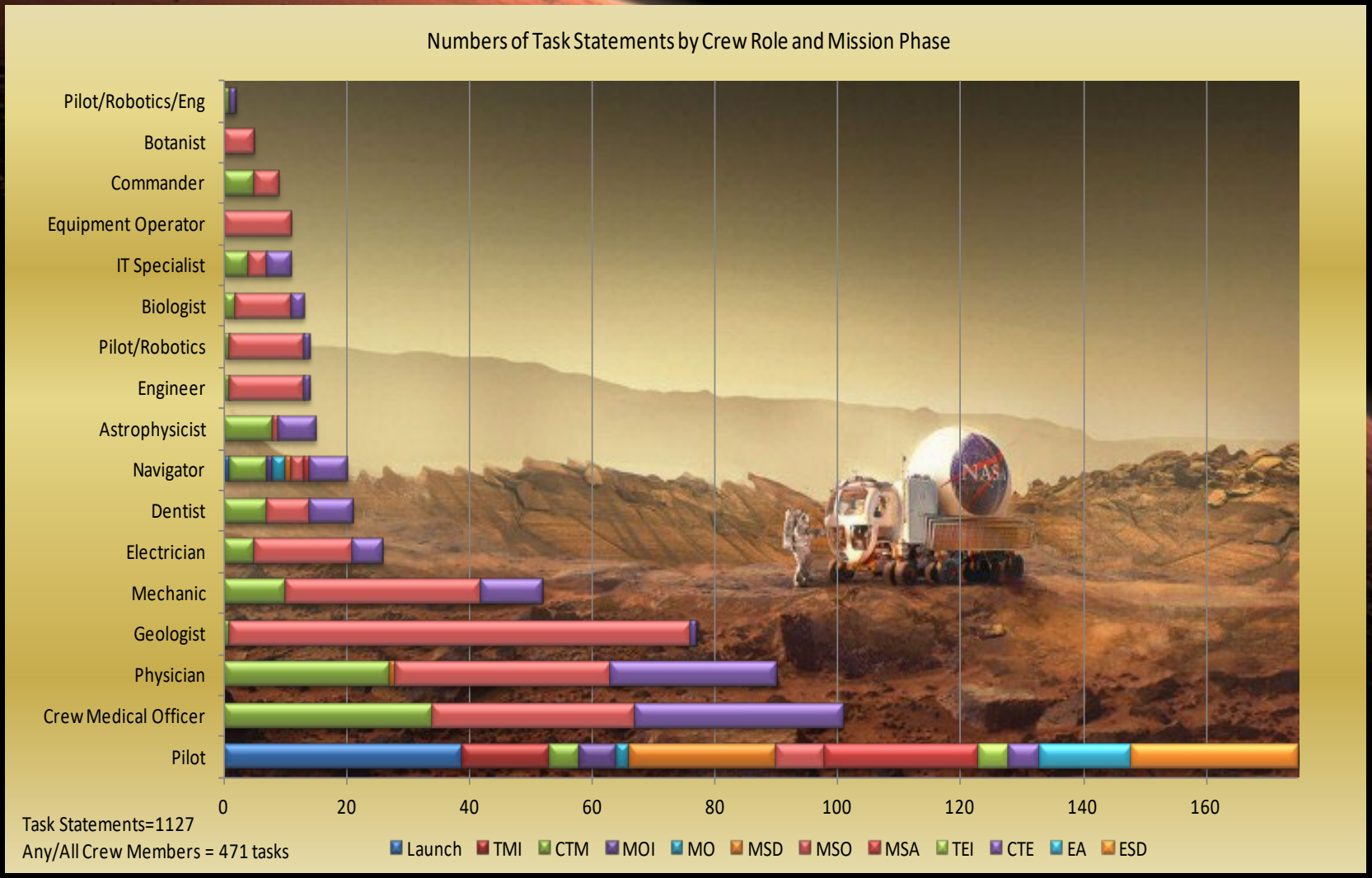
Task Analysis



Task Analysis



Task Analysis



Task Analysis

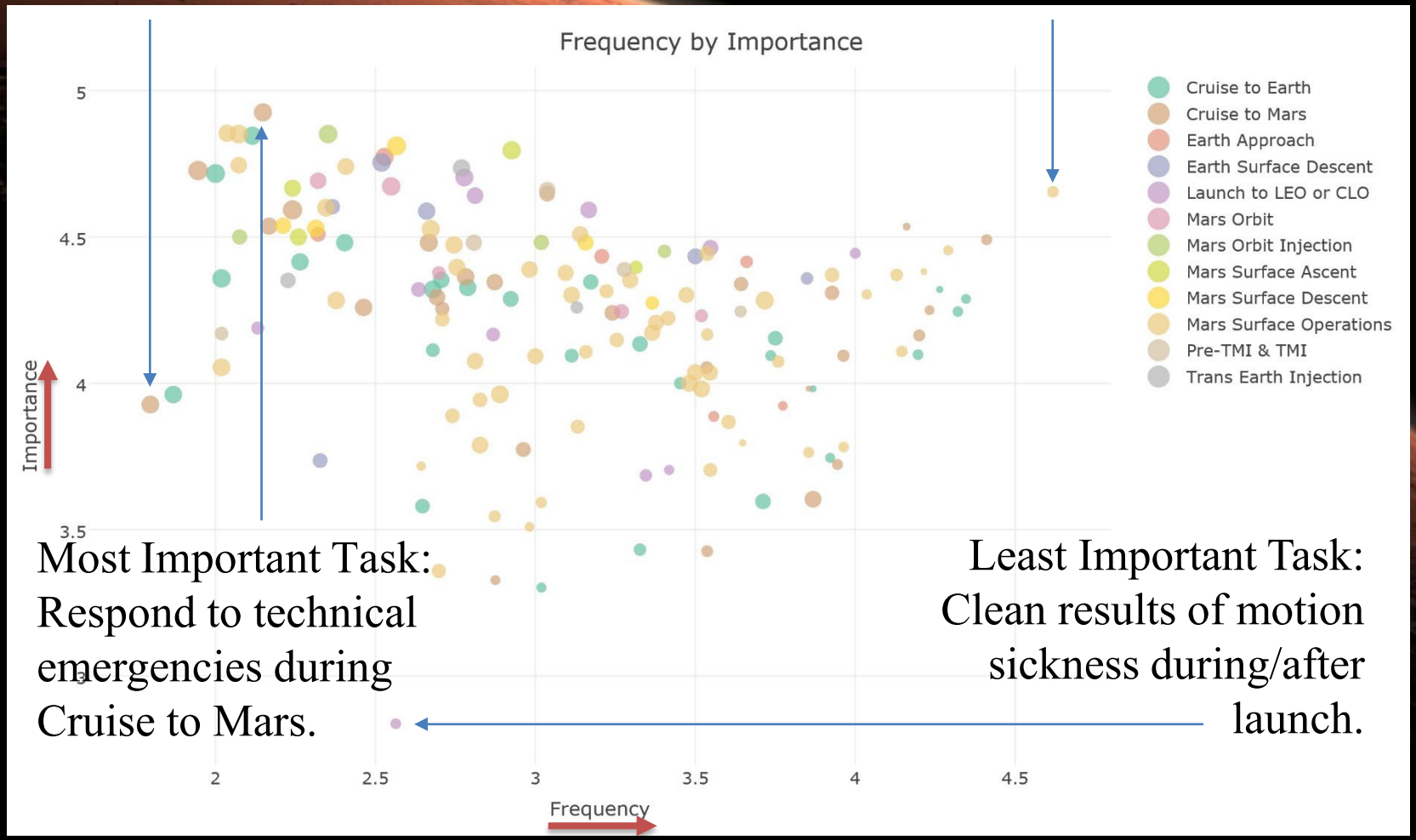
Task #	Task	*How frequently is the task performed?*					*How difficult is it to learn the task?*					*How important is the task to mission success?*				
		Not at all	--	--	--	Very	Not at all	--	--	--	Very	Not at all	--	--	--	Very
25	**Perform surface rover maintenance functions during Mars Surface Operations.**	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Remove accumulated dust from surface rover windows, manually while wearing surface EVA suit, to maintain optimal visibility.	*Comments?*														
	Conduct troubleshooting, manually/visually using schematics, procedures, and hand tools while wearing surface EVA suit, to identify fault in surface rover.															
	Remove/replace faulty component/connector manually/visually using hand tools and spare parts while wearing surface EVA suit to restore surface rover to operation.															

Example from the task-rating form completed by 60 SMEs.

Task Analysis

Least Frequent Task: Respond to dental emergencies during Cruise to Mars.

Most Frequent Task: Communicate with other crew members during Mars Surface Operations.



Most Important Task: Respond to technical emergencies during Cruise to Mars.

Least Important Task: Clean results of motion sickness during/after launch.

Dot Color = Mission Phase
Dot Size = Difficulty

The positions and values reflect internal validity of study results.

Crew Roles

The task analysis identified 8 primary crew specialties/roles and 4 ancillary crew roles:

- CMO
- Botanist
- Astrophysicist
- Equipment Operator

- Leader
- Biologist
- Geologist
- Physician
- Electrician
- Pilot/Navigator
- Mechanic/Engineer
- Computer Specialist

Objective: Develop cross-training and/or personnel-selection strategies to achieve a crew size of 5 or 6 astronauts.

Difficulty to Learn

Functional Category	Number of Task Statements
Medical	13
Piloting	12
EVA	5
Technical	2

	Summary Task Statement	Frequency	Difficulty	Importance	Criticality	Function
1	Respond to medical emergencies, following procedures and with equipment provided, during Cruise to Mars (CTM).	1.948	4.509	4.724	11.181	Medical
2	Conduct Extra-Vehicular Activity (EVA) to perform maintenance or retrieve items from outside the interplanetary space vehicle during Cruise to Mars.	2.246	4.491	4.596	11.333	EVA
3	Perform piloting functions during Mars Surface Descent.	2.589	4.375	4.821	11.786	Piloting
4	Respond to medical emergencies, following procedures and with equipment provided, during Cruise to Earth.	2.000	4.327	4.696	11.024	Medical
5	Perform piloting functions during Earth Descent.	2.545	4.268	4.750	11.563	Piloting
6	Respond to medical emergencies, following procedures and with equipment provided, during Mars Surface Operations (MSO).	2.069	4.263	4.825	11.157	Medical
7	Perform piloting functions during Mars Orbit Injection.	2.386	4.246	4.860	11.491	Piloting
8	Perform piloting functions during Mars Orbit operations	2.556	4.241	4.691	11.487	Piloting
9	Conduct EVA to perform maintenance or retrieve items from outside the interplanetary space vehicle during Cruise to Earth.	2.036	4.196	4.357	10.589	EVA
10	Monitor systems and perform piloting functions during Mars Surface Ascent.	2.912	4.158	4.807	11.877	Piloting
11	Perform piloting functions during Earth Approach.	2.518	4.107	4.786	11.411	Piloting
12	Perform medical diagnoses and evaluations, cognitively, during Cruise to Mars.	2.649	4.055	4.491	11.195	Medical
13	Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Mars.	2.109	4.055	4.818	10.982	Technical
14	Perform medical diagnoses and evaluations, cognitively, during Mars Surface Operations.	2.690	4.053	4.517	11.260	Medical
15	Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Mars.	2.140	4.053	4.930	11.123	Technical
16	Perform science-related EVA functions during Mars Surface Operations.	3.679	4.036	4.286	12.000	EVA
17	Enter control inputs, manually/visually with gloved hand, to pilot Earth Ascent Vehicle (EAV) during launch and cruise to LEO/CLO.	2.772	4.000	4.702	11.474	Piloting
18	Perform medical treatments during Mars Surface Operations.	2.328	3.965	4.586	10.879	Medical
19	Perform science-related EVA functions with heavy equipment during Mars Surface	2.877	3.964	3.946	10.788	EVA
20	Perform medical diagnoses and evaluations, cognitively, during Cruise to Earth	2.696	3.964	4.321	10.981	Medical
21	Respond to dental emergencies, following procedures and with equipment provided, during Cruise to Mars.	1.807	3.947	3.948	9.703	Medical
22	Conduct piloting functions during Cruise to Mars.	2.509	3.930	4.298	10.737	Piloting
23	Respond to dental emergencies during Mars Surface Operations.	2.018	3.929	4.052	9.998	Medical
24	Perform construction-related EVA functions with heavy equipment during MSO.	2.375	3.911	4.286	10.571	EVA
25	Perform post-Mars Descent maneuver functions.	2.333	3.907	4.556	10.796	Piloting
26	Monitor systems and perform piloting functions during Trans Earth Injection.	2.800	3.893	4.732	11.425	Piloting
27	Respond to dental emergencies, following procedures and with equipment provided, during Cruise to Earth.	1.875	3.891	3.964	9.730	Medical
28	Perform tests and examinations, physically, to support medical diagnoses during Cruise to Mars.	2.759	3.877	4.362	10.998	Medical
29	Adjust system controls, manually during buffetted descent, in response to displayed information.	2.673	3.870	4.585	11.128	Piloting
30	Perform medical treatments during Cruise to Earth.	2.273	3.870	4.436	10.579	Medical
31	Perform tests and examinations, physically, to support medical diagnoses during Mars Surface Operations.	2.741	3.860	4.483	11.084	Medical
32	Conduct piloting functions during Cruise to Earth.	2.407	3.852	4.500	10.759	Piloting

Medical
EVA
Piloting
Technical

Frequency

	Summary Task Statement	Frequency	Difficulty	Importance	Criticality	Function
1	Interact/communicate with other crew members directly during Mars Surface Operations (MSO).	4.638	2.298	4.672	11.609	Comms
2	Exercise daily using onboard equipment during Cruise to Mars (CTM).	4.390	2.179	4.500	11.068	Exercise
3	Prepare/eat meal, manually, using interplanetary space vehicle food hydration/heating equipment/galley during Cruise to Earth (CTE).	4.345	1.963	4.291	10.599	Habitability
4	Prepare and consume meals in surface habitat during MSO.	4.293	1.982	4.466	10.741	Habitability
5	Exercise daily using onboard equipment during Cruise to Earth.	4.286	2.073	4.232	10.591	Exercise
6	Sleep for approximately 8 hours each 24-hour period during CTE.	4.250	1.545	4.321	10.117	Habitability
7	Prepare/eat meal, manually, using interplanetary space vehicle food hydration/heating equipment/galley during Cruise to Mars.	4.237	1.982	4.254	10.474	Habitability
8	Sleep for approximately 8 hours each 24-hour period during MSO.	4.203	1.483	4.397	10.083	Habitability
9	Use interplanetary space vehicle waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Cruise to Earth.	4.185	2.113	4.093	10.391	Habitability
10	Use interplanetary space vehicle waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Cruise to Mars.	4.172	2.375	4.172	10.720	Habitability
11	Sleep for approximately 8 hours each 24-hour period during CTM.	4.153	1.621	4.542	10.316	Habitability
12	Use surface habitat waste management systems for liquid/solid waste (i.e., toilet/bodily function) during Mars Surface Operations.	4.138	2.281	4.103	10.522	Habitability
13	Conduct communications checks/communicate observations/evaluations to crew/MCC, verbally using communications system during MSO.	4.123	2.500	4.368	10.991	Comms
14	Perform exercise in surface habitat to maintain cardiovascular, muscle, and bone conditioning during Mars Surface Operations.	4.017	2.035	4.322	10.374	Exercise
15	Conduct communications checks/communicate observations/evaluations to crew/MCC verbally using communications system during CTM.	3.982	2.429	4.107	10.518	Comms
16	Conduct communications checks/communicate observations/evaluations to crew/MCC, verbally using comms system, during Launch to Orbit.	3.965	2.158	4.421	10.544	Comms
17	Use surface habitat hygiene systems for cleaning during MSO.	3.948	2.105	3.793	9.847	Habitability
18	Use interplanetary space vehicle hygiene systems for cleaning during CTM.	3.947	2.161	3.719	9.827	Habitability
19	Use interplanetary space vehicle hygiene systems for cleaning during CTE.	3.926	2.000	3.759	9.685	Habitability
20	Perform monitoring functions in surface habitat or modules to ensure crew and system health during Mars Surface Operations.	3.897	3.000	4.386	11.283	Monitoring
21	Monitor systems to ensure proper functioning during Cruise to Mars.	3.897	2.983	4.328	11.207	Monitoring
22	Conduct communications checks/communicate observations/evaluations to crew and MCC personnel during Earth Surface Descent.	3.855	2.473	4.364	10.691	Comms
23	Conduct recreational activities, individually and as a crew, during CTM.	3.828	1.411	3.966	9.204	Habitability
24	Conduct science and planning functions during Cruise to Mars.	3.821	3.625	3.607	11.054	Planning
25	Conduct recreational activities, individually and as a crew, during CTE.	3.821	1.537	3.982	9.341	Habitability
26	Perform surface habitat housekeeping functions during MSO.	3.810	2.158	3.759	9.727	Habitability
27	Prepare/eat meals during Earth Approach.	3.786	1.907	3.945	9.639	Habitability
28	Monitor systems to ensure proper functioning during Cruise to Earth.	3.778	3.074	4.185	11.037	Monitoring
29	Conduct communications checks/communicate observations/evaluations to crew and MCC, verbally using communications system during CTE.	3.768	2.161	4.107	10.036	Comms
30	Perform planning and administrative functions, individually and with other crew members during Mars Surface Operations.	3.754	2.526	4.070	10.351	Planning
31	Conduct science and planning functions during Cruise to Earth.	3.722	3.278	3.593	10.593	Planning
32	Perform science-related EVA functions during Mars Surface Operations.	3.679	4.036	4.286	12.000	EVA

Functional Category	Number of Task Statements
Habitability	16
Communicating	6
Exercise	3
Monitoring	3
Planning	3
EVA	1

Communicate

Habitability

Exercise

Monitoring

Planning

Importance

	Summary Task Statement	Frequency	Difficulty	Importance	Criticality	Function
1	Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Mars.	2.140	4.053	4.930	11.123	Technical
2	Perform piloting functions during Mars Orbit Injection.	2.386	4.246	4.860	11.491	Piloting
3	Perform emergency functions in surface habitat or modules during MSO.	2.052	3.810	4.845	10.707	Technical
4	Respond to medical emergencies, following procedures/with equipment provided, during Mars Surface Operations.	2.069	4.263	4.825	11.157	Medical
5	Perform piloting functions during Mars Surface Descent.	2.589	4.375	4.821	11.786	Piloting
6	Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Earth.	2.109	4.055	4.818	10.982	Technical
7	Monitor systems/perform piloting functions during Mars Surface Ascent.	2.912	4.158	4.807	11.877	Piloting
8	Perform piloting functions during Earth Approach.	2.518	4.107	4.786	11.411	Piloting
9	Perform piloting functions during Earth Descent.	2.545	4.268	4.750	11.563	Piloting
10	Prepare for Mars Surface Ascent during Mars Surface Operations.	2.069	3.586	4.741	10.397	Technical
11	Perform initial installation/activation/inspection of surface habitat systems during Mars Surface Operations.	2.386	3.649	4.737	10.772	Technical
12	Monitor systems/perform piloting functions during Trans Earth Injection.	2.800	3.893	4.732	11.425	Piloting
13	Respond to medical emergencies during Cruise to Mars.	1.948	4.509	4.724	11.181	Medical
14	Configure systems for Mars Orbit operations and descent.	2.321	3.625	4.709	10.656	Technical
15	Enter control inputs, manually/visually with gloved hand, to pilot Earth Ascent Vehicle (EAV) during launch and cruise to LEO/CLO.	2.772	4.000	4.702	11.474	Piloting
16	Respond to medical emergencies, following procedures and with equipment provided, during Cruise to Earth.	2.000	4.327	4.696	11.024	Medical
17	Perform piloting functions during Mars Orbit operations	2.556	4.241	4.691	11.487	Piloting
18	Prepare for Mars Surface Ascent maneuver.	2.263	3.737	4.684	10.684	Technical
19	Interact/communicate with other crew members directly during MSO.	4.638	2.298	4.672	11.609	Comms
20	Assess displayed and aural information, cognitively, to determine appropriate course of action during Cruise to Mars.	3.018	3.298	4.649	10.965	Technical
21	Assess displayed information, cognitively, to determine readiness for TMI	3.018	3.571	4.643	11.232	Technical
22	Enter control inputs, manually/visually with gloved hand, to configure and operate Earth Ascent Vehicle (EAV) before and after launch.	2.821	3.614	4.625	11.060	Piloting
23	Prepare for Earth Surface Descent.	2.370	3.200	4.600	10.170	Technical
24	Conduct Extra-Vehicular Activity (EVA) to perform maintenance or retrieve items from outside the interplanetary space vehicle during Cruise to Mars.	2.246	4.491	4.596	11.333	EVA
25	Perform medical treatments during Mars Surface Operations.	2.328	3.965	4.586	10.879	Medical
26	Adjust system controls, manually during buffetted descent, in response to displayed information.	2.673	3.870	4.585	11.128	Piloting
27	Assess displayed information, cognitively, to determine readiness to launch to LEO/CLO.	3.123	3.632	4.579	11.333	Technical
28	Prepare for Mars Surface Descent maneuver.	2.236	3.527	4.564	10.327	Technical
29	Perform post-Mars Descent maneuver functions.	2.333	3.907	4.556	10.796	Piloting
30	Sleep for approximately 8 hours each 24-hour period during CTM.	4.153	1.621	4.542	10.316	Habitability
31	Perform post-Mars Ascent maneuver functions.	2.286	3.772	4.526	10.584	Piloting
32	Perform medical treatments during Cruise to Mars.	2.158	3.786	4.526	10.470	Medical

Technical
Piloting
Medical

Functional Category	Number of Task Statements
Technical	12
Piloting	12
Medical	5
Communicating	1
Habitability	1
EVA	1

Criticality

	Summary Task Statement	Frequency	Difficulty	Importance	Criticality	Function
1	**Perform science-related EVA functions during Mars Surface Operations (MSO).**	3.679	4.036	4.286	**12.000**	Science EVA
2	Monitor systems/perform piloting functions during Mars Surface Ascent.	2.912	4.158	4.807	11.877	Piloting
3	Perform piloting functions during Mars Surface Descent.	2.589	4.375	4.821	11.786	Piloting
4	**Interact/communicate with crew members directly during MSO.**	**4.638**	2.298	4.672	11.609	Comms
5	Perform piloting functions during Earth Descent.	2.545	4.268	4.750	11.563	Piloting
6	Perform piloting functions during Mars Orbit Injection.	2.386	4.246	4.860	11.491	Piloting
7	Perform piloting functions during Mars Orbit operations	2.556	4.241	4.691	11.487	Piloting
8	Enter control inputs, manually/visually with gloved hand, to pilot Earth Ascent Vehicle (EAV) during launch and cruise to LEO/CLO.	2.772	4.000	4.702	11.474	Piloting
9	Monitor systems/perform piloting functions during Trans Earth Injection.	2.800	3.893	4.732	11.425	Piloting
10	Perform piloting functions during Earth Approach.	2.518	4.107	4.786	11.411	Piloting
11	Assess displayed information, cognitively, to determine readiness to launch to LEO/CLO.	3.123	3.632	4.579	11.333	Piloting
12	Conduct Extra-Vehicular Activity (EVA) to perform maintenance or retrieve items from outside the interplanetary space vehicle during Cruise to Mars.	2.246	4.491	4.596	11.333	EVA
13	Monitor displays/verify configurations before/during launch to LEO/CLO	3.554	3.333	4.439	11.326	Monitoring
14	Monitor systems during Earth Descent.	3.481	3.382	4.436	11.300	Monitoring
15	Perform monitoring functions in surface habitat or modules to ensure crew and system health during Mars Surface Operations.	3.897	3.000	4.386	11.283	Monitoring
16	Enter/exit surface habitat, manually while wearing pressure suit and helmet, during Mars Surface Operations.	3.544	3.246	4.474	11.263	EVA
17	Perform medical diagnoses and evaluations, cognitively, during MSO.	2.690	4.053	4.517	11.260	Medical
18	Perform robot operations-related functions during MSO.	3.527	3.750	3.982	11.259	Robotics
19	Perform geology-related science functions in surface habitat or modules during Mars Surface Operations.	3.491	3.754	4.000	11.245	Science
20	Assess displayed information, cognitively, to determine readiness for TMI.	3.018	3.571	4.643	11.232	Piloting
21	Monitor crew behavioral health/respond to behavioral health issues during Mars Surface Operations.	3.133	3.559	4.517	11.209	Medical
22	Monitor systems to ensure proper functioning during Cruise to Mars.	3.897	2.983	4.328	11.207	Monitoring
23	Perform medical diagnoses/evaluations, cognitively, during Cruise to Mars.	2.649	4.055	4.491	11.195	Medical
24	**Respond to medical emergencies, following procedures and with equipment provided, during Cruise to Mars.**	1.948	**4.509**	4.724	11.181	Medical
25	Perform surface rover piloting/driving functions during MSO.	3.464	3.411	4.304	11.179	Piloting
26	Respond to medical emergencies, following procedures and with equipment provided, during Mars Surface Operations.	2.069	4.263	4.825	11.157	Medical
27	Perform surface EVA physical functions on foot during MSO.	3.298	3.482	4.368	11.149	EVA
28	Adjust system controls, manually during buffeted descent, in response to displayed information.	2.673	3.870	4.585	11.128	Piloting
29	**Respond to technical emergencies, following procedures and with equipment provided, during Cruise to Mars.**	2.140	4.053	**4.930**	11.123	Technical
30	Monitor systems during Mars Surface Descent.	3.148	3.444	4.509	11.102	Piloting
31	Perform tests and examinations, physically, to support medical diagnoses during Mars Surface Operations.	2.741	3.860	4.483	11.084	Medical
32	Perform biology-related science functions in surface habitat or modules during Mars Surface Operations.	3.474	3.579	4.018	11.070	Science

Criticality

Frequency

Difficulty

Importance

Ability Analysis

Card-Sort: 52 Fleishman Abilities & 6 Social Skills by 72 SMEs.

Crew Role	Number of SMEs	Average Years Experience
Leader	42	15.9
Biologist	12	10.8
Geologist	15	12.4
Physician	11	21.2
Electrician	11	14.6
Pilot/Navigator	10	19.8
Mechanic/Engineer	10	17.7
Computer Specialist	10	17.8

Card-Sort: 52 Fleishman Abilities & 6 Social Skills by 72 SMEs.

Ability Analysis

Leader (n=42)	Mean
More Important (21)	1.00
Teamwork	7.17
Confidence	8.17
Problem Sensitivity	8.45
Patience	10.14
Emotional Control	10.98
Oral Expression	12.00
Tolerance	12.10
Inductive Reasoning	12.48
Speech Clarity	12.88
Deductive Reasoning	13.19
Oral Comprehension	13.71
Affability	14.71
Fluency of Ideas	16.98
Time Sharing	17.26
Originality	17.60
Information Ordering	18.86
Speech Hearing	19.10
Written Comprehension	19.43
Written Expression	21.93
Speed of Closure	23.02
Category Flexibility	23.60
Important	24.17
Visualization	25.07
Auditory Attention	25.81
Selective Attention	27.19
Memorization	27.62
Perceptual Speed	28.93
Reaction Time	29.07
Flexibility of Closure	30.38
General Hearing	31.00
Mathematical Reasoning	32.17
Spatial Orientation	35.12
Stamina	35.38
Number Facility	35.57
Response Orientation	37.05
Sound Localization	38.76
Near Vision	39.98
Less Important	40.81
Depth Perception	41.88
Rate Control	42.52
Control Precision	42.57
Manual Dexterity	42.83
Far Vision	42.88
Gross Body Equilibrium	43.83
Dynamic Strength	44.33
Gross Body Coordination	44.33
Peripheral Vision	44.83
Multi-Limb Coordination	45.69
Visual Color Discrimination	45.74
Finger Dexterity	48.02
Night Vision	48.02
Static Strength	48.21
Arm-Hand Steadiness	49.00
Trunk Strength	49.43
Dynamic Flexibility	50.36
Extent Flexibility	51.00
Speed of Limb Movement	51.14
Wrist-Finger Speed	51.38
Explosive Strength	52.00
Glare Sensitivity	52.17

Pilot/Navigator (n=10)	Mean
More Important (18)	1.00
Reaction Time	10.30
Control Precision	10.80
Spatial Orientation	12.10
Rate Control	15.30
Time Sharing	16.90
Confidence	17.00
Emotional Control	17.50
Response Orientation	18.30
Teamwork	19.00
Speed of Closure	20.50
Near Vision	20.60
Perceptual Speed	21.00
Multi-Limb Coordination	23.00
Far Vision	23.80
Visualization	23.80
Information Ordering	24.40
Manual Dexterity	24.70
Deductive Reasoning	25.50
Important	25.90
Arm-Hand Steadiness	26.00
Depth Perception	26.10
Selective Attention	26.10
Problem Sensitivity	27.10
Night Vision	27.90
Speech Hearing	28.30
Patience	28.60
Oral Comprehension	28.70
Inductive Reasoning	28.80
Glare Sensitivity	29.10
Peripheral Vision	29.30
Speech Clarity	29.80
Visual Color Discrimination	29.90
Finger Dexterity	30.80
Auditory Attention	31.00
Gross Body Equilibrium	33.80
Memorization	34.80
General Hearing	35.10
Affability	35.20
Oral Expression	35.40
Tolerance	35.60
Stamina	37.40
Number Facility	37.80
Wrist-Finger Speed	37.90
Mathematical Reasoning	38.50
Dynamic Flexibility	40.60
Gross Body Coordination	41.70
Written Comprehension	41.80
Flexibility of Closure	42.10
Originality	42.10
Category Flexibility	42.40
Extent Flexibility	43.50
Dynamic Strength	43.60
Sound Localization	44.30
Trunk Strength	46.80
Less Important	47.90
Speed of Limb Movement	48.30
Fluency of Ideas	50.20
Written Expression	50.90
Static Strength	51.50
Explosive Strength	52.90

Physician (n=11)	Mean
More Important (18)	1.00
Problem Sensitivity	6.00
Inductive Reasoning	7.55
Deductive Reasoning	8.09
Confidence	12.36
Patience	15.36
Speed of Closure	15.55
Teamwork	16.18
Oral Comprehension	17.82
Manual Dexterity	17.91
Finger Dexterity	19.00
Originality	19.00
Written Comprehension	20.18
Affability	20.45
Emotional Control	20.55
Information Ordering	20.55
Fluency of Ideas	21.00
Selective Attention	21.00
Oral Expression	22.00
Important	24.91
Arm-Hand Steadiness	25.18
Tolerance	25.36
Visualization	25.55
Time Sharing	25.82
Speech Clarity	26.00
Flexibility of Closure	26.18
Speech Hearing	27.00
Perceptual Speed	27.91
Spatial Orientation	29.18
Reaction Time	29.64
Depth Perception	30.00
Auditory Attention	31.91
Written Expression	32.18
Near Vision	32.36
Memorization	33.64
Multi-Limb Coordination	34.27
Number Facility	34.82
Control Precision	35.09
Response Orientation	36.27
Stamina	36.91
Mathematical Reasoning	37.36
General Hearing	37.45
Gross Body Coordination	38.73
Wrist-Finger Speed	39.64
Category Flexibility	41.82
Gross Body Equilibrium	42.18
Visual Color Discrimination	42.55
Peripheral Vision	43.00
Dynamic Flexibility	44.91
Dynamic Strength	45.00
Less Important	45.64
Rate Control	46.09
Far Vision	46.45
Sound Localization	47.36
Extent Flexibility	47.45
Static Strength	47.64
Glare Sensitivity	49.18
Trunk Strength	51.73
Speed of Limb Movement	53.64
Explosive Strength	54.27
Night Vision	57.18

Biologist (n=12)	Mean
More Important (21)	1.00
Inductive Reasoning	9.17
Confidence	10.00
Deductive Reasoning	10.67
Information Ordering	12.25
Patience	12.42
Selective Attention	12.58
Problem Sensitivity	14.00
Arm-Hand Steadiness	17.75
Finger Dexterity	17.75
Originality	18.17
Written Comprehension	18.50
Manual Dexterity	18.83
Near Vision	19.25
Flexibility of Closure	19.58
Time Sharing	20.67
Speed of Closure	21.50
Fluency of Ideas	22.08
Written Expression	22.75
Visual Color Discrimination	23.17
Mathematical Reasoning	23.92
Wrist-Finger Speed	24.08
Important	24.50
Teamwork	24.50
Oral Expression	24.75
Category Flexibility	25.17
Number Facility	25.42
Oral Comprehension	25.50
Control Precision	26.17
Memorization	26.75
Visualization	27.25
Emotional Control	27.58
Perceptual Speed	29.67
Speech Clarity	30.17
Tolerance	33.17
Affability	33.25
Depth Perception	34.25
Reaction Time	34.42
Rate Control	37.08
Speech Hearing	41.08
Glare Sensitivity	41.33
Multi-Limb Coordination	42.75
Auditory Attention	42.83
Spatial Orientation	43.00
Response Orientation	43.33
General Hearing	43.58
Gross Body Coordination	44.67
Less Important	44.75
Extent Flexibility	45.75
Stamina	45.75
Trunk Strength	45.83
Dynamic Flexibility	47.83
Gross Body Equilibrium	47.83
Peripheral Vision	47.83
Sound Localization	48.08
Dynamic Strength	48.67
Night Vision	48.75
Speed of Limb Movement	50.42
Static Strength	51.50
Far Vision	52.75
Explosive Strength	58.00

Geologist (n=15)	Mean
More Important (14)	1.00
Inductive Reasoning	9.93
Deductive Reasoning	12.60
Teamwork	12.80
Patience	15.80
Confidence	15.87
Spatial Orientation	16.80
Originality	17.33
Oral Expression	17.47
Selective Attention	19.07
Visualization	19.40
Flexibility of Closure	20.67
Problem Sensitivity	21.40
Emotional Control	22.07
Stamina	22.60
Important	22.67
Fluency of Ideas	23.27
Written Comprehension	23.33
Affability	23.47
Far Vision	23.53
Visual Color Discrimination	24.40
Speech Clarity	25.67
Tolerance	25.93
Speed of Closure	26.13
Near Vision	26.33
Oral Comprehension	26.33
Manual Dexterity	27.07
Written Expression	27.20
Information Ordering	27.73
Gross Body Coordination	28.53
Gross Body Equilibrium	28.87
Time Sharing	29.87
Category Flexibility	30.80
Dynamic Strength	31.20
Memorization	31.87
Depth Perception	33.20
Finger Dexterity	33.47
Perceptual Speed	33.47
Mathematical Reasoning	33.87
Trunk Strength	33.93
Arm-Hand Steadiness	36.40
Extent Flexibility	36.67
Speech Hearing	36.80
Static Strength	36.87
Number Facility	37.60
Multi-Limb Coordination	39.40
Control Precision	41.60
Dynamic Flexibility	41.80
Less Important	44.67
Reaction Time	45.40
Rate Control	46.20
Glare Sensitivity	46.40
Explosive Strength	47.33
General Hearing	48.27
Response Orientation	48.93
Wrist-Finger Speed	49.33
Auditory Attention	49.73
Speed of Limb Movement	50.53
Sound Localization	51.40
Peripheral Vision	53.47
Night Vision	55.27

Computer Specialist (n=10)	Mean
More Important (4)	1.00
Inductive Reasoning	7.10
Deductive Reasoning	7.80
Problem Sensitivity	8.80
Information Ordering	15.50
Important	18.80
Mathematical Reasoning	19.10
Written Comprehension	19.40
Oral Comprehension	20.20
Time Sharing	20.70
Oral Expression	20.80
Confidence	21.00
Near Vision	21.10
Selective Attention	21.20
Memorization	22.00
Speed of Closure	22.20
Originality	23.70
Speech Clarity	24.00
Patience	25.30
Teamwork	25.80
Finger Dexterity	28.00
Visualization	28.10
Fluency of Ideas	28.80
Perceptual Speed	29.00
Flexibility of Closure	30.00
Manual Dexterity	30.10
Emotional Control	30.50
Control Precision	30.90
Number Facility	31.60
Wrist-Finger Speed	31.90
Reaction Time	32.00
Category Flexibility	32.10
Arm-Hand Steadiness	32.50
Speech Hearing	32.60
Response Orientation	32.80
General Hearing	33.00
Sound Localization	33.00
Rate Control	33.30
Visual Color Discrimination	34.40
Auditory Attention	34.60
Multi-Limb Coordination	35.50
Affability	37.30
Gross Body Coordination	37.60
Tolerance	37.80
Written Expression	38.10
Extent Flexibility	39.60
Less Important	39.80
Depth Perception	41.50
Dynamic Flexibility	41.60
Spatial Orientation	42.00
Night Vision	42.40
Glare Sensitivity	43.60
Stamina	43.80
Gross Body Equilibrium	44.20
Trunk Strength	44.90
Peripheral Vision	46.00
Static Strength	46.30
Far Vision	46.60
Speed of Limb Movement	47.10
Dynamic Strength	47.20
Explosive Strength	53.30

Electrician (n=11)	Mean
More Important (15)	1.00
Inductive Reasoning	9.09
Problem Sensitivity	10.55
Confidence	10.64
Deductive Reasoning	11.45
Information Ordering	16.18
Visual Color Discrimination	17.18
Finger Dexterity	18.09
Manual Dexterity	18.91
Originality	19.09
Selective Attention	20.27
Mathematical Reasoning	20.82
Visualization	20.91
Patience	21.55
Near Vision	21.73
Speed of Closure	22.09
Important	24.36
Teamwork	24.55
Arm-Hand Steadiness	25.00
Night Vision	25.09
Oral Expression	26.27
Time Sharing	26.27
Written Comprehension	26.55
Number Facility	26.73
Memorization	26.82
Flexibility of Closure	28.45
Perceptual Speed	28.91
Oral Comprehension	29.00
General Hearing	29.73
Reaction Time	29.82
Speech Clarity	29.91
Auditory Attention	31.09
Sound Localization	31.73
Fluency of Ideas	32.18
Dynamic Flexibility	32.73
Control Precision	32.91
Extent Flexibility	33.36
Written Expression	33.82
Affability	34.82
Category Flexibility	36.36
Multi-Limb Coordination	36.73
Emotional Control	37.00
Speech Hearing	37.09
Wrist-Finger Speed	37.27
Response Orientation	38.09
Gross Body Equilibrium	38.27
Rate Control	38.73
Gross Body Coordination	40.09
Glare Sensitivity	40.73
Depth Perception	41.09
Stamina	42.73
Less Important	43.64
Spatial Orientation	44.27
Tolerance	45.00
Peripheral Vision	46.82
Dynamic Strength	49.82
Speed of Limb Movement	50.64
Far Vision	50.91
Static Strength	51.09
Trunk Strength	51.36
Explosive Strength	58.18

Mechanic/Engineer (n=10)	Mean
More Important (13)	1.00
Inductive Reasoning	11.40
Problem Sensitivity	11.40
Deductive Reasoning	11.90
Manual Dexterity	14.00
Patience	17.70
Written Comprehension	17.70
Originality	18.60
Visualization	19.30
Mathematical Reasoning	22.20
Teamwork	22.30
Confidence	23.00
Information Ordering	23.80
Arm-Hand Steadiness	24.00
Important	24.10
Rate Control	24.30
Control Precision	25.90
Auditory Attention	26.40
Finger Dexterity	26.50
Reaction Time	26.50
Speed of Closure	26.70
Flexibility of Closure	26.80
Static Strength	27.60
Multi-Limb Coordination	28.50
Dynamic Strength	29.70
Oral Comprehension	30.00
General Hearing	30.50
Gross Body Coordination	30.90
Tolerance	31.10
Fluency of Ideas	31.60
Sound Localization	32.60
Emotional Control	34.10
Visual Color Discrimination	34.10
Speech Hearing	34.30
Time Sharing	34.40
Number Facility	34.70
Oral Expression	34.70
Response Orientation	34.70
Spatial Orientation	34.90
Memorization	35.10
Near Vision	35.30
Gross Body Equilibrium	35.50
Selective Attention	35.70
Speech Clarity	35.70
Affability	36.20
Stamina	36.70
Explosive Strength	37.20
Wrist-Finger Speed	37.30
Perceptual Speed	38.60
Depth Perception	38.90
Trunk Strength	39.20
Dynamic Flexibility	39.40
Written Expression	40.40
Category Flexibility	41.20
Extent Flexibility	42.80
Night Vision	44.50
Less Important	46.10
Peripheral Vision	46.60
Far Vision	49.30
Speed of Limb Movement	50.40
Glare Sensitivity	55.00

Social Skills / Abilities / All Specialties Combined

Ability Analysis

Inductive Reasoning	Flexibility of Closure	Depth Perception
Deductive Reasoning	Fluency of Ideas	General Hearing
Problem Sensitivity	Mathematical Reasoning	Response Orientation
Confidence	Arm-Hand Steadiness	Stamina
Patience	Reaction Time	Gross Body Coordination
Teamwork	Affability	Wrist-Finger Speed
Information Ordering	Perceptual Speed	Gross Body Equilibrium
Originality	Memorization	Sound Localization
Speed of Closure	Control Precision	Far Vision
Selective Attention	Tolerance	Dynamic Strength
Written Comprehension	Visual Color Discrimination	Dynamic Flexibility
Visualization	Speech Hearing	Extent Flexibility
Oral Comprehension	Spatial Orientation	Night Vision
Time Sharing	Number Facility	Peripheral Vision
Manual Dexterity	Written Expression	Glare Sensitivity
Oral Expression	Auditory Attention	Static Strength
Emotional Control	Category Flexibility	Trunk Strength
Speech Clarity	Rate Control	Speed of Limb Movement
Near Vision	Multi-Limb Coordination	Explosive Strength
Finger Dexterity		

Cognitive (i.e., Problem-Solving) Abilities

Ability Analysis

Inductive Reasoning	Flexibility of Closure	Depth Perception
Deductive Reasoning	Fluency of Ideas	General Hearing
Problem Sensitivity	Mathematical Reasoning	Response Orientation
Confidence	Arm-Hand Steadiness	Stamina
Patience	Reaction Time	Gross Body Coordination
Teamwork	Affability	Wrist-Finger Speed
Information Ordering	Perceptual Speed	Gross Body Equilibrium
Originality	Memorization	Sound Localization
Speed of Closure	Control Precision	Far Vision
Selective Attention	Tolerance	Dynamic Strength
Written Comprehension	Visual Color Discrimination	Dynamic Flexibility
Visualization	Speech Hearing	Extent Flexibility
Oral Comprehension	Spatial Orientation	Night Vision
Time Sharing	Number Facility	Peripheral Vision
Manual Dexterity	Written Expression	Glare Sensitivity
Oral Expression	Auditory Attention	Static Strength
Emotional Control	Category Flexibility	Trunk Strength
Speech Clarity	Rate Control	Speed of Limb Movement
Near Vision	Multi-Limb Coordination	Explosive Strength
Finger Dexterity		

Physical Abilities

Ability Analysis

Inductive Reasoning	Flexibility of Closure	Depth Perception
Deductive Reasoning	Fluency of Ideas	General Hearing
Problem Sensitivity	Mathematical Reasoning	Response Orientation
Confidence	Arm-Hand Steadiness	Stamina
Patience	Reaction Time	Gross Body Coordination
Teamwork	Affability	Wrist-Finger Speed
Information Ordering	Perceptual Speed	Gross Body Equilibrium
Originality	Memorization	Sound Localization
Speed of Closure	Control Precision	Far Vision
Selective Attention	Tolerance	Dynamic Strength
Written Comprehension	Visual Color Discrimination	Dynamic Flexibility
Visualization	Speech Hearing	Extent Flexibility
Oral Comprehension	Spatial Orientation	Night Vision
Time Sharing	Number Facility	Peripheral Vision
Manual Dexterity	Written Expression	Glare Sensitivity
Oral Expression	Auditory Attention	Static Strength
Emotional Control	Category Flexibility	Trunk Strength
Speech Clarity	Rate Control	Speed of Limb Movement
Near Vision	Multi-Limb Coordination	Explosive Strength
Finger Dexterity		

Card-Sort: 52 Fleishman Abilities & 6 Social Skills by 72 SMEs.

Ability Analysis

	Skill/Ability Rank by Crew Specialty/Role Ranks 1 - 29								
	Leader	**Pilot**	**Physician**	**Biologist**	**Geologist**	**Computer**	**Electrician**	**Mechanic**	**Combined**
1	Teamwork	Reaction Time	Problem Sensitivity	Inductive Reasoning	Inductive Reasoning	Inductive Reasoning	Inductive Reasoning	Inductive Reasoning	Inductive Reasoning
2	Confidence	Control Precision	Inductive Reasoning	Confidence	Deductive Reasoning	Deductive Reasoning	Problem Sensitivity	Problem Sensitivity	Deductive Reasoning
3	Problem Sensitivity	Spatial Orientation	Deductive Reasoning	Deductive Reasoning	Teamwork	Problem Sensitivity	Confidence	Deductive Reasoning	Problem Sensitivity
4	Patience	Rate Control	Confidence	Information Ordering	Patience	Information Ordering	Deductive Reasoning	Manual Dexterity	Confidence
5	Emotional Control	Time Sharing	Patience	Patience	Confidence	Mathematical Reasoning	Information Ordering	Patience	Patience
6	Oral Expression	Confidence	Speed of Closure	Selective Attention	Spatial Orientation	Written Comprehension	Visual Color Discrimination	Written Comprehension	Teamwork
7	Tolerance	Emotional Control	Teamwork	Problem Sensitivity	Originality	Oral Comprehension	Finger Dexterity	Originality	Information Ordering
8	Inductive Reasoning	Response Orientation	Oral Comprehension	Arm-Hand Steadiness	Oral Expression	Time Sharing	Manual Dexterity	Visualization	Originality
9	Speech Clarity	Teamwork	Manual Dexterity	Finger Dexterity	Selective Attention	Oral Expression	Originality	Mathematical Reasoning	Speed of Closure
10	Deductive Reasoning	Speed of Closure	Finger Dexterity	Originality	Visualization	Confidence	Selective Attention	Teamwork	Selective Attention
11	Oral Comprehension	Near Vision	Originality	Written Comprehension	Flexibility of Closure	Near Vision	Mathematical Reasoning	Confidence	Written Comprehension
12	Affability	Perceptual Speed	Written Comprehension	Manual Dexterity	Problem Sensitivity	Selective Attention	Visualization	Information Ordering	Visualization
13	Fluency of Ideas	Multi-Limb Coordination	Affability	Near Vision	Emotional Control	Memorization	Patience	Arm-Hand Steadiness	Oral Comprehension
14	Time Sharing	Far Vision	Emotional Control	Flexibility of Closure	Stamina	Speed of Closure	Near Vision	Rate Control	Time Sharing
15	Originality	Visualization	Information Ordering	Time Sharing	Fluency of Ideas	Originality	Speed of Closure	Control Precision	Oral Expression
16	Information Ordering	Information Ordering	Fluency of Ideas	Speed of Closure	Written Comprehension	Speech Clarity	Teamwork	Auditory Attention	Manual Dexterity
17	Speech Hearing	Manual Dexterity	Selective Attention	Fluency of Ideas	Affability	Patience	Arm-Hand Steadiness	Finger Dexterity	Emotional Control
18	Written Comprehension	Deductive Reasoning	Oral Expression	Written Expression	Far Vision	Teamwork	Night Vision	Reaction Time	Speech Clarity
19	Written Expression	Arm-Hand Steadiness	Arm-Hand Steadiness	Visual Color Discrimination	Visual Color Discrimination	Finger Dexterity	Oral Expression	Speed of Closure	Near Vision
20	Speed of Closure	Depth Perception	Tolerance	Mathematical Reasoning	Speech Clarity	Visualization	Time Sharing	Flexibility of Closure	Finger Dexterity
21	Category Flexibility	Selective Attention	Visualization	Wrist-Finger Speed	Tolerance	Fluency of Ideas	Written Comprehension	Static Strength	Flexibility of Closure
22	Visualization	Problem Sensitivity	Time Sharing	Teamwork	Speed of Closure	Perceptual Speed	Number Facility	Multi-Limb Coordination	Fluency of Ideas
23	Auditory Attention	Night Vision	Speech Clarity	Oral Expression	Near Vision	Flexibility of Closure	Memorization	Dynamic Strength	Mathematical Reasoning
24	Selective Attention	Speech Hearing	Flexibility of Closure	Category Flexibility	Oral Comprehension	Manual Dexterity	Flexibility of Closure	Oral Comprehension	Affability
25	Memorization	Patience	Speech Hearing	Number Facility	Manual Dexterity	Emotional Control	Perceptual Speed	General Hearing	Arm-Hand Steadiness
26	Perceptual Speed	Oral Comprehension	Perceptual Speed	Oral Comprehension	Written Expression	Control Precision	Oral Comprehension	Gross Body Coordination	Reaction Time
27	Reaction Time	Inductive Reasoning	Spatial Orientation	Control Precision	Information Ordering	Number Facility	General Hearing	Tolerance	Perceptual Speed
28	Flexibility of Closure	Glare Sensitivity	Reaction Time	Memorization	Gross Body Coordination	Wrist-Finger Speed	Reaction Time	Fluency of Ideas	Memorization
29	General Hearing	Peripheral Vision	Depth Perception	Visualization	Gross Body Equilibrium	Reaction Time	Speech Clarity	Sound Localization	Control Precision
	Key: Cognitive Abilities=				Social Skills=			Physical Abilities=	

Ability Analysis

	Skill/Ability Rank by Crew Specialty/Role Ranks 30 - 58								
	Leader	**Pilot**	**Physician**	**Biologist**	**Geologist**	**Computer**	**Electrician**	**Mechanic**	**Combined**
30	Mathematical Reasoning	Speech Clarity	Auditory Attention	Emotional Control	Time Sharing	Category Flexibility	Auditory Attention	Emotional Control	Tolerance
31	Spatial Orientation	Visual Color Discrimination	Written Comprehension	Perceptual Speed	Category Flexibility	Arm-Hand Steadiness	Sound Localization	Visual Color Discrimination	Visual Color Discrimination
32	Stamina	Finger Dexterity	Written Expression	Speech Clarity	Dynamic Strength	Speech Hearing	Fluency of Ideas	Speech Hearing	Speech Hearing
33	Number Facility	Auditory Attention	Memorization	Tolerance	Memorization	Response Orientation	Dynamic Flexibility	Time Sharing	Spatial Orientation
34	Response Orientation	Gross Body Equilibrium	Multi-Limb Coordination	Affability	Depth Perception	General Hearing	Control Precision	Number Facility	Number Facility
35	Sound Localization	Memorization	Number Facility	Depth Perception	Finger Dexterity	Sound Localization	Extent Flexibility	Oral Expression	Written Expression
36	Near Vision	General Hearing	Control Precision	Reaction Time	Perceptual Speed	Rate Control	Written Expression	Response Orientation	Auditory Attention
37	Depth Perception	Affability	Response Orientation	Rate Control	Mathematical Reasoning	Visual Color Discrimination	Affability	Spatial Orientation	Category Flexibility
38	Rate Control	Oral Expression	Stamina	Speech Hearing	Trunk Strength	Auditory Attention	Category Flexibility	Memorization	Rate Control
39	Control Precision	Tolerance	Mathematical Reasoning	Glare Sensitivity	Arm-Hand Steadiness	Multi-Limb Coordination	Multi-Limb Coordination	Near Vision	Multi-Limb Coordination
40	Manual Dexterity	Stamina	General Hearing	Multi-Limb Coordination	Extent Flexibility	Affability	Emotional Control	Gross Body Equilibrium	Depth Perception
41	Far Vision	Number Facility	Gross Body Coordination	Auditory Attention	Speech Hearing	Gross Body Coordination	Speech Hearing	Selective Attention	General Hearing
42	Gross Body Equilibrium	Wrist-Finger Speed	Wrist-Finger Speed	Spatial Orientation	Static Strength	Tolerance	Wrist-Finger Speed	Speech Clarity	Response Orientation
43	Dynamic Strength	Mathematical Reasoning	Category Flexibility	Response Orientation	Number Facility	Written Expression	Response Orientation	Affability	Stamina
44	Gross Body Coordination	Dynamic Flexibility	Gross Body Equilibrium	General Hearing	Multi-Limb Coordination	Extent Flexibility	Gross Body Equilibrium	Stamina	Gross Body Coordination
45	Peripheral Vision	Gross Body Coordination	Visual Color Discrimination	Gross Body Coordination	Control Precision	Depth Perception	Rate Control	Explosive Strength	Wrist-Finger Speed
46	Multi-Limb Coordination	Written Comprehension	Peripheral Vision	Extent Flexibility	Dynamic Flexibility	Dynamic Flexibility	Gross Body Coordination	Wrist-Finger Speed	Gross Body Equilibrium
47	Visual Color Discrimination	Flexibility of Closure	Dynamic Flexibility	Stamina	Reaction Time	Spatial Orientation	Glare Sensitivity	Perceptual Speed	Sound Localization
48	Finger Dexterity	Originality	Dynamic Strength	Trunk Strength	Rate Control	Night Vision	Depth Perception	Depth Perception	Far Vision
49	Night Vision	Category Flexibility	Rate Control	Dynamic Flexibility	Glare Sensitivity	Glare Sensitivity	Stamina	Trunk Strength	Dynamic Flexibility
50	Static Strength	Extent Flexibility	Far Vision	Gross Body Equilibrium	Explosive Strength	Stamina	Spatial Orientation	Dynamic Flexibility	Dynamic Strength
51	Arm-Hand Steadiness	Dynamic Strength	Sound Localization	Peripheral Vision	General Hearing	Gross Body Equilibrium	Tolerance	Written Expression	Extent Flexibility
52	Trunk Strength	Sound Localization	Extent Flexibility	Sound Localization	Response Orientation	Trunk Strength	Peripheral Vision	Category Flexibility	Night Vision
53	Dynamic Flexibility	Trunk Strength	Static Strength	Dynamic Strength	Wrist-Finger Speed	Peripheral Vision	Dynamic Strength	Extent Flexibility	Glare Sensitivity
54	Extent Flexibility	Speed of Limb Movement	Glare Sensitivity	Night Vision	Auditory Attention	Static Strength	Speed of Limb Movement	Night Vision	Peripheral Vision
55	Speed of Limb Movement	Fluency of Ideas	Trunk Strength	Speed of Limb Movement	Sound Localization	Far Vision	Far Vision	Peripheral Vision	Static Strength
56	Wrist-Finger Speed	Written Expression	Speed of Limb Movement	Static Strength	Speed of Limb Movement	Speed of Limb Movement	Static Strength	Far Vision	Trunk Strength
57	Explosive Strength	Static Strength	Explosive Strength	Far Vision	Peripheral Vision	Dynamic Strength	Trunk Strength	Speed of Limb Movement	Speed of Limb Movement
58	Glare Sensitivity	Explosive Strength	Night Vision	Explosive Strength	Night Vision	Explosive Strength	Explosive Strength	Glare Sensitivity	Explosive Strength
	Key: Cognitive Abilities=				Social Skills=		Physical Abilities=		

Crew Composition / Cross-Training

A: Six-Person Crew

Primary Specialties/Roles	Backup Responsibilities
Pilot/Navigator (Robotics & Rovers)	Equipment Operator/CMO
Physician/Astrophysicist	Biologist/Geologist
Mechanic/Equipment Operator	Pilot/Navigator/Astrophysicist
Electrician/Computer Specialist	Mechanic/CMO/Botanist
Geologist/Leader	Electrician/Computer Specialist
Biologist/Botanist	Leader/CMO

B: Five-Person Crew

Primary Specialty/Roles	Backup Responsibilities
Pilot/Navigator (Robotics & Rovers)	Geologist/Leader/CMO
Physician/Biologist/Astrophysicist	Electrician/Computer Specialist
Mechanic/Equipment Operator	Biologist/CMO/Botanist
Electrician/Computer Specialist	Mechanic/Equipment Operator/CMO
Geologist/Leader/Botanist	Pilot/Navigator/Astrophysicist

C: Five-Person Crew

Primary Specialty/Roles	Backup Responsibilities
Pilot/Navigator (Robotics & Rovers)	Geologist/Leader/CMO
Physician/Astrophysicist/Botanist	Pilot/Navigator/Biologist
Mechanic/Equipment Operator	Electrician/Computer Specialist/CMO
Electrician/Computer Specialist	Mechanic/Equipment Operator
Geologist/Biologist/Leader	Botanist/Astrophysicist/CMO

D: Four-Person Crew

Primary Specialty/Roles	Backup Responsibilities
Pilot/Navigator/Leader/Astrophysicist	Geologist/Computer Specialist/CMO
Physician/Computer Specialist	Biologist/Mechanic/Electrician/Botanist
Mechanic/Electrician/Equipment Operator	Pilot/Navigator/Astrophysicist/CMO
Geologist/Biologist/Botanist	Equipment Operator/Leader/CMO

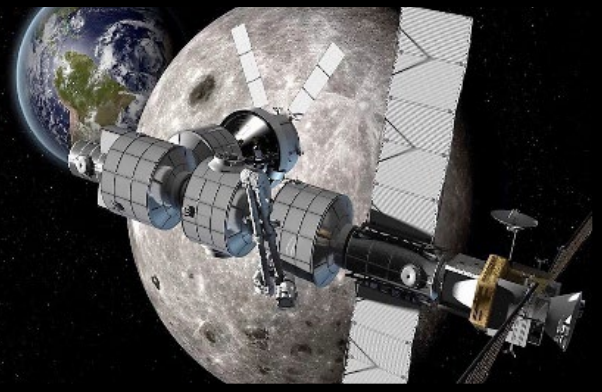
The Pilot/Navigator would have lead responsibility for robotics and rovers during Mars Surface Operations in all four hypothetical crew compositions.

Research Products

- List of 1,125 tasks by mission phase;
- Ratings of Mars expedition tasks by frequency, difficulty to learn, importance, and criticality;
- Rank-ordered lists of the physical, cognitive, and social abilities necessary;
- Abilities, skills, and knowledge that can be retained and generalized across tasks and specialties;

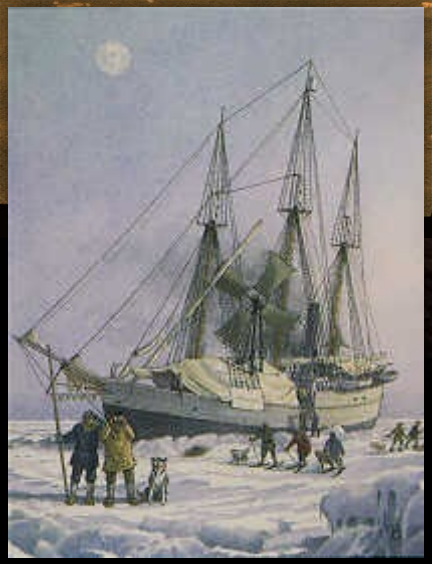
Research Products

- Recommendations for training strategies;
- Recommendations for crew size/composition;
- Recommendations for the design of equipment, habitats, and procedures for exploration-class space missions; and,
- A list of 647 Gateway tasks by mission phase.

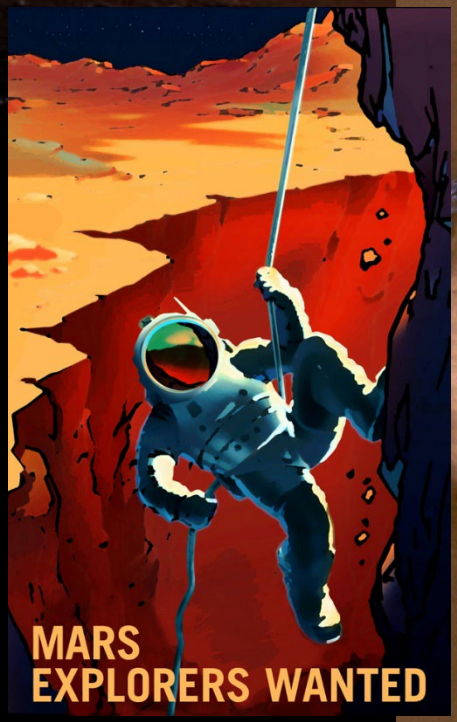


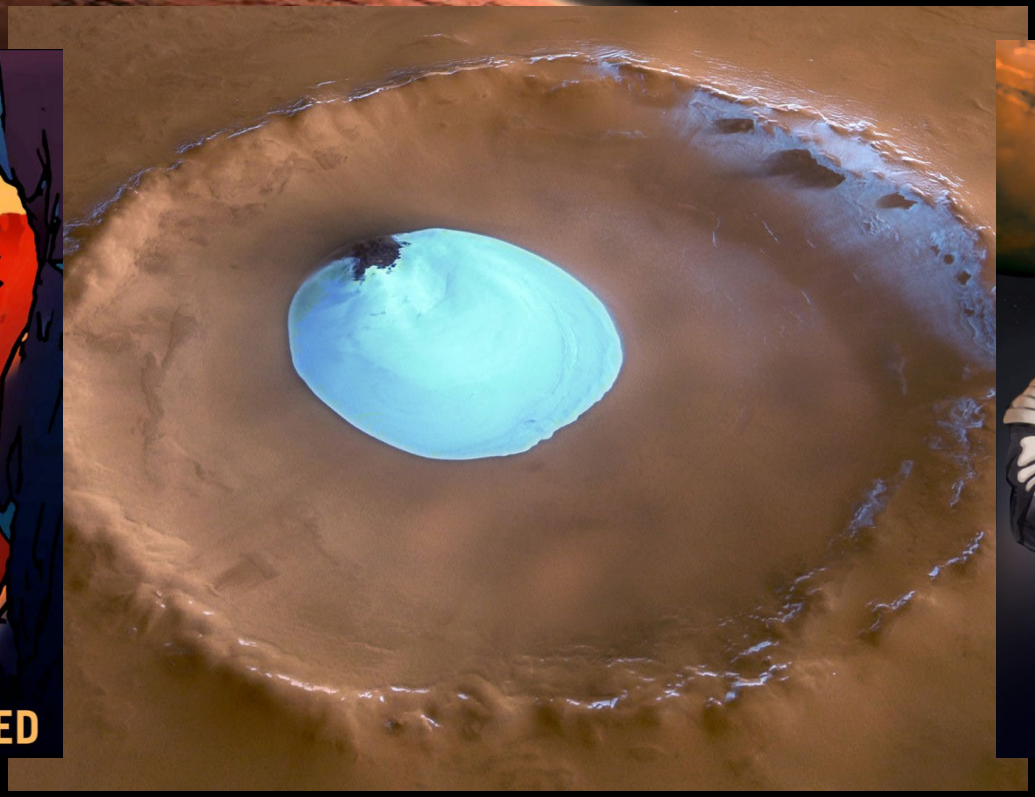
Sightseeing on Mars

Fram Crater



Sightseeing on Mars





Louth Crater

Diameter: 36 kilometers (22.4 mi) /
Ice: 15 kilometers (9 mi)

Sightseeing on Mars

Korolov Crater

Diameter: 81.4 kilometers (50.6 mi)

Earth From Mars

For More Information…

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