IT TAKES PARTNERS TO CREATE SOLUTIONS MANAGEMENT WANTS

Cristina Banks, Chair, UC Berkeley

Kathleen Mosier, IEA & TeamScape LLC

Kriss Kennedy, University of Houston

Christopher Miller, Smart Information Flow Technology (SIFT)

Andrew Imada, A.S. Imada & Associates

INTERDISCIPLINARITY

- It involves the combining of two or more academic disciplines into one activity (e.g., a research project). It draws knowledge from several other fields like sociology, anthropology, psychology, economics etc. It is about creating something by thinking across boundaries. (Wikipedia)

- Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (National Academies of Science)

PERSPECTIVES

- HFE is inherently an interdisciplinary science.
- Too often, HFE can develop “tunnel vision” and focuses on the problem at hand instead of all of the factors in the surrounding context.
- By working this way, HFE professionals miss the opportunity to become part of a network of problem solvers needed to address the system of factors causing harm or poor results.
- By not being part of the network, HFE is not appreciated for its contributions.
- To develop effective systems and work environments, becoming a partner in a network of experts will provide the best results.
- This panel addresses this issue:
  - *Working with interdisciplinary partners on complex problems can create the opportunity for HFE to engage in broader impact work and demonstrate its value by sharing its knowledge and expertise in critical aspects of a design solution.*

HOW DOES THIS WORK?

- Start by understanding the problem, deeply.
- Each partner explores how its knowledge and expertise may address one or more aspects of the problem.
- Each partner shares the relevance of their knowledge and expertise in understanding the problem and/or addressing one or more aspects of it.
- As partners share, a growing awareness of their overlap and intersection emerges, creating a new understanding of the problem.
- A new understanding may also reveal critical gaps in knowledge and expertise, which may result in additional partners or additional study.
- Given the new problem definition, each partner's contribution can be integrated together as appropriate into a multi-faceted, innovative system.

THE PROBLEM

- VISION:
  - *Astronauts traveling to Mars and back* ***thrive*** *and not just survive long-duration flight.*

- OBJECTIVE:
  - *Promote and maintain astronaut health, well-being and productivity during long duration spaceflight lasting up to 3 years.*

- PROBLEM:
  - *How to design the internal spacecraft habitat for long duration flight to Mars.*

PANEL

- Kathleen Mosier
  - Cognitive and psychological challenges in teams and teamwork in space operations
- Kriss Kennedy
  - Designing exploration habitats using an interdisciplinary approach
- Christopher Miller
  - Automation and technology as “team players”
- Cristina Banks
  - Designing habitat for basic human needs
- Andrew Imada
  - Building on what we know to create solutions for the Mars mission

DISCUSSION

- In what ways can HFE be integrated into such a network of partners?
- How can HFE benefit in general from partnerships like this one?
- What might be some of the challenges you might face working with other disciplines when solving complex problems like the Mars spacecraft habitat?

Teams and Teamwork in Space Operations

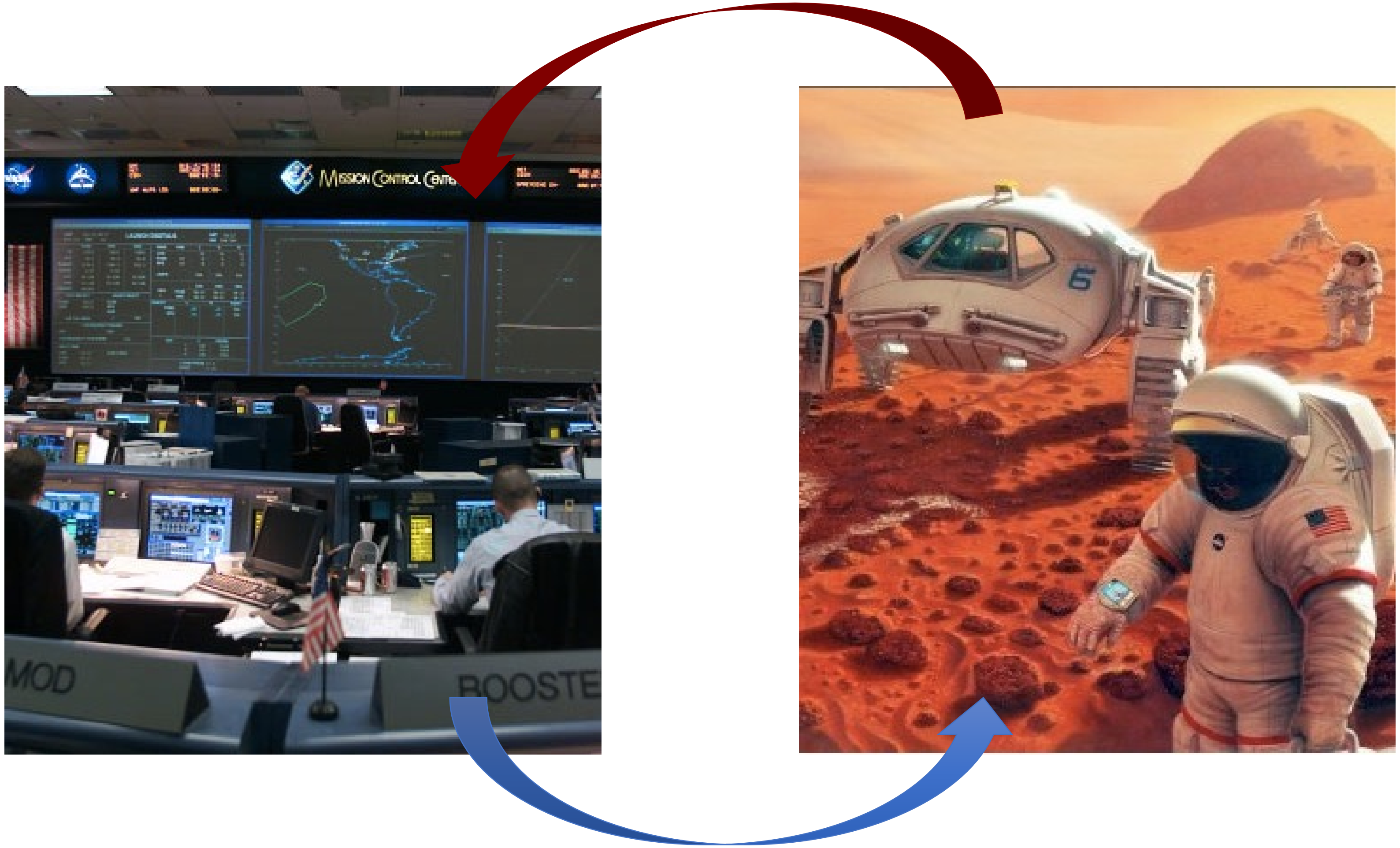
Kathleen Mosier

TeamScape LLC

Ute Fischer

Georgia Institute of Technology

CHALLENGE: Remote Collaboration within a Multi-Team System



Cognitive and Psychosocial Challenges

- Need for resilience and cohesion over time despite...
- Isolation and…
- Confinement in an…
- Extreme environment (ICE)
- Partnership with ground as members of multi-team system (MTS)
- Need to collaborate with ground despite…
- Communication delay and…
- Need for autonomy


K.Y
DML

Imagine living and working in a small, confined space with five other teammates for over a year. Your team needs to complete a series of scientific experiments and perform other rigorous tasks, eventually exploring a distant location in a dangerous, even life-threatening mission. If you are successful, you will then spend 6 months "commuting" home in the same confined quarters and challenging conditions. During this assignment, headquarters cannot provide you with quick advice or coaching, because there is up to 20-minute communication delay (one-way), but you still need to coordinate as a team with people back at headquarters. From a personal perspective, during these 2 to 3 years, you cannot see Earth, feel gravity, or spend time with your family. And if you or any of your teammates are having a bad day, you cannot simply go out for a walk or call in sick.

Salas, E., Tannenbaum, S. I., Kozlowski, S. W. J., Miller, C. A., Mathieu, J. E., & Vessey, W. B. (2015). Teams in space exploration: A new frontier for the science of team effectiveness. *Current Directions in Psychological Science*, *24*(3), 200-207, pp. 200-201

How to ensure team safety and success during long-duration space missions?

- Selection
- Design of space craft to facilitate
  - Team functioning
  - Team task performance
  - Communication within crew and MTS
    - Establish common ground for
    - Shared mental models
- Research, training, procedures

Research, Training, Procedures

Impact on team processes

- Training and interventions to mitigate negative impact on cohesion, performance

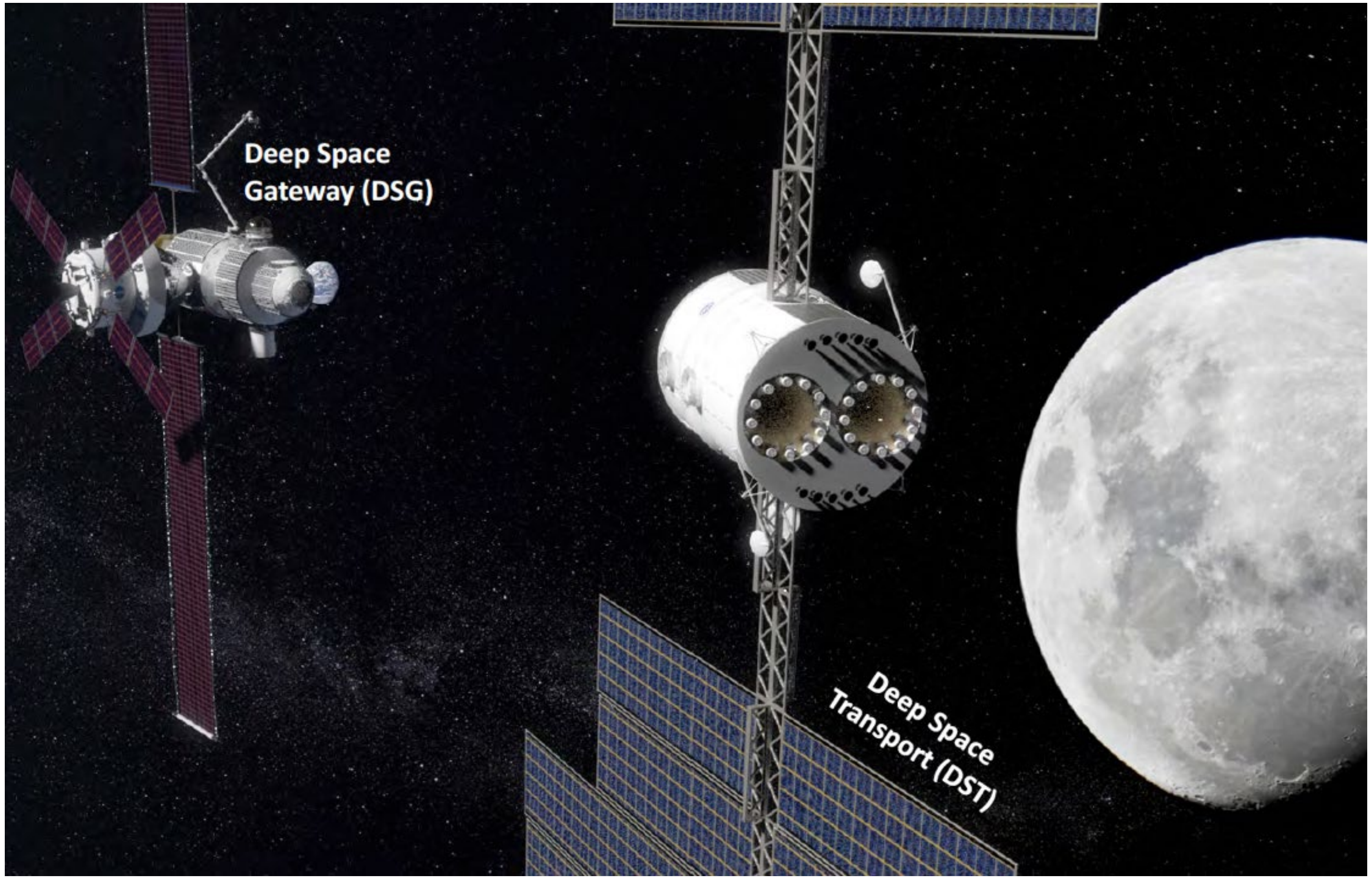
Impact of communication delay

- Training and procedures to mitigate negative impact of comm delay

Impact of autonomy

- Training and procedures to facilitate autonomy and at the same time maintain integrity of MTS

Thanks!



Human Factors & Ergonomics Society

63rd International Annual Meeting

October 28-31, 2019 Seattle

Designing Exploration Habitats An Interdisciplinary Approach

Kriss J. Kennedy
Architect / Space Architect
October 29, 2019

Career as a NASA Space Architect (30 yrs.)

Three (3) degrees in Architecture
- 1 in Space Architecture (Masters)

Worked on over 45 designs and projects

Written ~ 60 publications, papers, or chapters in books

published in numerous magazines, periodicals & books

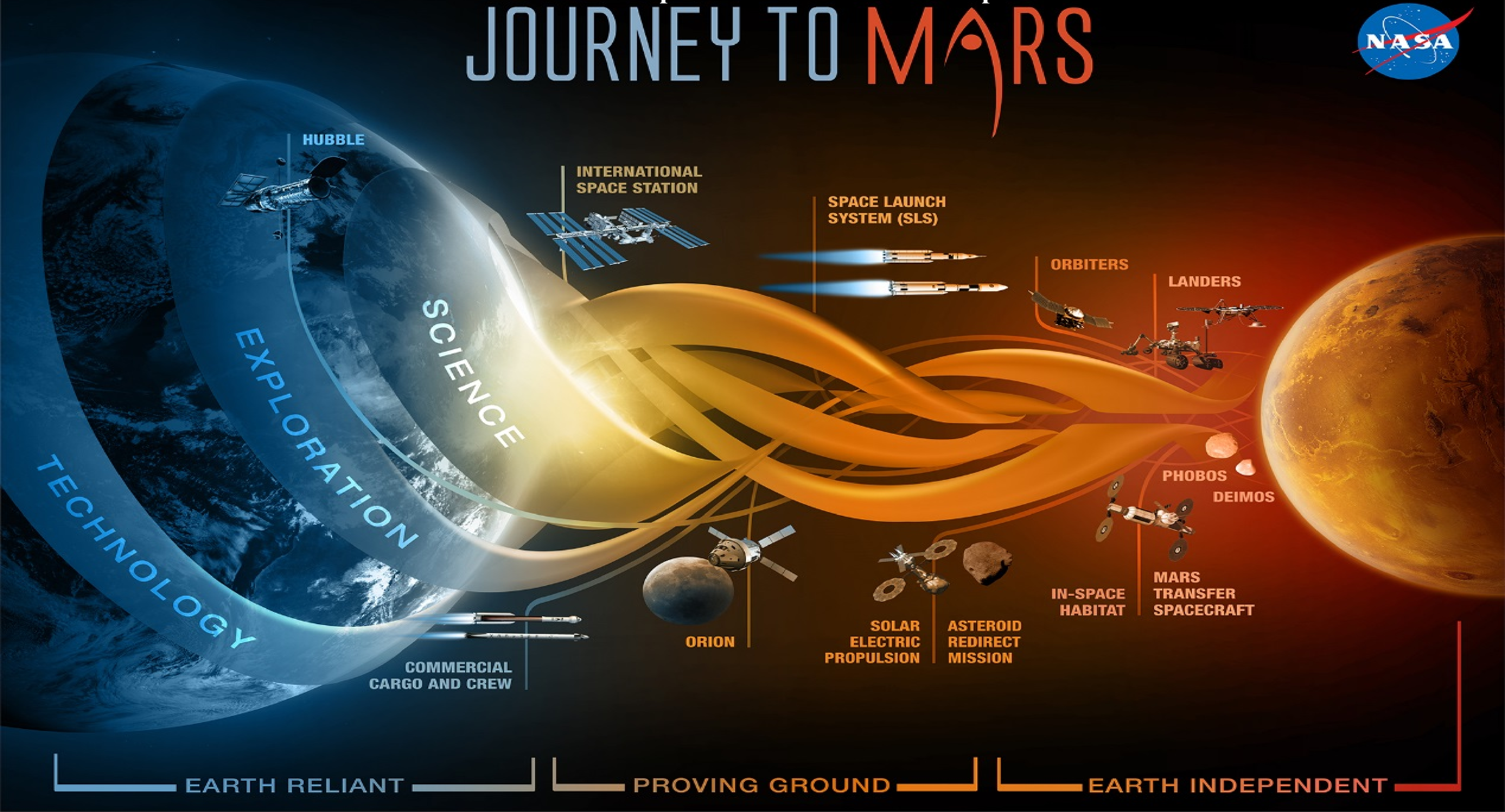
Has two patents & numerous NASA Technology Brief Awards. TransHab won the NASA Invention of the Year-2017

Recognized by his architect peers as one of the new upcoming architects in Texas as published in the millennium issue January 2000 Texas Architect magazine.

First space architect awarded the prestigious Rotary National Award for Space Achievement in March 2000

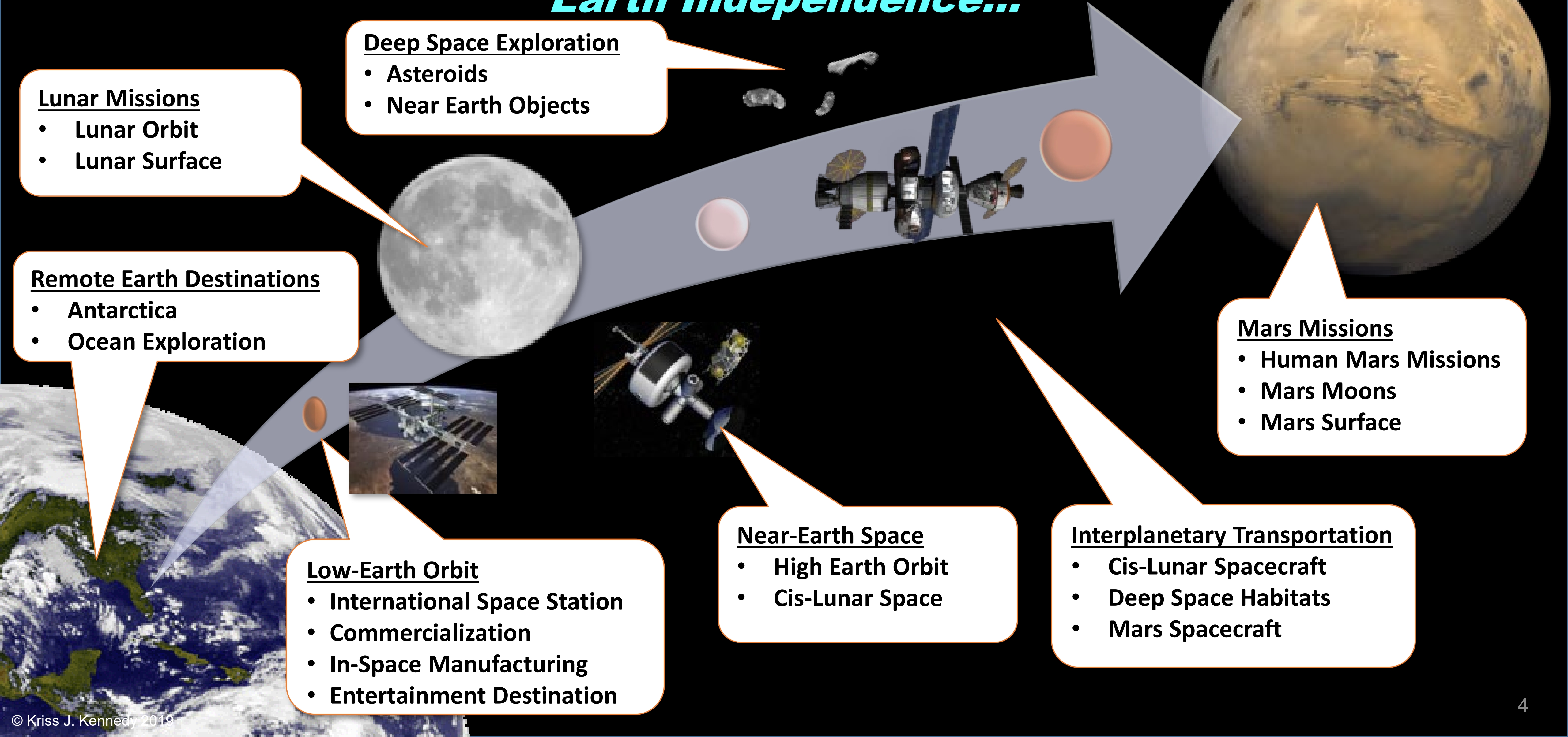
Registered licensed architect in the State of Texas since 1995

Human Exploration to Mars Roadmap



Human Exploration Destination Systems

sustained human presence
Earth Independence…



Remote Earth Destinations
- Antarctica
- Ocean Exploration

Lunar Missions
- Lunar Orbit
- Lunar Surface

Deep Space Exploration
- Asteroids
- Near Earth Objects

Low-Earth Orbit
- International Space Station
- Commercialization
- In-Space Manufacturing
- Entertainment Destination

Near-Earth Space
- High Earth Orbit
- Cis-Lunar Space

Interplanetary Transportation
- Cis-Lunar Spacecraft
- Deep Space Habitats
- Mars Spacecraft

Mars Missions
- Human Mars Missions
- Mars Moons
- Mars Surface

Human Spaceflight Operations

Crew Operations - IVA

Sustain crew on human exploration missions. These functions are necessary to insure the safety of the crew. It also includes providing the functions necessary to sustain the crew from a health and well being perspective.

Crew Operations – Supporting EVA

Enable Redundant EVA Function & Enhanced EVA Capability. These functions are necessary to provide the crew with additional means to conduct routine EVAs. The extent provided is driven by the mission duration and the number of EVAs required to conduct that mission.

Mission Operations

Enable Enhanced Mission Operations Capability. These functions are those that enable the exploration crew to conduct operations in concert with the Earth based mission control. For longer exploration missions it should also establish autonomy from the Earth based "mission control" enabling command and control with other exploration assets such as orbital assets, rovers, landers, etc.

Science Operations

Enable IVA Bio/Life Science & GeoScience Capability. These functions are necessary to conduct the Human Research and science involved with the exploration mission. It can include human research, biologic research, crew sample collection, sample analyses, sample prioritization and storage, and any sample return required. It also is meant to include any specific "environmental" requirements specific to Life Science or GeoScience

Logistics & Maintenance Operations - IVA & EVA

Enable Maintenance, Resupply, & Spares Cache. These functions are those that allows for maintaining the exploration assets during recognized maintenance intervals. It also includes those functions necessary to resupply the habitat(s) with consumables (both pressurized and unpressurized) to support the crew for the mission. Lastly, it also includes the functions necessary to deliver and store the necessary spares related to the maintenance as well as unexpected failures.

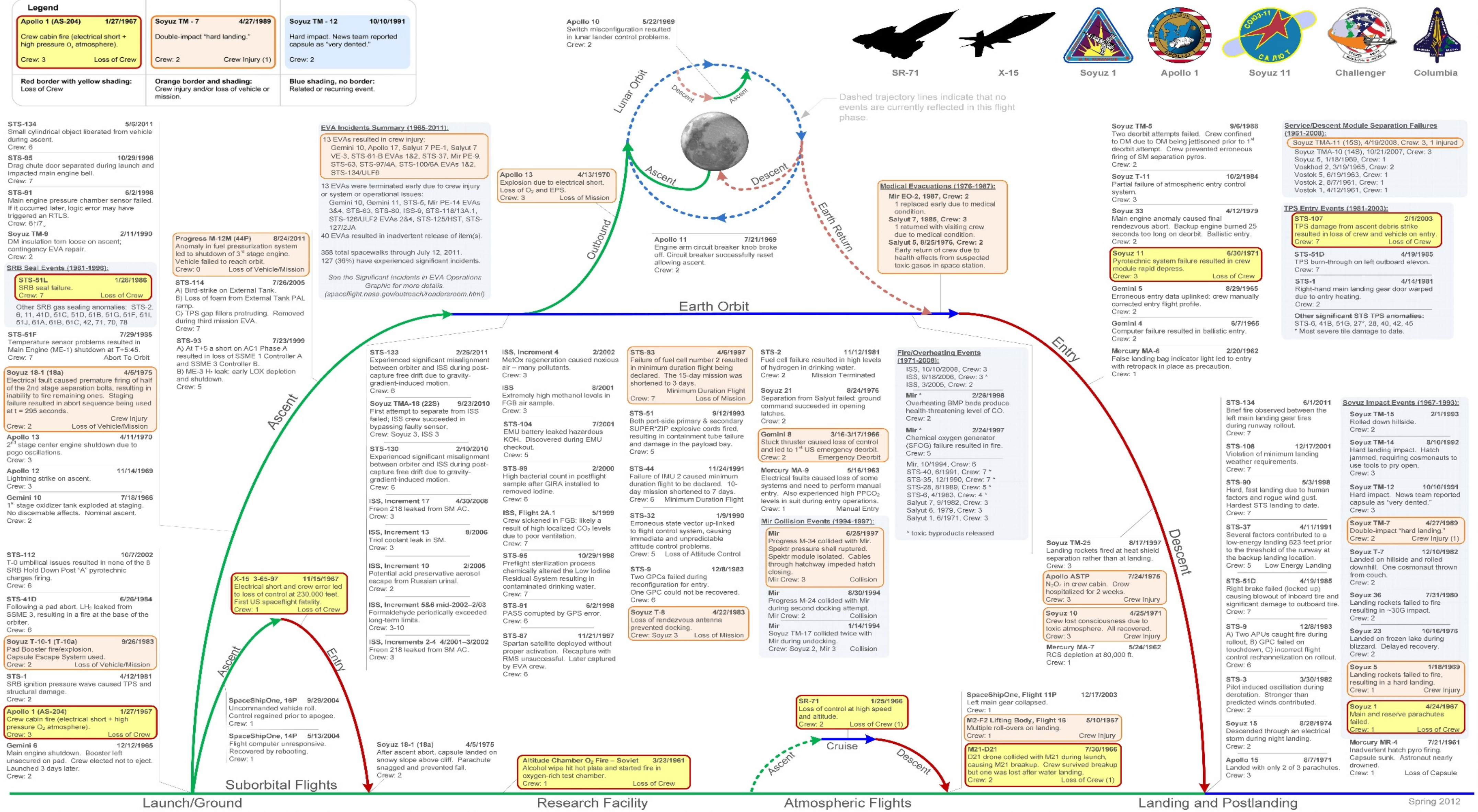
Challenges of Human Spaceflight

- Hazards of the space environment, vehicle environment, and mission architecture present significant challenges to human performance and mission success.
- Spontaneous medical events occur in astronauts despite extensive selection and screening
- On-orbit countermeasures and medical capabilities have not eliminated significant events in space or need for evacuation
- Human errors have contributed to events in space that have affected crew health and mission success
- History of Human Spaceflight (Dr. Jonathan Clark)

https://spaceflight.nasa.gov/outreach/SigInc_Poster_2012.jpg

Significant Incidents and Close Calls in Human Spaceflight

A Product of the JSC S&MA Flight Safety Office



Legend

Apollo 1 (AS-204) 1/27/1967
Crew cabin fire (electrical short + high pressure O_2 atmosphere).
Crew: 3 Loss of Crew

Soyuz TM - 7 4/27/1989
Double-impact "hard landing."
Crew: 2 Crew Injury (1)

Soyuz TM - 12 10/10/1991
Hard impact. News team reported capsule as "very dented."
Crew: 2

Red border with yellow shading: Loss of Crew

Orange border and shading: Crew injury and/or loss of vehicle or mission.

Blue shading, no border: Related or recurring event.

Dashed trajectory lines indicate that no events are currently reflected in this flight phase.

Launch/Ground and Ascent

STS-134 5/6/2011
Small cylindrical object liberated from vehicle during ascent.
Crew: 6

STS-95 10/29/1998
Drag chute door separated during launch and impacted main engine bell.
Crew: 7

STS-91 6/2/1998
Main engine pressure chamber sensor failed. If it occurred later, logic error may have triggered an RTLS.
Crew: 6↑/7↓

Soyuz TM-9 2/11/1990
DM insulation torn loose on ascent; contingency EVA repair.
Crew: 2

SRB Seal Events (1981-1996):

STS-51L 1/28/1986
SRB seal failure.
Crew: 7 Loss of Crew

Other SRB gas sealing anomalies: STS-2, 6, 11, 41D, 51C, 51D, 51B, 51G, 51F, 51I, 51J, 61A, 61B, 61C, 42, 71, 70, 78

STS-51F 7/29/1985
Temperature sensor problems resulted in Main Engine (ME-1) shutdown at T+5:45.
Crew: 7 Abort To Orbit

Soyuz 18-1 (18a) 4/5/1975
Electrical fault caused premature firing of half of the 2nd stage separation bolts, resulting in inability to fire remaining ones. Staging failure resulted in abort sequence being used at t = 295 seconds.
Crew: 2 Crew Injury, Loss of Vehicle/Mission

Apollo 13 4/11/1970
2nd stage center engine shutdown due to pogo oscillations.
Crew: 3

Apollo 12 11/14/1969
Lightning strike on ascent.
Crew: 3

Gemini 10 7/18/1966
1st stage oxidizer tank exploded at staging. No discernable affects. Nominal ascent.
Crew: 2

STS-112 10/7/2002
T-0 umbilical issues resulted in none of the 8 SRB Hold Down Post "A" pyrotechnic charges firing.
Crew: 6

STS-41D 6/26/1984
Following a pad abort, LH_2 leaked from SSME 3, resulting in a fire at the base of the orbiter.
Crew: 6

Soyuz T-10-1 (T-10a) 9/26/1983
Pad Booster fire/explosion.
Capsule Escape System used.
Crew: 2 Loss of Vehicle/Mission

STS-1 4/12/1981
SRB ignition pressure wave caused TPS and structural damage.
Crew: 2

Apollo 1 (AS-204) 1/27/1967
Crew cabin fire (electrical short + high pressure O_2 atmosphere).
Crew: 3 Loss of Crew

Gemini 6 12/12/1965
Main engine shutdown. Booster left unsecured on pad. Crew elected not to eject. Launched 3 days later.
Crew: 2

Progress M-12M (44P) 8/24/2011
Anomaly in fuel pressurization system led to shutdown of 3rd stage engine. Vehicle failed to reach orbit.
Crew: 0 Loss of Vehicle/Mission

STS-114 7/26/2005
A) Bird-strike on External Tank.
B) Loss of foam from External Tank PAL ramp.
C) TPS gap fillers protruding. Removed during third mission EVA.
Crew: 7

STS-93 7/23/1999
A) At T+5 a short on AC1 Phase A resulted in loss of SSME 1 Controller A and SSME 3 Controller B.
B) ME-3 H_2 leak: early LOX depletion and shutdown.
Crew: 5

Suborbital Flights

X-15 3-65-97 11/15/1967
Electrical short and crew error led to loss of control at 230,000 feet. First US spaceflight fatality.
Crew: 1 Loss of Crew

SpaceShipOne, 16P 9/29/2004
Uncommanded vehicle roll. Control regained prior to apogee.
Crew: 1

SpaceShipOne, 14P 5/13/2004
Flight computer unresponsive. Recovered by rebooting.
Crew: 1

Soyuz 18-1 (18a) 4/5/1975
After ascent abort, capsule landed on snowy slope above cliff. Parachute snagged and prevented fall.
Crew: 2

Lunar Missions

Apollo 13 4/13/1970
Explosion due to electrical short. Loss of O_2 and EPS.
Crew: 3 Loss of Mission

Apollo 10 5/22/1969
Switch misconfiguration resulted in lunar lander control problems.
Crew: 2

Apollo 11 7/21/1969
Engine arm circuit breaker knob broke off. Circuit breaker successfully reset allowing ascent.
Crew: 2

Earth Orbit

EVA Incidents Summary (1965-2011):

13 EVAs resulted in crew injury:
Gemini 10, Apollo 17, Salyut 7 PE-1, Salyut 7 VE-3, STS-61-B EVAs 1&2, STS-37, Mir PE-9, STS-63, STS-97/4A, STS-100/6A EVAs 1&2, STS-134/ULF6

13 EVAs were terminated early due to crew injury or system or operational issues:
Gemini 10, Gemini 11, STS-5, Mir PE-14 EVAs 3&4, STS-63, STS-80, ISS-9, STS-118/13A.1, STS-126/ULF2 EVAs 2&4, STS-125/HST, STS-127/2JA

40 EVAs resulted in inadvertent release of item(s).

358 total spacewalks through July 12, 2011.
127 (36%) have experienced significant incidents.

See the Significant Incidents in EVA Operations Graphic for more details. (spaceflight.nasa.gov/outreach/readersroom.html)

STS-133 2/26/2011
Experienced significant misalignment between orbiter and ISS during post-capture free drift due to gravity-gradient-induced motion.
Crew: 6

Soyuz TMA-18 (22S) 9/23/2010
First attempt to separate from ISS failed; ISS crew succeeded in bypassing faulty sensor.
Crew: Soyuz 3, ISS 3

STS-130 2/10/2010
Experienced significant misalignment between orbiter and ISS during post-capture free drift due to gravity-gradient-induced motion.
Crew: 6

ISS, Increment 17 4/30/2008
Freon 218 leaked from SM AC.
Crew: 3

ISS, Increment 13 8/2006
Triol coolant leak in SM.
Crew: 3

ISS, Increment 10 2/2005
Potential acid preservative aerosol escape from Russian urinal.
Crew: 2

ISS, Increment 5&6 mid-2002–2/03
Formaldehyde periodically exceeded long-term limits.
Crew: 3-10

ISS, Increments 2-4 4/2001–3/2002
Freon 218 leaked from SM AC.
Crew: 3

ISS, Increment 4 2/2002
MetOx regeneration caused noxious air – many pollutants.
Crew: 3

ISS 8/2001
Extremely high methanol levels in FGB air sample.
Crew: 3

STS-104 7/2001
EMU battery leaked hazardous KOH. Discovered during EMU checkout.
Crew: 5

STS-99 2/2000
High bacterial count in postflight sample after GIRA installed to removed iodine.
Crew: 6

ISS, Flight 2A.1 5/1999
Crew sickened in FGB; likely a result of high localized CO_2 levels due to poor ventilation.
Crew: 7

STS-95 10/29/1998
Preflight sterilization process chemically altered the Low Iodine Residual System resulting in contaminated drinking water.
Crew: 7

STS-91 6/2/1998
PASS corrupted by GPS error.
Crew: 6

STS-87 11/21/1997
Spartan satellite deployed without proper activation. Recapture with RMS unsuccessful. Later captured by EVA crew.
Crew: 6

STS-83 4/6/1997
Failure of fuel cell number 2 resulted in minimum duration flight being declared. The 15-day mission was shortened to 3 days.
Crew: 7 Minimum Duration Flight, Loss of Mission

STS-51 9/12/1993
Both port-side primary & secondary SUPER*ZIP explosive cords fired, resulting in containment tube failure and damage in the payload bay.
Crew: 5

STS-44 11/24/1991
Failure of IMU 2 caused minimum duration flight to be declared. 10-day mission shortened to 7 days.
Crew: 6 Minimum Duration Flight

STS-32 1/9/1990
Erroneous state vector up-linked to flight control system, causing immediate and unpredictable attitude control problems.
Crew: 5 Loss of Attitude Control

STS-9 12/8/1983
Two GPCs failed during reconfiguration for entry.
One GPC could not be recovered.
Crew: 6

Soyuz T-8 4/22/1983
Loss of rendezvous antenna prevented docking.
Crew: Soyuz 3 Loss of Mission

STS-2 11/12/1981
Fuel cell failure resulted in high levels of hydrogen in drinking water.
Crew: 2 Mission Terminated

Soyuz 21 8/24/1976
Separation from Salyut failed; ground command succeeded in opening latches.
Crew: 2

Gemini 8 3/16-3/17/1966
Stuck thruster caused loss of control and led to 1st US emergency deorbit.
Crew: 2 Emergency Deorbit

Mercury MA-9 5/16/1963
Electrical faults caused loss of some systems and need to perform manual entry. Also experienced high $PPCO_2$ levels in suit during entry operations.
Crew: 1 Manual Entry

Mir Collision Events (1994-1997):

Mir 6/25/1997
Progress M-34 collided with Mir. Spektr pressure shell ruptured. Spektr module isolated. Cables through hatchway impeded hatch closing.
Mir Crew: 3 Collision

Mir 8/30/1994
Progress M-24 collided with Mir during second docking attempt.
Mir Crew: 2 Collision

Mir 1/14/1994
Soyuz TM-17 collided twice with Mir during undocking.
Crew: Soyuz 2, Mir 3 Collision

Fire/Overheating Events (1971-2008):

ISS, 10/10/2008, Crew: 3
ISS, 9/18/2006, Crew: 3 *
ISS, 3/2005, Crew: 2

Mir * 2/26/1998
Overheating BMP beds produce health-threatening level of CO.
Crew: 2

Mir * 2/24/1997
Chemical oxygen generator (SFOG) failure resulted in fire.
Crew: 5

Mir, 10/1994, Crew: 6
STS-40, 6/1991, Crew: 7 *
STS-35, 12/1990, Crew: 7 *
STS-28, 8/1989, Crew: 5 *
STS-6, 4/1983, Crew: 4 *
Salyut 7, 9/1982, Crew: 3
Salyut 6, 1979, Crew: 3
Salyut 1, 6/1971, Crew: 3

* toxic byproducts released

Medical Evacuations (1976-1987):

Mir EO-2, 1987, Crew: 2
1 replaced early due to medical condition.
Salyut 7, 1985, Crew: 3
1 returned with visiting crew due to medical condition.
Salyut 5, 8/25/1976, Crew: 2
Early return of crew due to health effects from suspected toxic gases in space station.

Research Facility

Altitude Chamber O_2 Fire – Soviet 3/23/1961
Alcohol wipe hit hot plate and started fire in oxygen-rich test chamber.
Crew: 1 Loss of Crew

Atmospheric Flights

SR-71 1/25/1966
Loss of control at high speed and altitude.
Crew: 2 Loss of Crew (1)

SpaceShipOne, Flight 11P 12/17/2003
Left main gear collapsed.
Crew: 1

M2-F2 Lifting Body, Flight 16 5/10/1967
Multiple roll-overs on landing.
Crew: 1 Crew Injury

M21-D21 7/30/1966
D21 drone collided with M21 during launch, causing M21 breakup. Crew survived breakup but one was lost after water landing.
Crew: 2 Loss of Crew (1)

Entry

Soyuz TM-5 9/6/1988
Two deorbit attempts failed. Crew confined to DM due to OM being jettisoned prior to 1st deorbit attempt. Crew prevented erroneous firing of SM separation pyros.
Crew: 2

Soyuz T-11 10/2/1984
Partial failure of atmospheric entry control system.
Crew: 3

Soyuz 33 4/12/1979
Main engine anomaly caused final rendezvous abort. Backup engine burned 25 seconds too long on deorbit. Ballistic entry.
Crew: 2

Soyuz 11 6/30/1971
Pyrotechnic system failure resulted in crew module rapid depress.
Crew: 3 Loss of Crew

Gemini 5 8/29/1965
Erroneous entry data uplinked: crew manually corrected entry flight profile.
Crew: 2

Gemini 4 6/7/1965
Computer failure resulted in ballistic entry.
Crew: 2

Mercury MA-6 2/20/1962
False landing bag indicator light led to entry with retropack in place as precaution.
Crew: 1

Service/Descent Module Separation Failures (1961-2008):

Soyuz TMA-11 (15S), 4/19/2008, Crew: 3, 1 injured
Soyuz TMA-10 (14S), 10/21/2007, Crew: 3
Soyuz 5, 1/18/1969, Crew: 1
Voskhod 2, 3/19/1965, Crew: 2
Vostok 5, 6/19/1963, Crew: 1
Vostok 2, 8/7/1961, Crew: 1
Vostok 1, 4/12/1961, Crew: 1

TPS Entry Events (1981-2003):

STS-107 2/1/2003
TPS damage from ascent debris strike resulted in loss of crew and vehicle on entry.
Crew: 7 Loss of Crew

STS-51D 4/19/1985
TPS burn-through on left outboard elevon.
Crew: 7

STS-1 4/14/1981
Right-hand main landing gear door warped due to entry heating.
Crew: 2

Other significant STS TPS anomalies:
STS-6, 41B, 51G, 27*, 28, 40, 42, 45
* Most severe tile damage to date.

Descent

Soyuz TM-25 8/17/1997
Landing rockets fired at heat shield separation rather than at landing.
Crew: 3

Apollo ASTP 7/24/1975
N_2O_4 in crew cabin. Crew hospitalized for 2 weeks.
Crew: 3 Crew Injury

Soyuz 10 4/25/1971
Crew lost consciousness due to toxic atmosphere. All recovered.
Crew: 3 Crew Injury

Mercury MA-7 5/24/1962
RCS depletion at 80,000 ft.
Crew: 1

Landing and Postlanding

STS-134 6/1/2011
Brief fire observed between the left main landing gear tires during runway rollout.
Crew: 7

STS-108 12/17/2001
Violation of minimum landing weather requirements.
Crew: 7

STS-90 5/3/1998
Hard, fast landing due to human factors and rogue wind gust. Hardest STS landing to date.
Crew: 7

STS-37 4/11/1991
Several factors contributed to a low-energy landing 623 feet prior to the threshold of the runway at the backup landing location.
Crew: 5 Low Energy Landing

STS-51D 4/19/1985
Right brake failed (locked up) causing blowout of inboard tire and significant damage to outboard tire.
Crew: 7

STS-9 12/8/1983
A) Two APUs caught fire during rollout, B) GPC failed on touchdown, C) incorrect flight control rechannelization on rollout.
Crew: 6

STS-3 3/30/1982
Pilot induced oscillation during derotation. Stronger than predicted winds contributed.
Crew: 2

Soyuz 15 8/28/1974
Descended through an electrical storm during night landing.
Crew: 2

Apollo 15 8/7/1971
Landed with only 2 of 3 parachutes.
Crew: 3

Soyuz Impact Events (1967-1993):

Soyuz TM-15 2/1/1993
Rolled down hillside.
Crew: 2

Soyuz TM-14 8/10/1992
Hard landing impact. Hatch jammed, requiring cosmonauts to use tools to pry open.
Crew: 3

Soyuz TM-12 10/10/1991
Hard impact. News team reported capsule as "very dented."
Crew: 3

Soyuz TM-7 4/27/1989
Double-impact "hard landing."
Crew: 2 Crew Injury (1)

Soyuz T-7 12/10/1982
Landed on hillside and rolled downhill. One cosmonaut thrown from couch.
Crew: 2

Soyuz 36 7/31/1980
Landing rockets failed to fire resulting in ~30G impact.
Crew: 2

Soyuz 23 10/16/1976
Landed on frozen lake during blizzard. Delayed recovery.
Crew: 2

Soyuz 5 1/18/1969
Landing rockets failed to fire, resulting in a hard landing.
Crew: 1 Crew Injury

Soyuz 1 4/24/1967
Main and reserve parachutes failed.
Crew: 1 Loss of Crew

Mercury MR-4 7/21/1961
Inadvertent hatch pyro firing. Capsule sunk. Astronaut nearly drowned.
Crew: 1 Loss of Capsule

Acronyms

AC	Air Conditioner
APU	Auxiliary Power Unit
BMP	Microimpurities Removal System
CDRA	Carbon Dioxide Removal System
CMG	Control Moment Gyroscope
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DM	Descent Module
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
EV	Extravehicular
EVA	Extravehicular Activity
FSO	Flight Safety Office
GIRA	Galley Iodine Removal Assembly
GPC	General Purpose Computer
GPS	Global Positioning System
H_2	Hydrogen
IMU	Inertial Measurement Unit
ISS	International Space Station
KOH	Potassium Hydroxide
LH_2	Liquid Hydrogen
LOC	Loss of Crew
LOV	Loss of Vehicle
MDF	Minimum Duration Flight
ME	Main Engine
MetOx	Metal Oxide
MMOD	Micro-Meteoroid Orbital Debris
N_2O_4	Nitrogen Tetroxide
O_2	Oxygen
OM	Orbital Module
OSMA	Office of Saftey & Mission Assurance
PAL	Protuberance Air Load
PASS	Primary Avionics Software System
RCS	Reaction Control System/Subsystem
RMS	Remote Manipulator System
RTLS	Return to Launch Site
SFOG	Solid Fuel Oxygen Generator
S&MA	Safety & Mission Assurance
SM	Service Module
SRB	Solid Rocket Booster
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
TPS	Thermal Protection System
US	United States

Visit the NASA Human Spaceflight Readers' Room (http://spaceflight.nasa.gov/outreach/readersroom.html) for the latest version of the Significant Incidents and Close Calls in Human Spaceflight chart.

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The *Significant Incidents and Close Calls in Human Spaceflight* graphic is primarily focused on human spaceflight incidents that have occurred while a crew was aboard a space vehicle. It includes suborbital, orbital, and lunar missions. The two ground facility events and two atmospheric flight events are included due to the significance of the events to spaceflight. The altitude chamber O_2 fire in Russia occurred prior to the loss of the Apollo 1 crew in an O_2 fire and could have served as a lesson learned had it been known in the US. The EMU fire resulted in the redesign of the EMU and heightened awareness of design and materials selection for man-rated systems using a pure O_2 environment. The M2-F2 lifting body accident occurred during the development of the space shuttle and yielded human engineering lessons learned. The SR-71 accident is the highest and fastest vehicle breakup on record that was survivable, and it represents the demonstrated limit of crew survival with currently fielded technologies. *Note: This document is a work in progress. It is continually under review and frequently updated. Please direct comments and questions to the Flight Safety Office contacts at right.*

NASA’s Human Research Program
Hazards of Spaceflight

Altered Gravity - Physiological Changes

Balance Disorders
Fluid Shifts
Cardiovascular Deconditioning
Vision Impairment
Muscle Atrophy
Bone Loss

Space Radiation

Acute In-flight effects
Long term cancer risk

Distance from earth

Drives the need for additional “autonomous” medical care capacity – cannot come home for treatment

Hostile/ Closed Environment

Vehicle Design
Environmental – CO_2 Levels, Toxic Exposures, Water, Food

Isolation & Confinement

Behavioral aspect of isolation
Sleep disorders

Exploration Habitat Design Challenges

- Physiological and Psychological Well-being
  - Designing for Health & Wellness in mind
- Long-Term Isolation and Confinement Psychological Challenges
  - Astronaut Diaries & Research, Jack Stuster
  - Distance from “Home” & Earth
- Human Research Program: Identifying & Mitigating Human Health & Well-being Risks
- Internal Architecture
  - Adaptive, Biomimicry, Feelings and Comforts of Home, Diurnal Cycle

Design & Evaluation Criteria

CRITERIA:

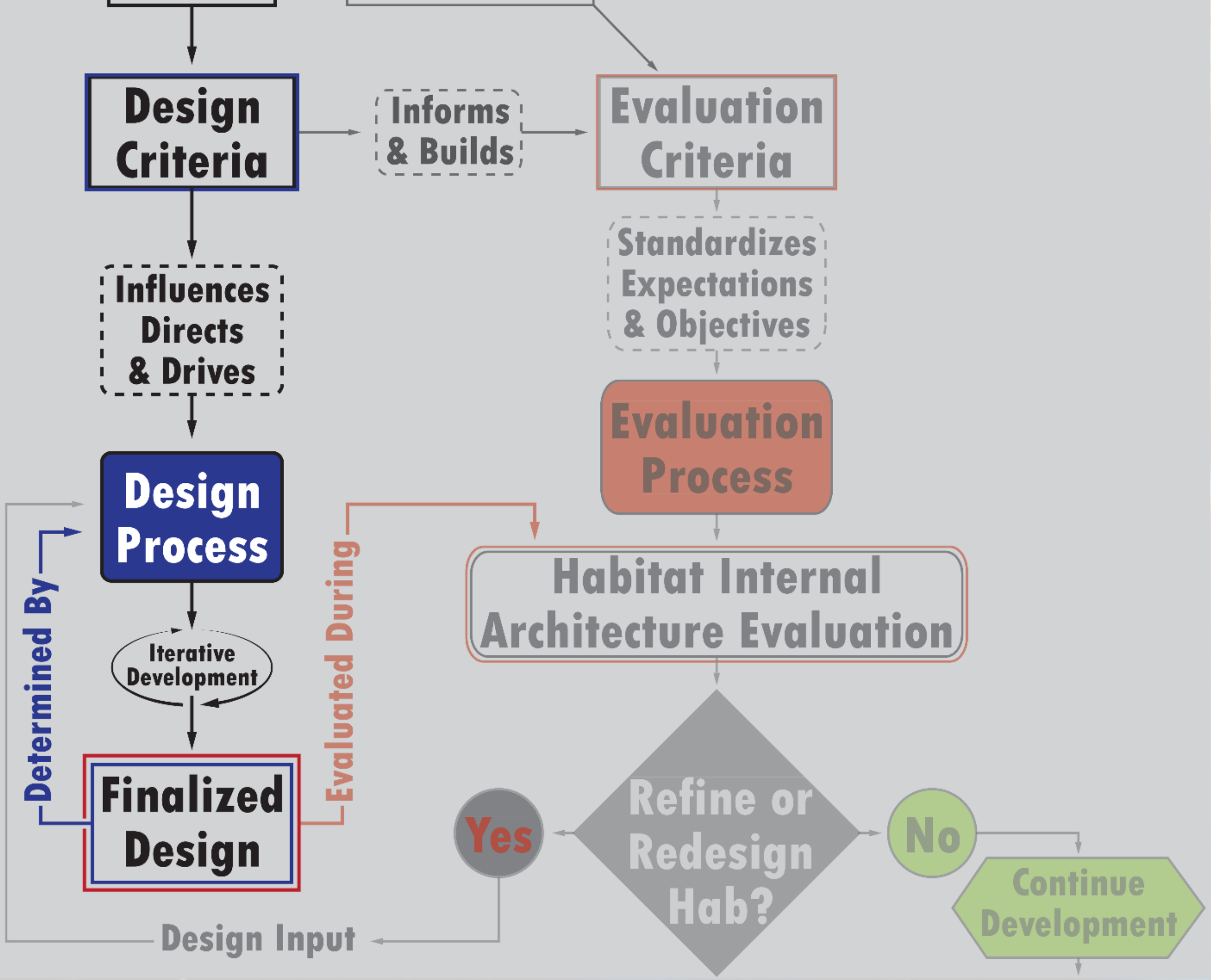
Principles or Standards by which something may be **Defined** or **Understood**

Design Criteria & Process

The Design Process is the method in which designers **Define** the forms, functions, and performance of their concept that addresses the needs and constraints provided by the project's design criteria or other guidelines.

Evaluation Criteria & Process

The Habitat Internal Architectural Evaluation is the activity in which the design's forms, functions, and performance are **Evaluated** based on expectations and objectives defined by interdisciplinary teams.



Design Criteria

Informs & Builds

Evaluation Criteria

Influences Directs & Drives

Standardizes Expectations & Objectives

Design Process

Evaluation Process

Iterative Development

Determined By

Evaluated During

Habitat Internal Architecture Evaluation

Finalized Design

Refine or Redesign Hab?

Yes

No

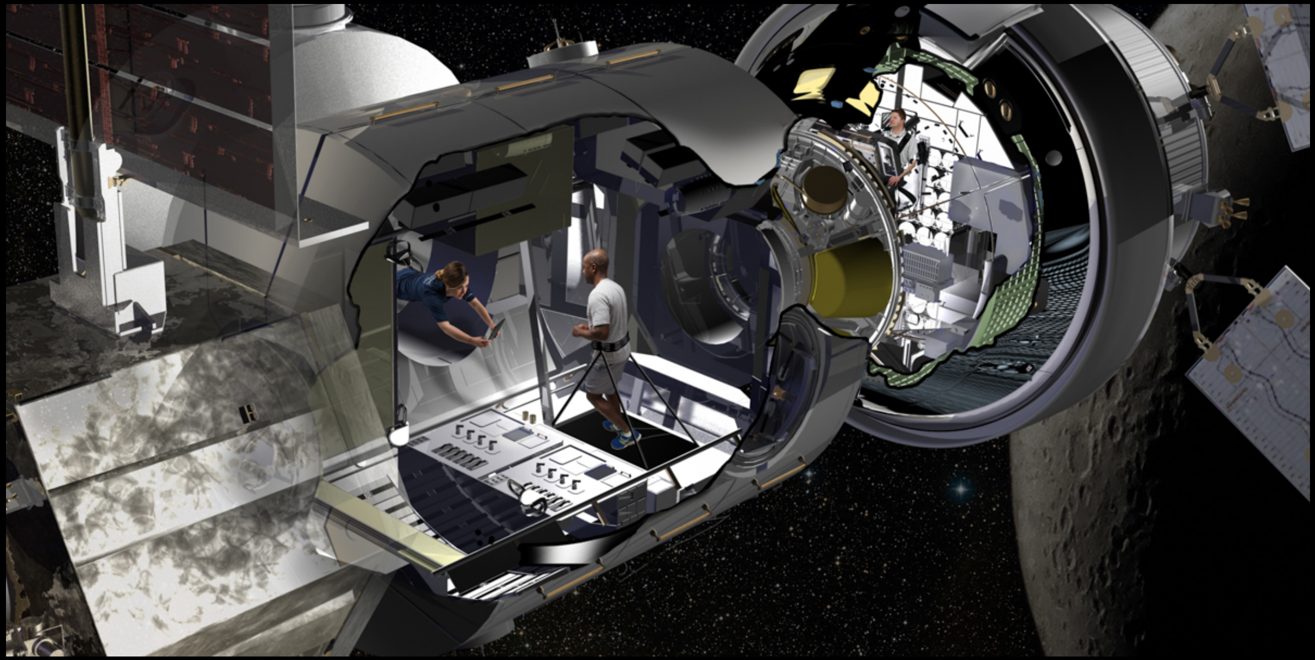
Continue Development

Design Input

Exploration Habitat Design Criteria
Multi-Discipline

- **Programmatic**
  - **Constraints**: Technical Risk, Cost, Schedule, and Mass.
  - **Longevity**: Upgradability, Extensibility, Robustness, and Maintainability.
  - **Strategy**: Mission Objectives, Political Alignments, and Stakeholder Agreements.
- **Human Systems Integration**
  - **Behavioral Health**: Public and Private Spaces, Spatial Organization, Social Territories, Cultural Expression, Wayfinding, and Experience.
  - **Ergonomics**: Accessibility, Anthropometry, Microgravity Habitation, Injury Mitigation, and Usability.
  - **Internal Habitat**: Organization of Hardware and Crew Systems, Crew Activities, Interactability, Variations of Use, Operational Efficiency, Scale of Spaces, Spatial Relations, Traffic and Movement, Orientation, and Environmental Quality.
- **Operations & Training**
  - **Interaction between Crew and Spacecraft**: Object Management, Ease of Learning, and Knowledge Capture.
  - **In-Situ Education**: On-Orbit and Just-In-Time.
  - **Ground Crew:** Mission Operations Support and Situational Awareness
  - **On-Orbit Crew Activities**: Variations of Crew Activities, Task Performance, Workstation Use and Autonomy
- **Engineering**
  - **Design Margins**: Reliability, Reusability, Technology, and Materiality.
  - **Levels of Testing**: Components, Assemblies, and Subsystems Validation and Verification, and Integrated Testing.
  - **Systems Design**: Functional Allocation, Design Integration, Ease of Modification, IVA Support for External Equipment, Minimized Secondary Structure, Stowage Design, and Modularity.
  - **Sustainability**: Preventative Maintenance, Longevity, Repairability, Automation, and Commonality.
- **Manufacturing and Assembly**
  - **Element Manufacturing**: Efficiency of Production, Assembly, Integration, Manufacturing Techniques, and Schedule.
  - **Ground Processing**: Pre-Launch Integration, Cargo Loading, and Activation through Closeout.
  - **On-Orbit Internal Integration**: Deployment and In-Situ Assembly.

Internal Architecture VR Evaluations



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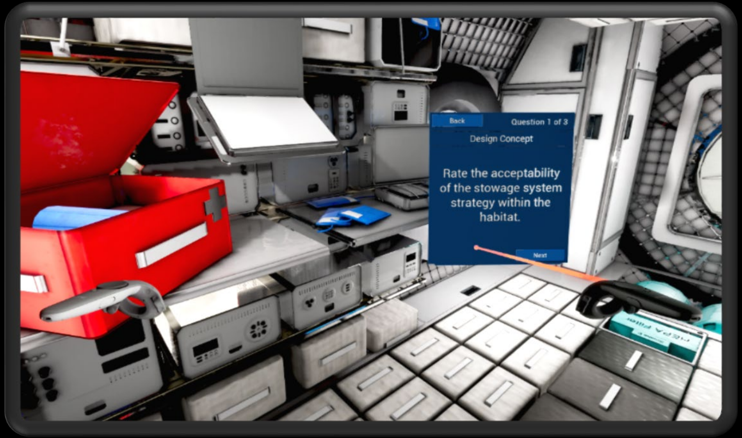
Back Question 1 of 3

Design Concept

Rate the acceptability of the stowage system strategy within the habitat.

Next



Back Question 1 of 3

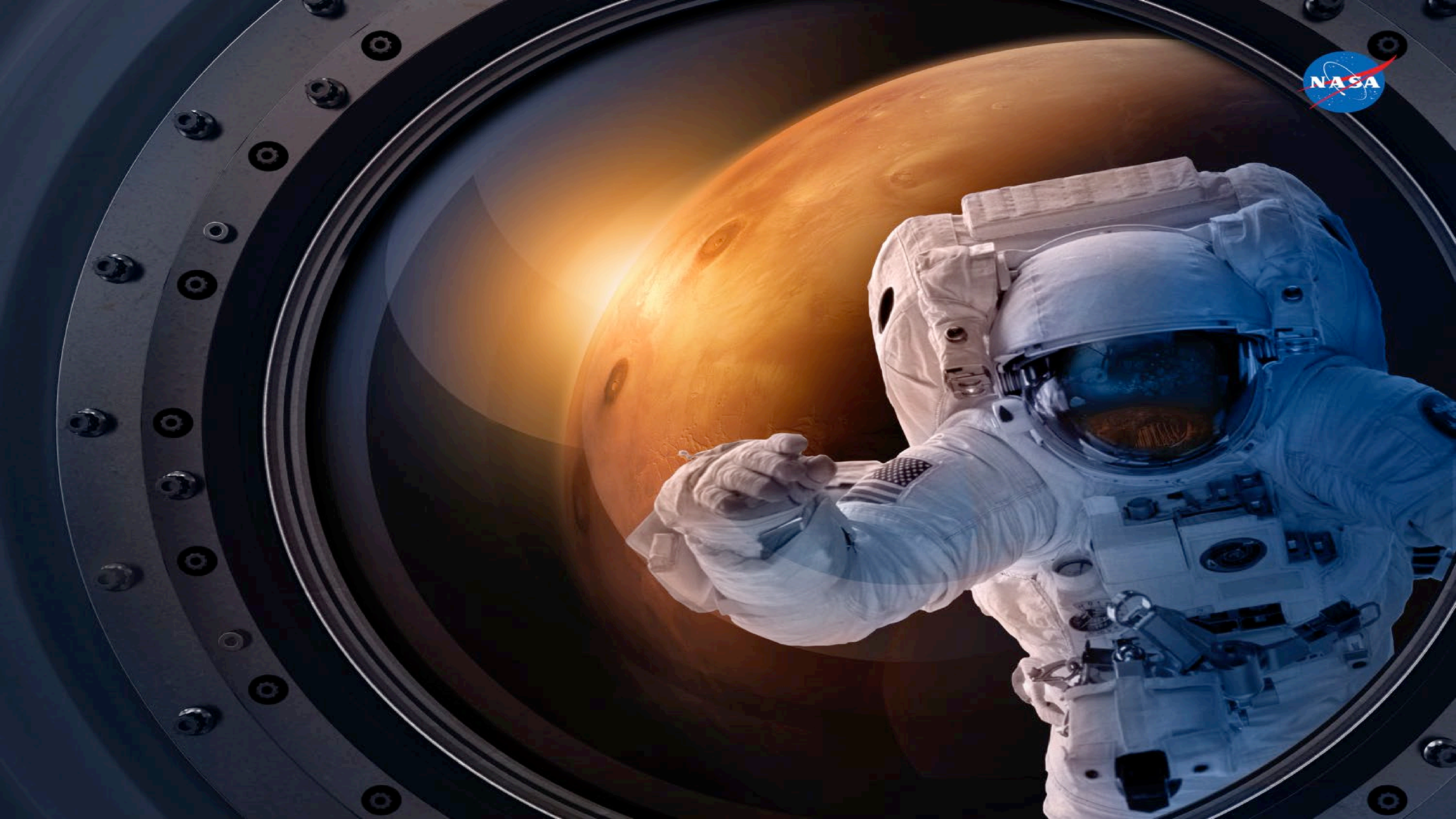
Design Concept

Rate the acceptability of the stowage system strategy within the habitat.

Next

Summary

- Deep Space Human Missions mandate design for Human Physiological and Psychological Well-being
  - Long-Term Isolation and Confinement Psychological Challenges
  - Designing for Health & Wellness in mind
  - Astronaut Diaries & Research, Jack Stuster
  - Distance from “Home” & Earth
- Human Research Program: Identifying & Mitigating Human Health & Well-being Risks
- Internal Architecture
  - Adaptive, Biomimicry, Feelings and Comforts of Home, Diurnal Cycle
- A Multi-disciplinary Design & Management Approach
  - Complex Problems call for Diversity, Inclusion, and Innovation
  - Human Systems Integration
  - Understand the diverse needs of Users (astronauts and trainers), Customers, and Stakeholders



Automation and Technology as “Team Players”

Chris Miller– Smart Information Flow Technologies

SIFT

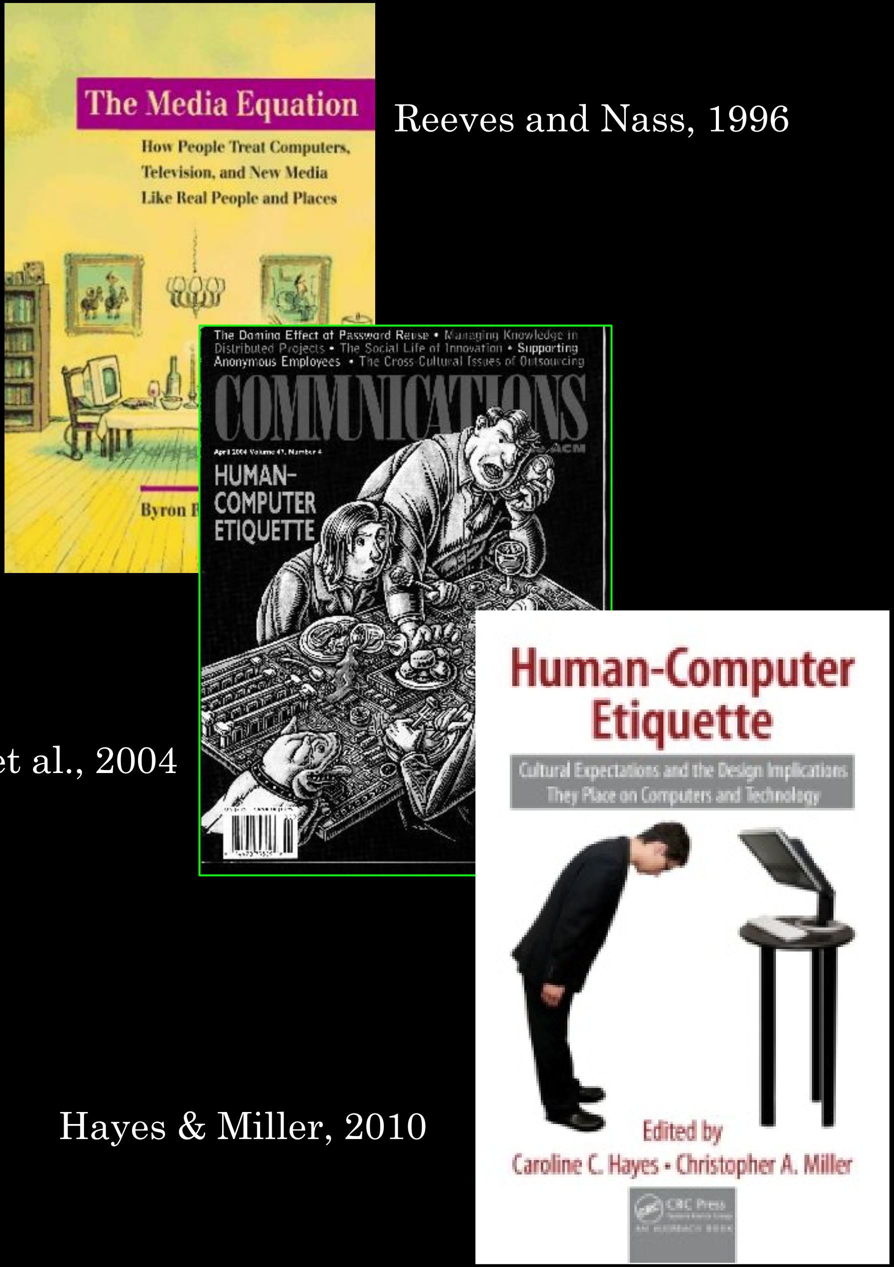
The Crew Habitat Experience

- Homogenous and monotonous experiences (visual and social)
  - Visual experience is better on-planet, but still not earth-normal
- Time lags increase separation/disruption from diverse human interactions
- Surrounded (literally and psycho-socially) by technology


[redacted] [redacted] [redacted] [redacted] [redacted]

Technology (Automation) in Habitats

- Technology is omnipresent in habitats
- HF engineers tend to think of functionality and safety in design
- Tech can facilitate or inhibit… or monitor … or influence… human-human social interactions
- But Tech can also be a “social actor”
  - For better and for worse



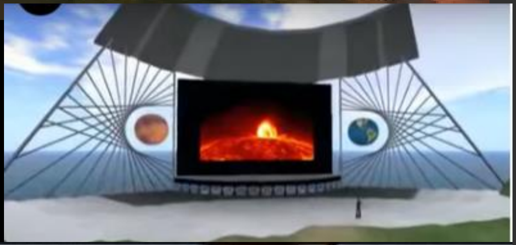
Reeves and Nass, 1996

Miller, et al., 2004

Hayes & Miller, 2010

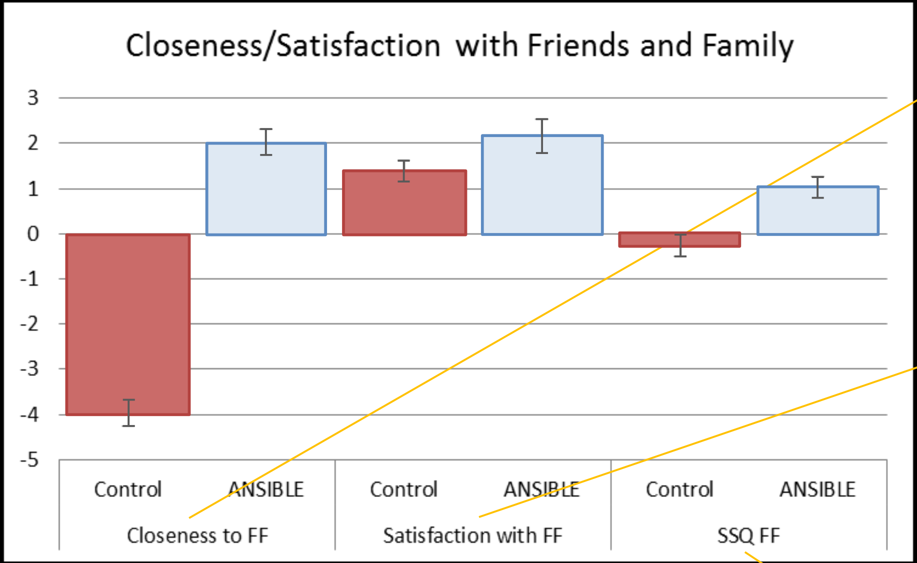
ANSIBLE– Tech as Mediator

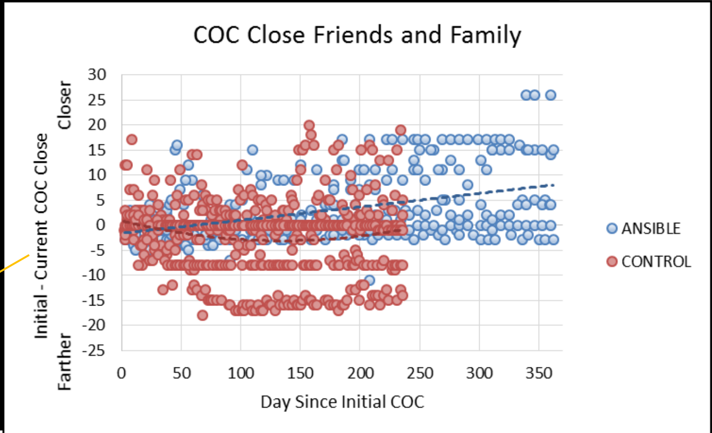
- A Network for Social Interactions for Bilateral Life Enhancement
- Multi-modal toolset used pre, during, and post flight to connect a flight crew with their family, friends, and the ground crew
- Adapts, rearranges, and modifies human interaction streams to minimize the disruptive impact of communication latencies
- Leverages virtual worlds (VW) to provide a space where humans and intelligent virtual agents (VA) can be companions, advisors, provided psychological support, and share experiences.
- 3+ year NASA exploratory effort

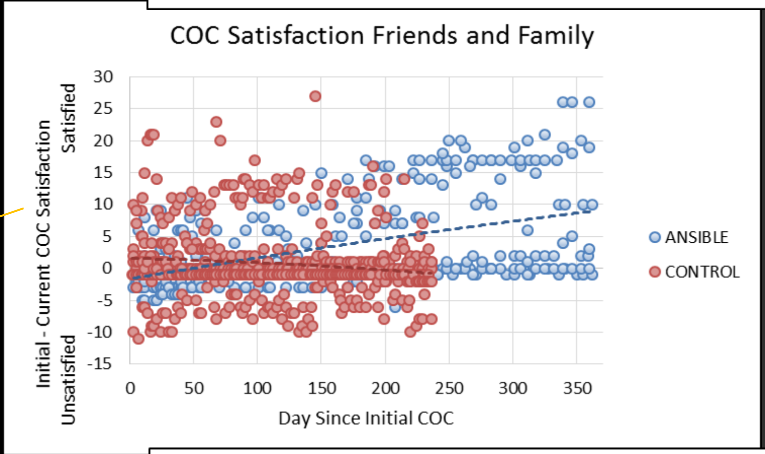


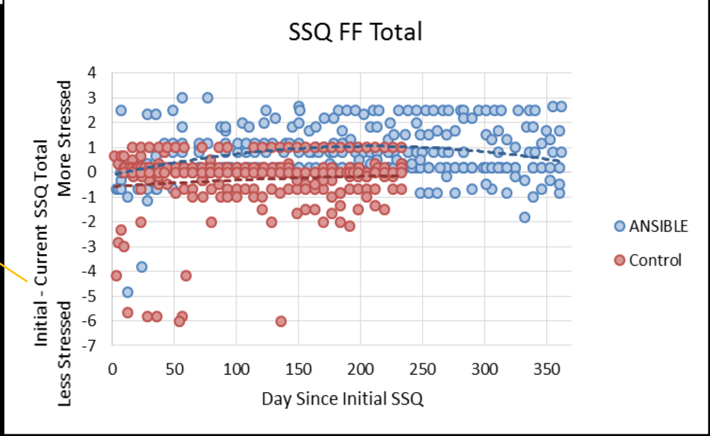
Results of Two HI-SEAS Field Tests

- 8 month habitat study without ANSIBLE
- 12 month habitat study with ANSIBLE



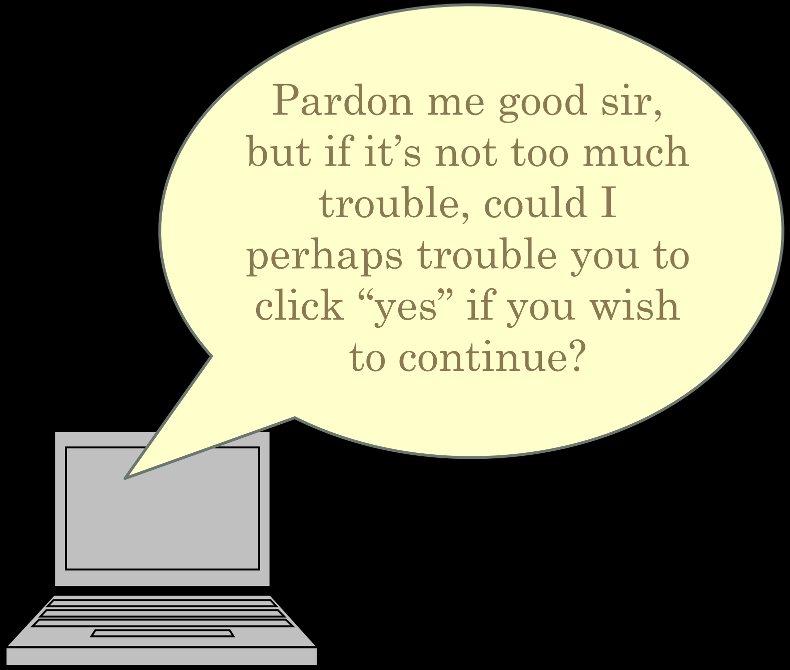


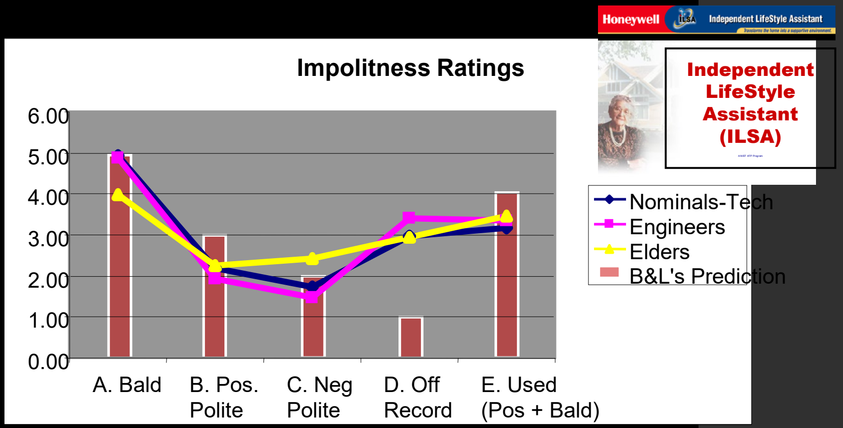


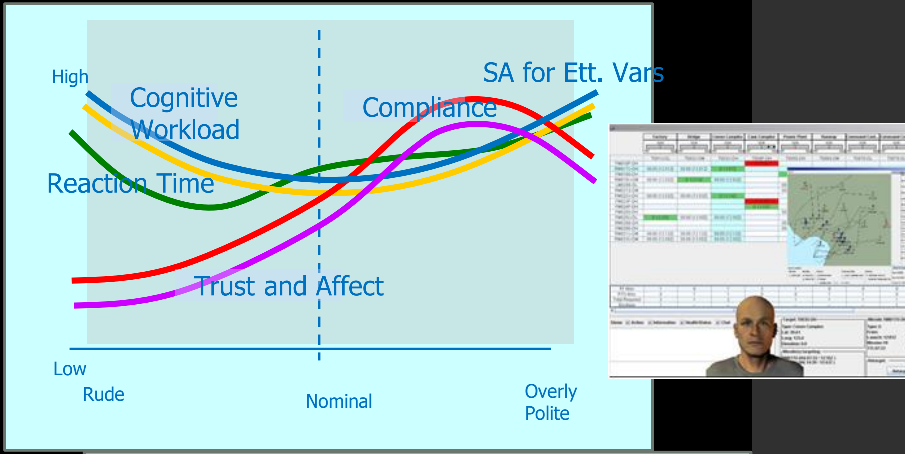


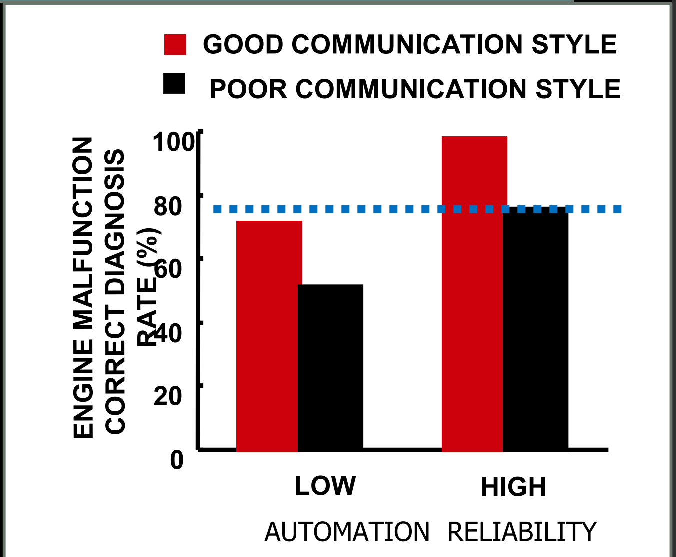
Tech as Social Actor

- Nass’s CASA results predict that, frequently, automation will be have the same effects as a human actor in the same role
- “Etiquette Principle” says ‘if a human, acting via this medium, were to act this way, how would they be regarded? Is that regard desirable in design?’









BASIC HUMAN NEEDS

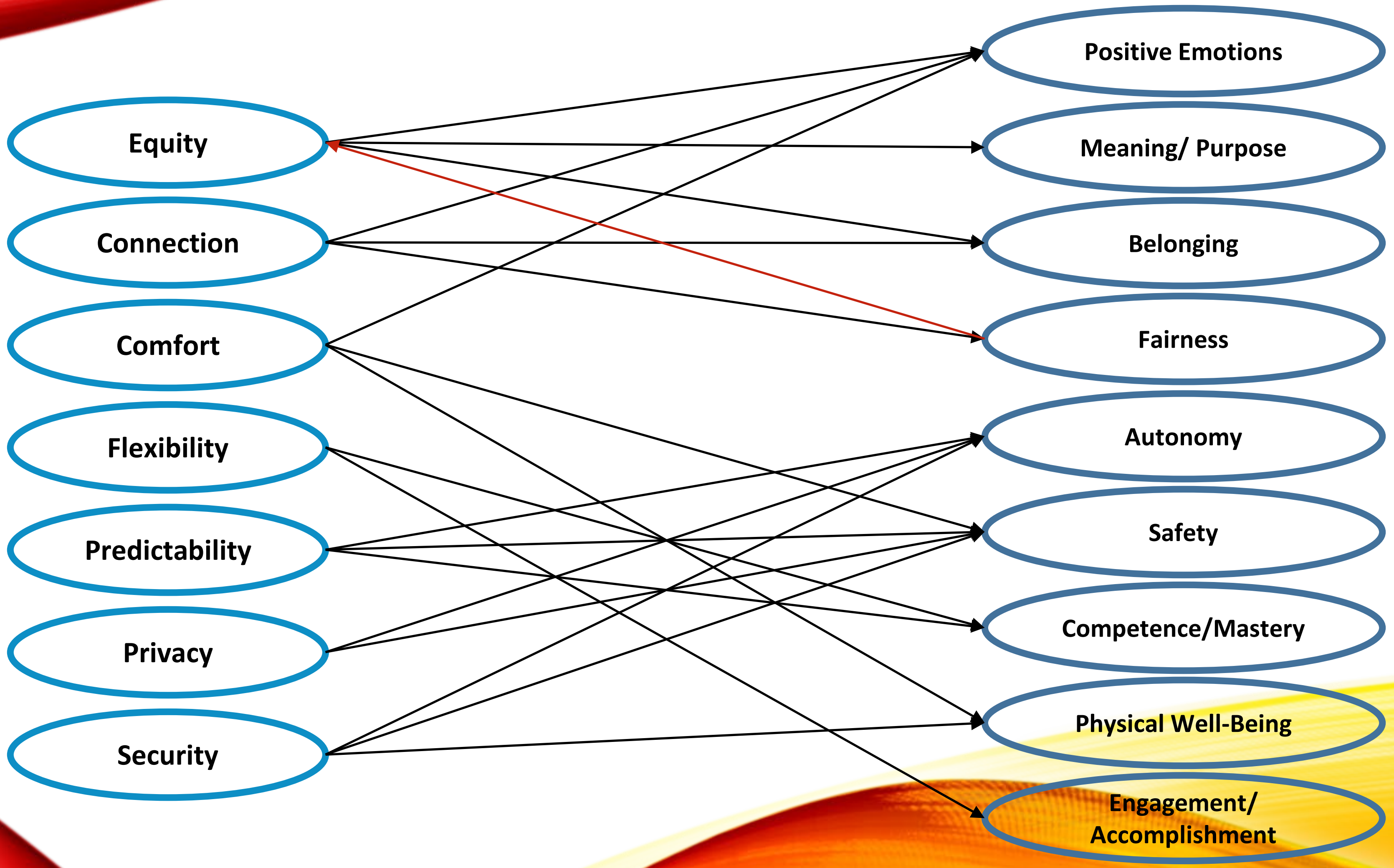
Cristina Banks, PhD
Interdisciplinary Center for Healthy Workplaces, UC Berkeley

SCIENTIFIC FINDINGS

- Satisfaction of basic human needs leads to health, well-being, and productivity (e.g., Maslach & Banks, 2017; Deci & Ryan, 2000)

- Basic needs most relevant to spacecraft habitat are:
  - Autonomy
  - Belongingness
  - Competence/Mastery
  - Positive Emotions
  - Fairness
  - Meaning/Purpose
  - Safety

How do we design for need satisfaction?



Equity
Connection
Comfort
Flexibility
Predictability
Privacy
Security

Positive Emotions
Meaning/ Purpose
Belonging
Fairness
Autonomy
Safety
Competence/Mastery
Physical Well-Being
Engagement/ Accomplishment

healthyworkplaces
AN INTERDISCIPLINARY CENTER

DESIGN CONSIDERATIONS

- How to build comfort into the spacecraft?
- How to ensure physical and psychological safety?
- How to make systems more predictable?
- How to strengthen social connections?
- How to build flexibility into the routine?
- How to create privacy on-demand?
- How to demonstrate equity?

Building on What We Know to Create Solutions for the Mars Mission

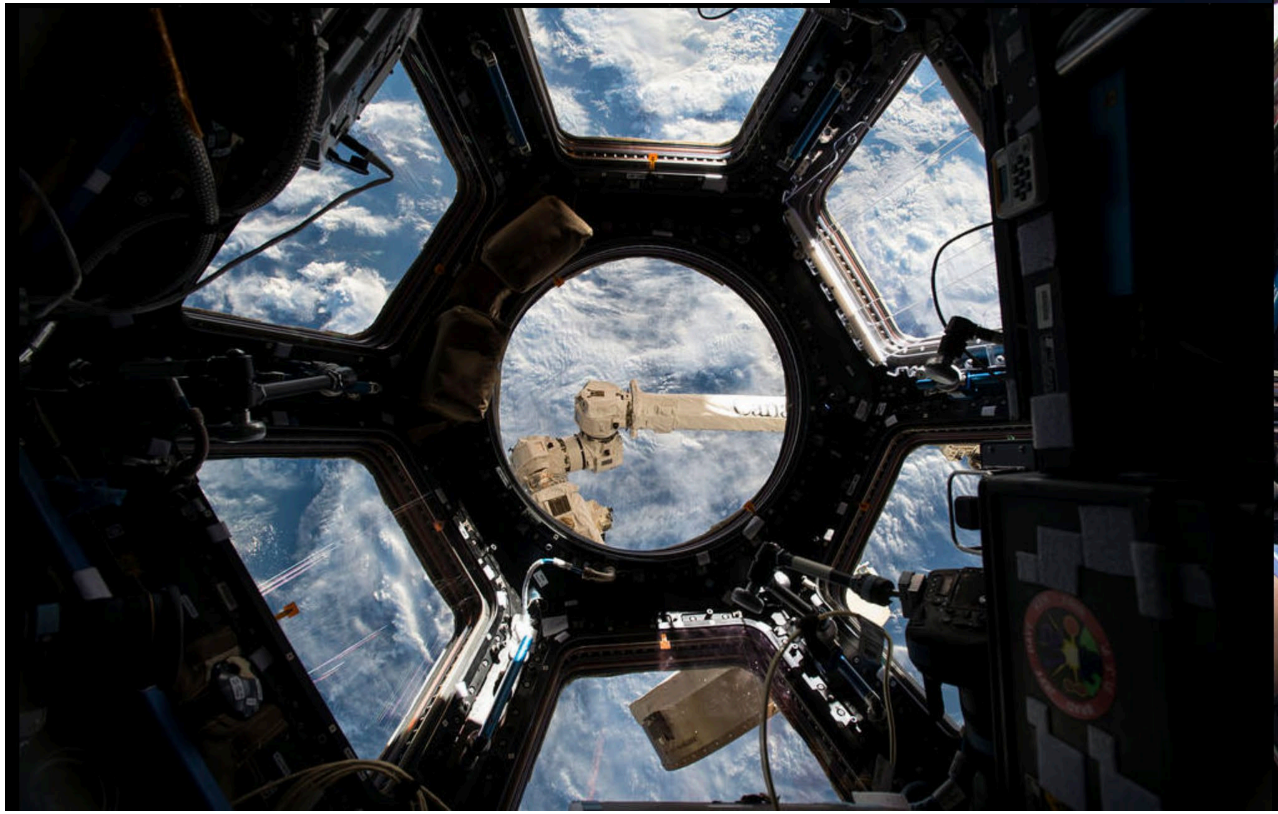
Andrew S. Imada

It’s a complex system – Act accordingly

- Focus on the mission, not HFE
  - HFE as a means, not an end
  - Frame HFE as a solution to problems and mission goals
- Human habitability is only one element
  - Recognize the value of each silo and their interdependencies
  - Engage “foreigners” in HFE to solve their problems (boundary spanning)
- FAB
  - **F**eature – anthropometrically appropriate space suit
  - **A**dvantage – fits wider range of users, more comfortable
  - **B**enefit – reduces costs, inventory, more productivity, successful space walks

Focus on successes and lessons that enhance human performance and habitability in space (Appreciative Inquiry)

- Selection for Apollo, Gemini and Space Station and now, long term teamwork
- Training – VR fidelity with math and physics enhances performance
- Orion and Lunar Gateway interface design (compatibility)
- Space Station
  - LM Base Camp proposal includes Space Station-like two Orion systems
  - 3-D printing
  - Cupola



Find Champions

- Use HFE or HSI organizations within directorates as entry points

- Engage stakeholders, SMEs in HFE decisions (Participatory Ergonomics)
  - Crew from previous and future flights
    - Rapid prototyping
    - Task analyses
    - Preferences, compatibility
  - Non-fliers with long term experience (Space Station crews)
  - Decision makers experience in mock ups to feel design and understand technical performance requirements (e.g., Annunciator)

What we know and what we can contribute

- We have a lot to contribute to mission success.
  We played important roles in previous missions.

- We don't know everything about the context; few do.
  We do know about human interactions, which are key to success in space.

- We understand the dynamics of humans in unusual environments.
  How we choose who is there, what they are doing and their interactions with others are critical to mission success.

This is classic HFE