Risk and Analogs in Human Spaceflight

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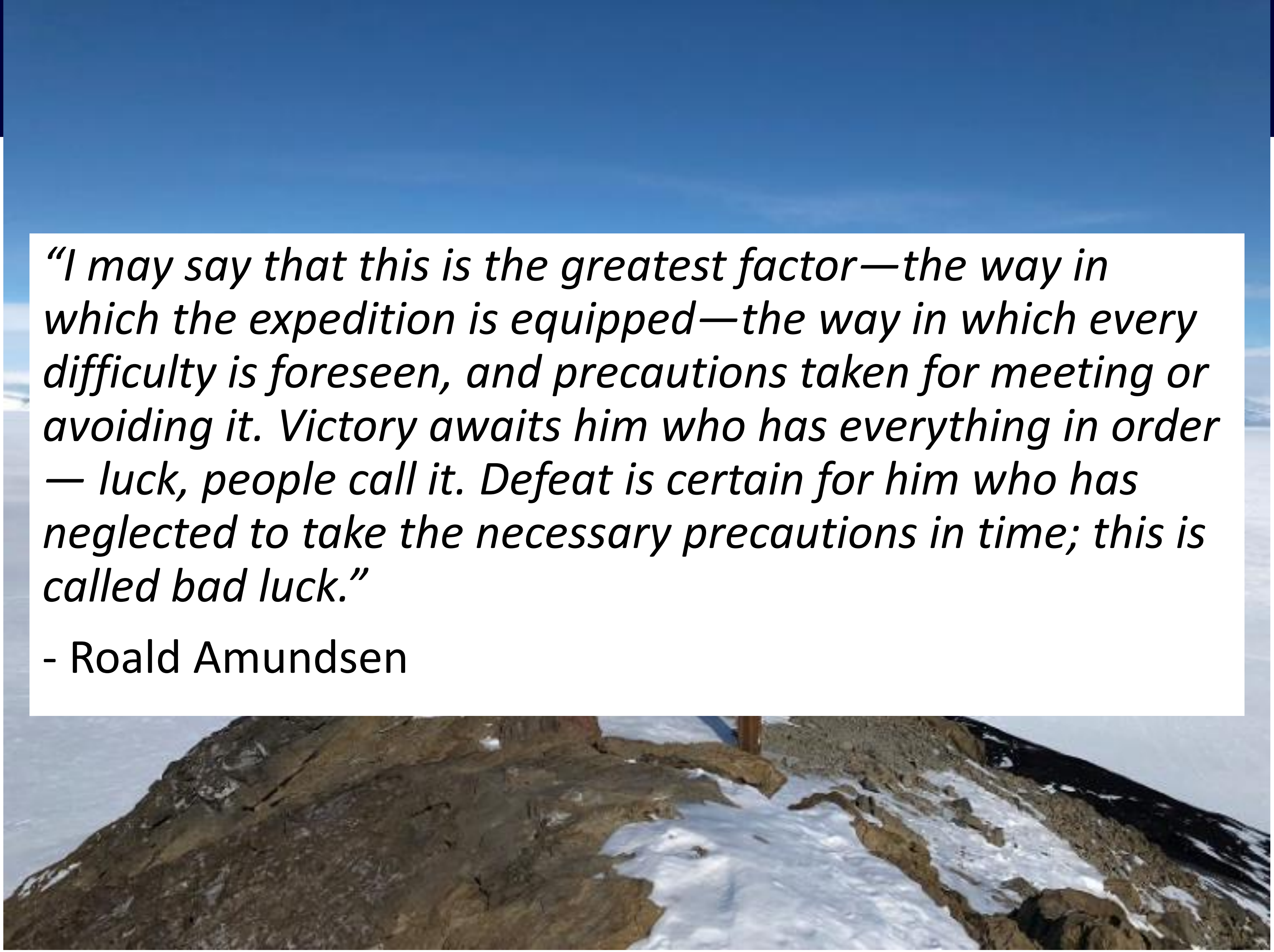
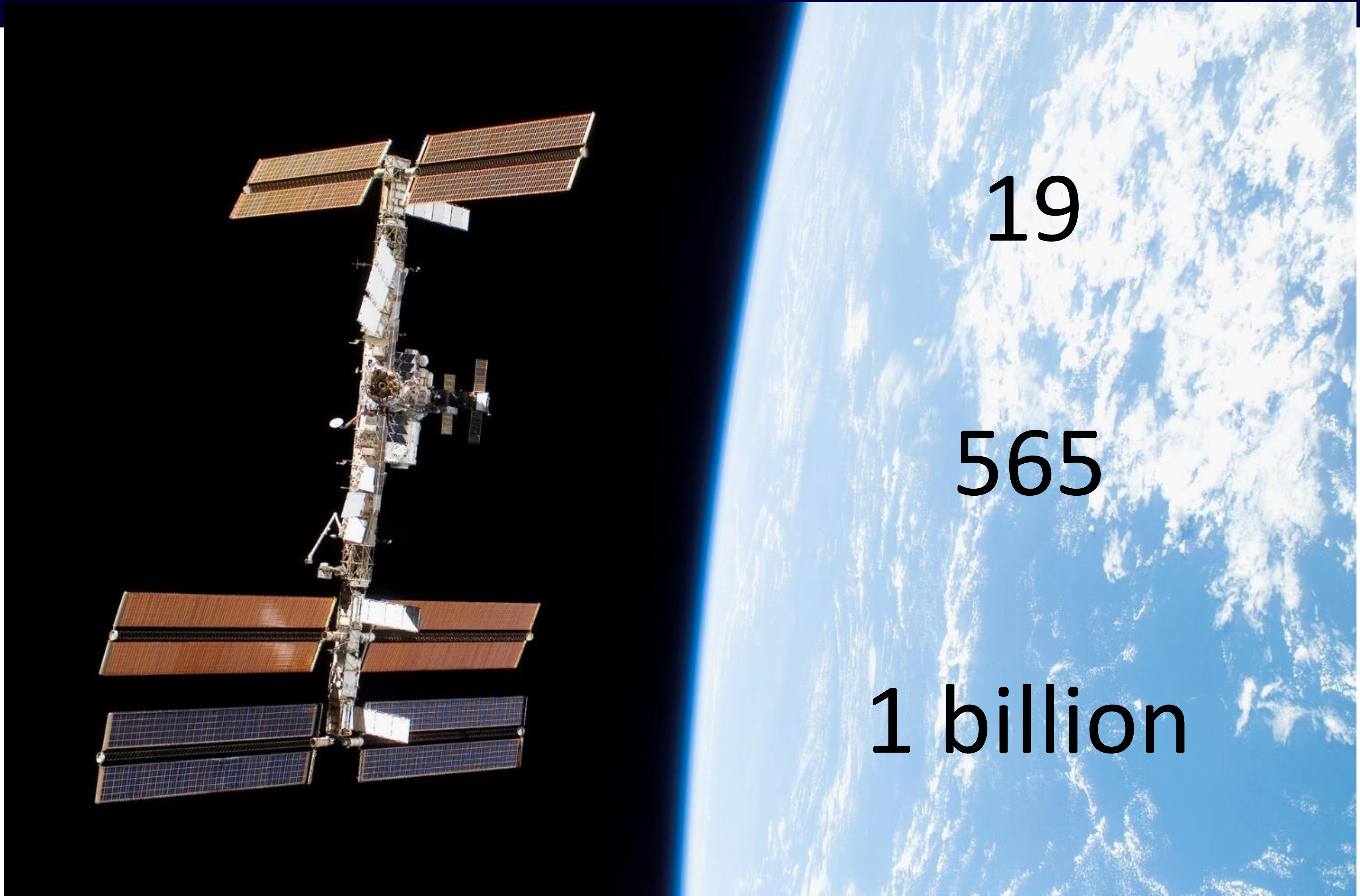
02/20/2020



"I may say that this is the greatest factor—the way in which the expedition is equipped—the way in which every difficulty is foreseen, and precautions taken for meeting or avoiding it. Victory awaits him who has everything in order — luck, people call it. Defeat is certain for him who has neglected to take the necessary precautions in time; this is called bad luck."

\- Roald Amundsen

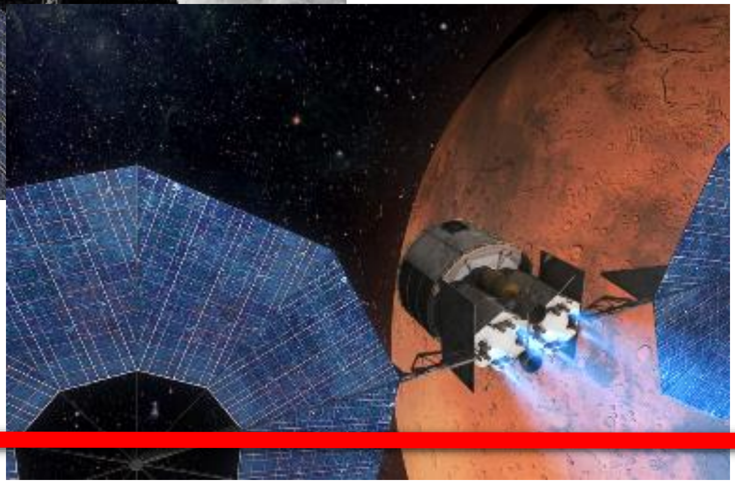
Complex Engineered Systems



Progressive Earth Independence

- Real Time Communications
- Evacuation Capability (1.5 – 36 hrs)
- Strong Consumables Resupply

- Near Real Time Communications
- Evacuation Capability (**3 – 11 days**)
- **Limited** Consumables Resupply

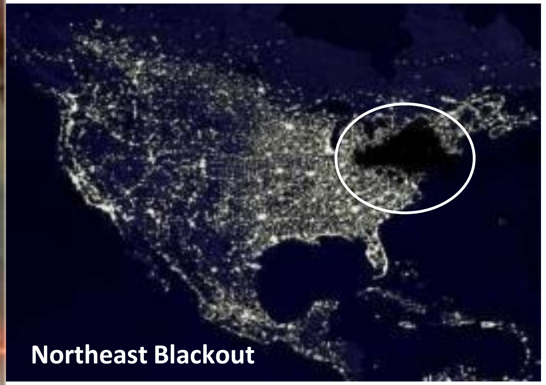


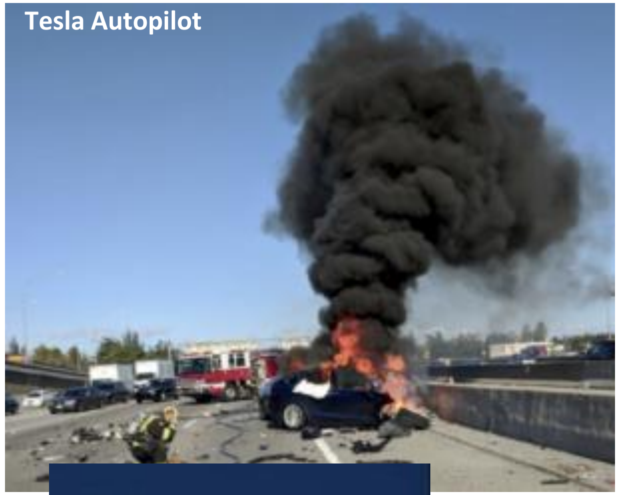
- **No** Real Time Communications
- **No** Evacuation Capability
- **No** Consumables Resupply

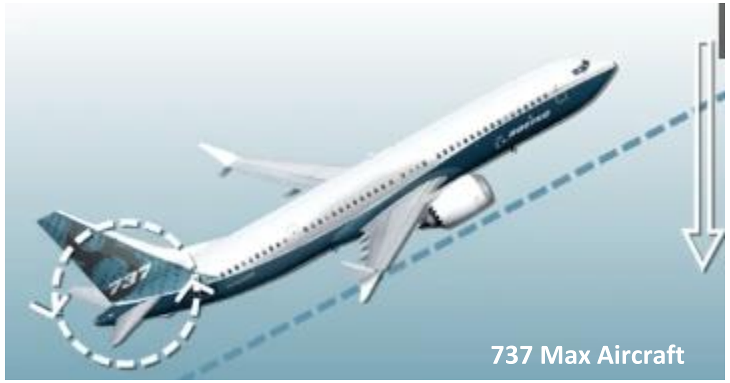
Increasing Exposure to Hazards

Complex Engineered Systems

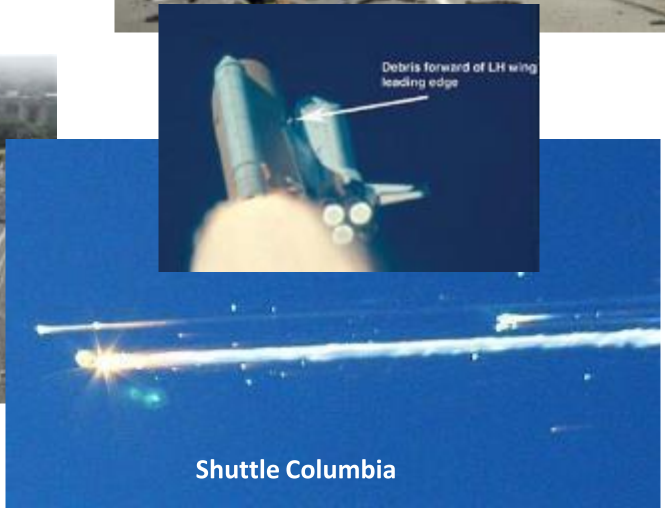

Deepwater Horizon Drilling Vessel


Northeast Blackout


Tesla Autopilot

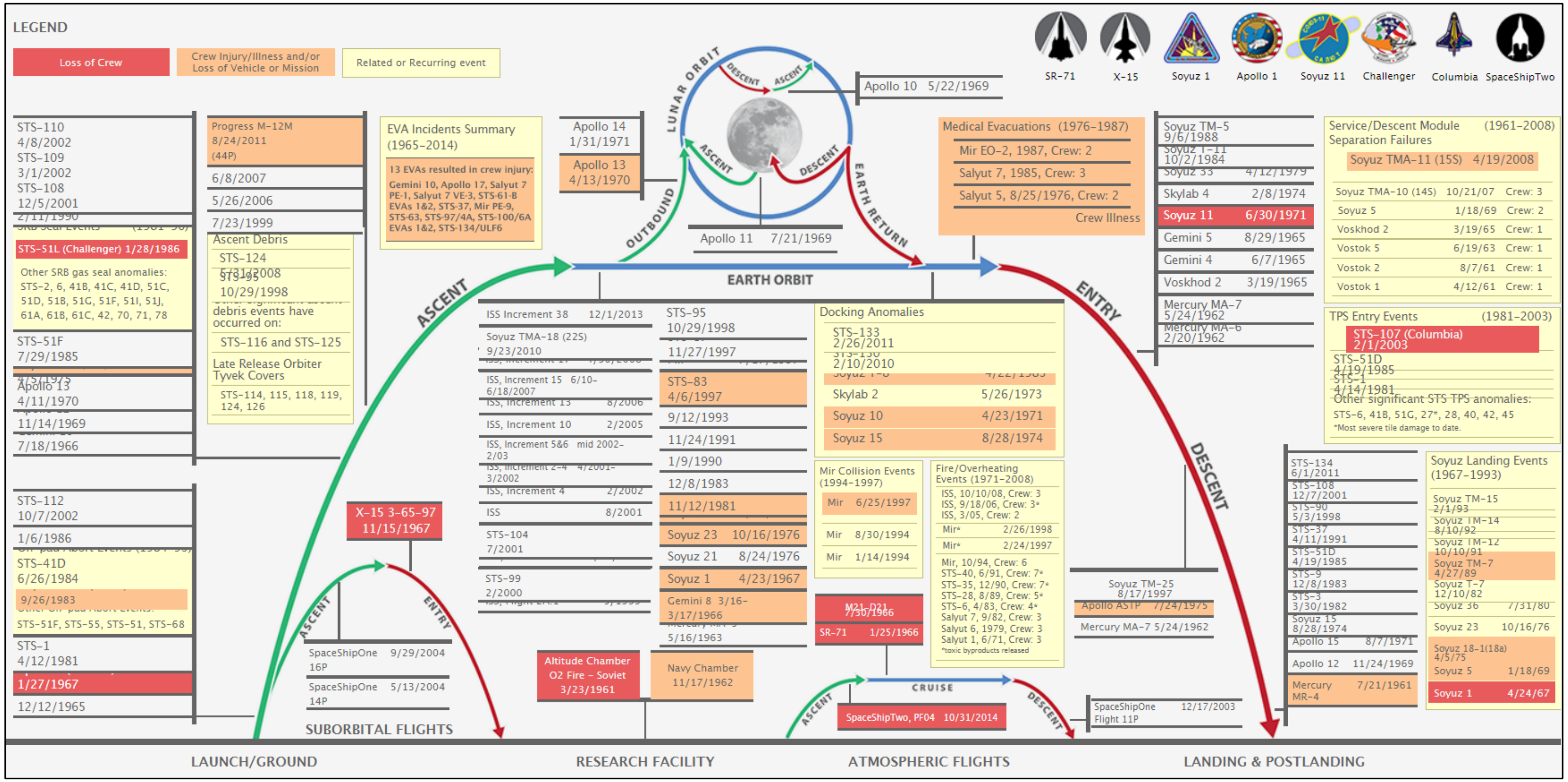

737 Max Aircraft


Spain Rail Accident



Shuttle Columbia

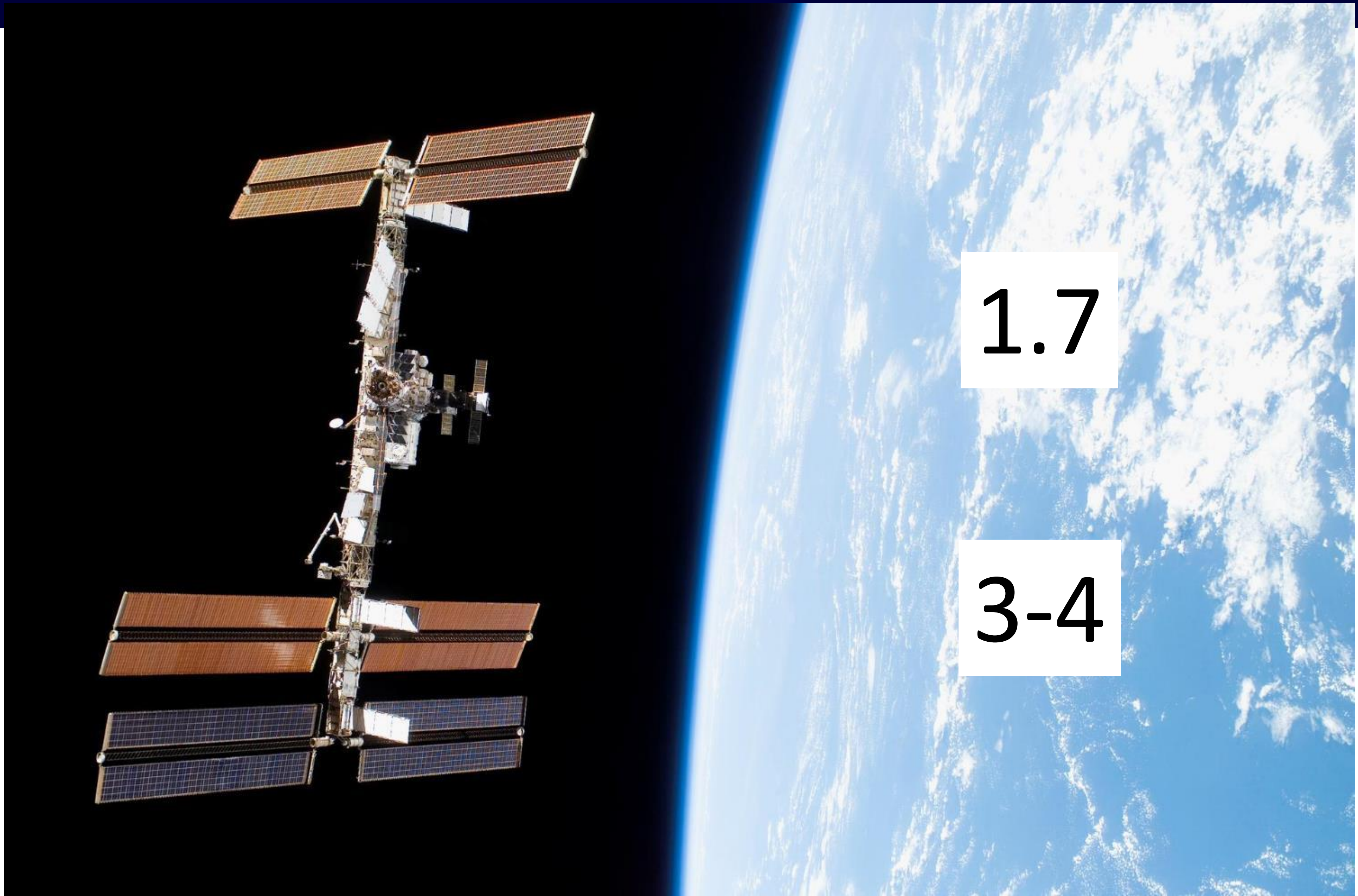
Significant Incidents & Close Calls in Human Spaceflight



- The "***Significant Incidents and Close Calls in Human Spaceflight***" chart was created and is maintained by JSC's Flight Safety Office to raise awareness of lessons learned through the years.

Publicly available:
https://spaceflight.nasa.gov/outreach/SignificantIncidents/index.html

Complex Engineered Systems

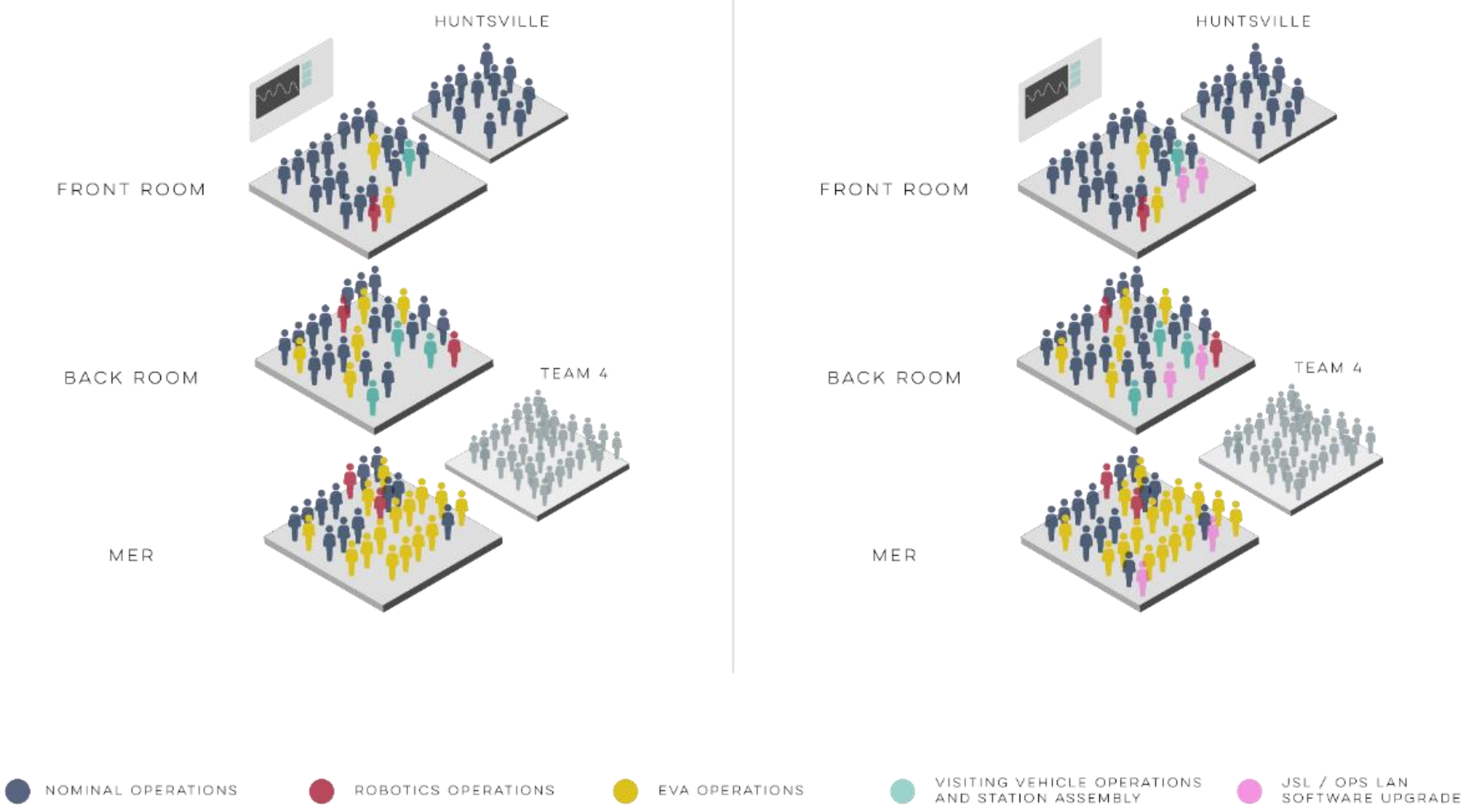


What does autonomous mean?

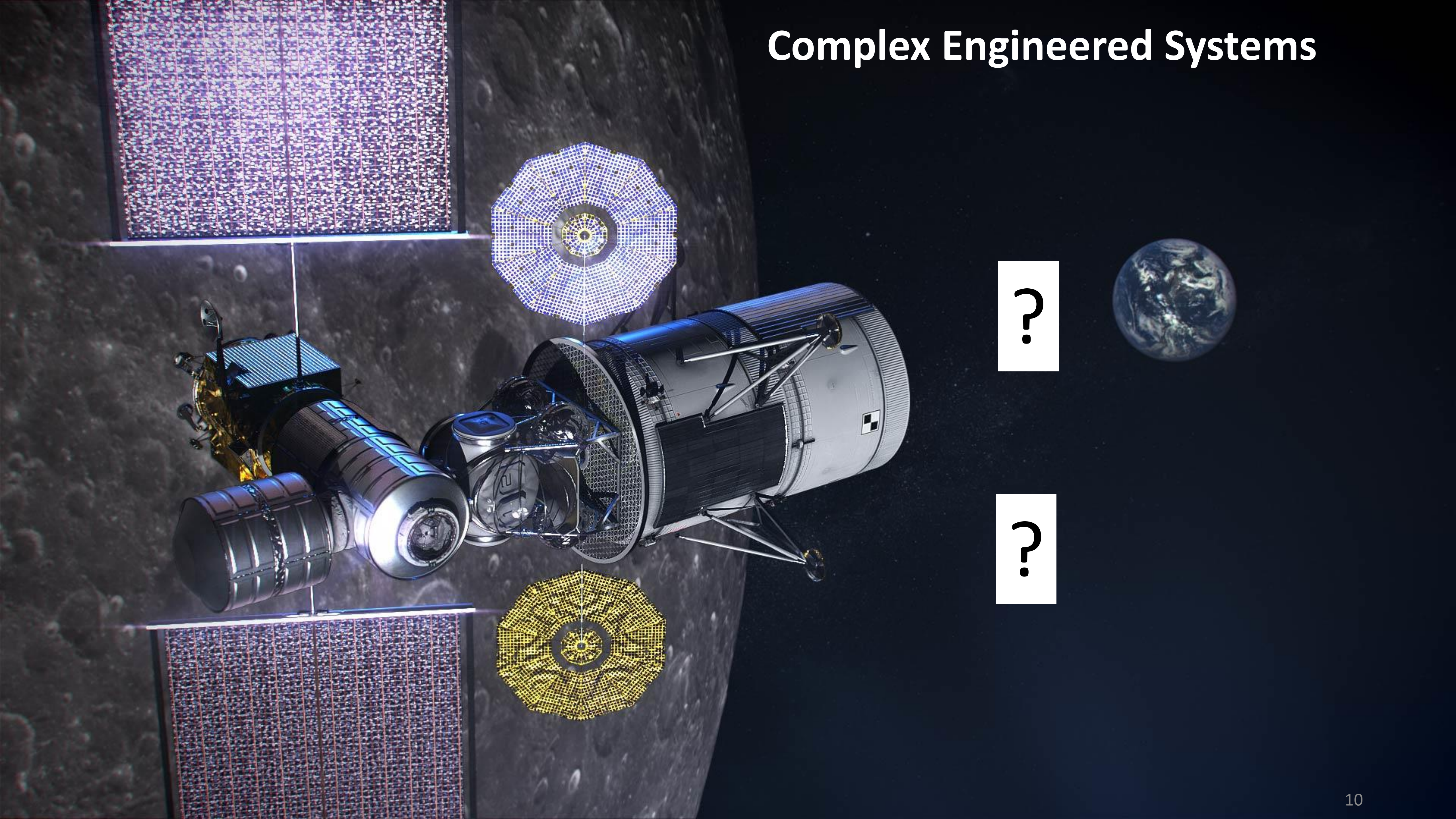
First hour response to a critical event can involve around **150 people** (All-hands-on-deck)

MCC Staffing

Early 2000s | 2019



Complex Engineered Systems



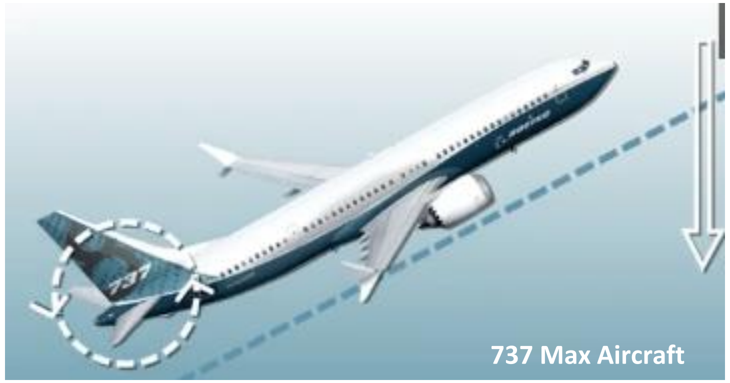
“Today’s spacecraft are giant bundles of software wrapped in metal.”

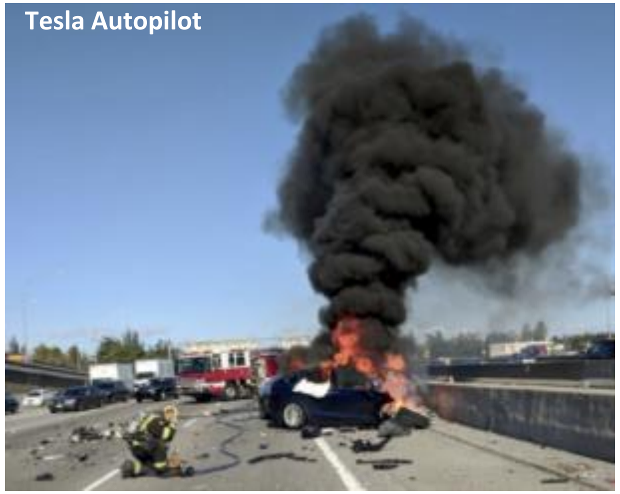
The Washington Post
Democracy Dies in Darkness

Space

NASA finds ‘fundamental’ software problems in Boeing’s Starliner spacecraft

The malfunctions could have had ‘catastrophic’ consequences, a space agency official says

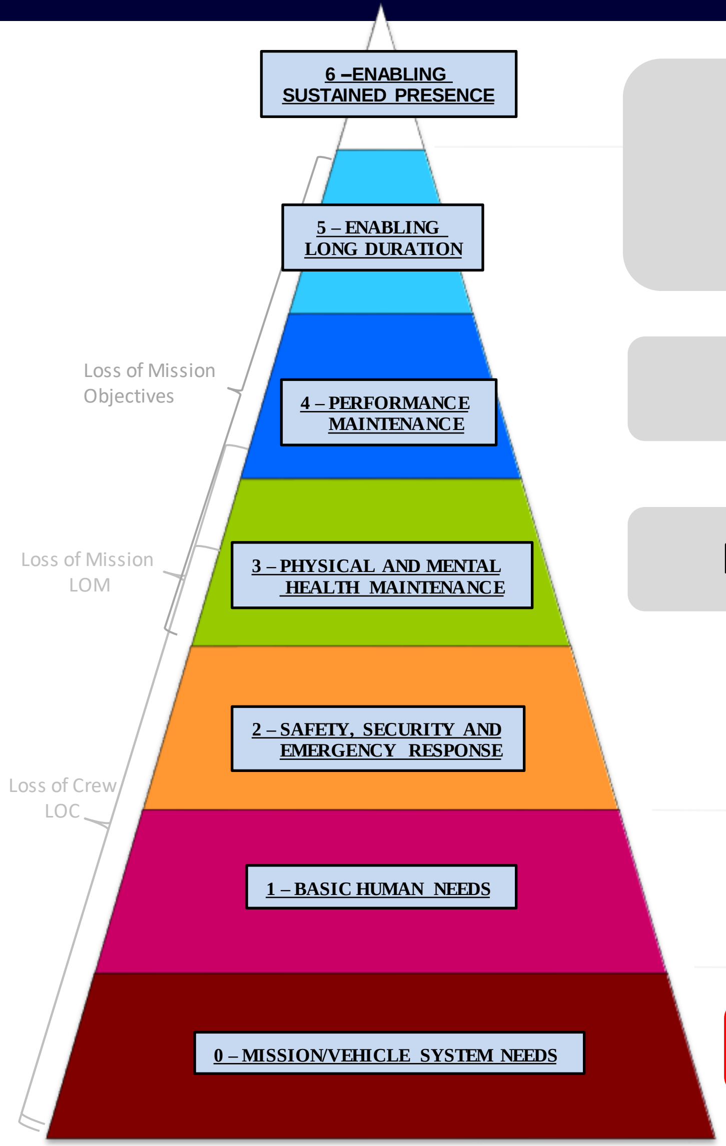




Big Picture of Risks

DRM Categories Details	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
Human Spaceflight Risks	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation
	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years
Renal Stone Formation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inflight Medical Conditions	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation
Vision Alterations	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inadequate Human Systems Integration Architecture	Accepted with Monitoring	Accepted with Monitoring	+Standard Refinement; May Require Mitigation	Requires Mitigation	Standard Refinement, May Require Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Cardiac Rhythm Problems	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
Cognitive or Behavioral Conditions	Accepted with Monitoring	Requires Mitigation	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation
Space Radiation Exposure	Accepted	Accepted	Accepted	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with PELs	Accepted with PELs	Accepted with PELs	Requires Mitigation	Requires Mitigation	Requires Mitigation
Carbon Dioxide Exposure	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Inadequate Food and Nutrition	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Requires Mitigation
Ineffective or Toxic Medications	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
EVA Operations	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted / Optimize	Requires Mitigation	Accepted / Optimize	Requires Mitigation
Psychosocial Adaptation within a Team	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring

HSIA is Foundational for Risk



Adequate Infrastructure, health and performance maintenance

Merger of Health, Cognition, Training, etc.

Medical, Behavioral and Cognitive Function

Ability to Respond

Food and Water, Air, Sleep

Human Systems Integration Architecture (HSIA)

(*) HSIA includes “Training” and contingency ground operations

NASA Human System Integration Domains

HSI

Human Factors Engineering
Design for human-system interactions given human limitations and capabilities

Operations Resources
Design for flight and ground crew objectives and constraints including autonomy and automation

Safety
Minimize risks to personnel and design for mission success

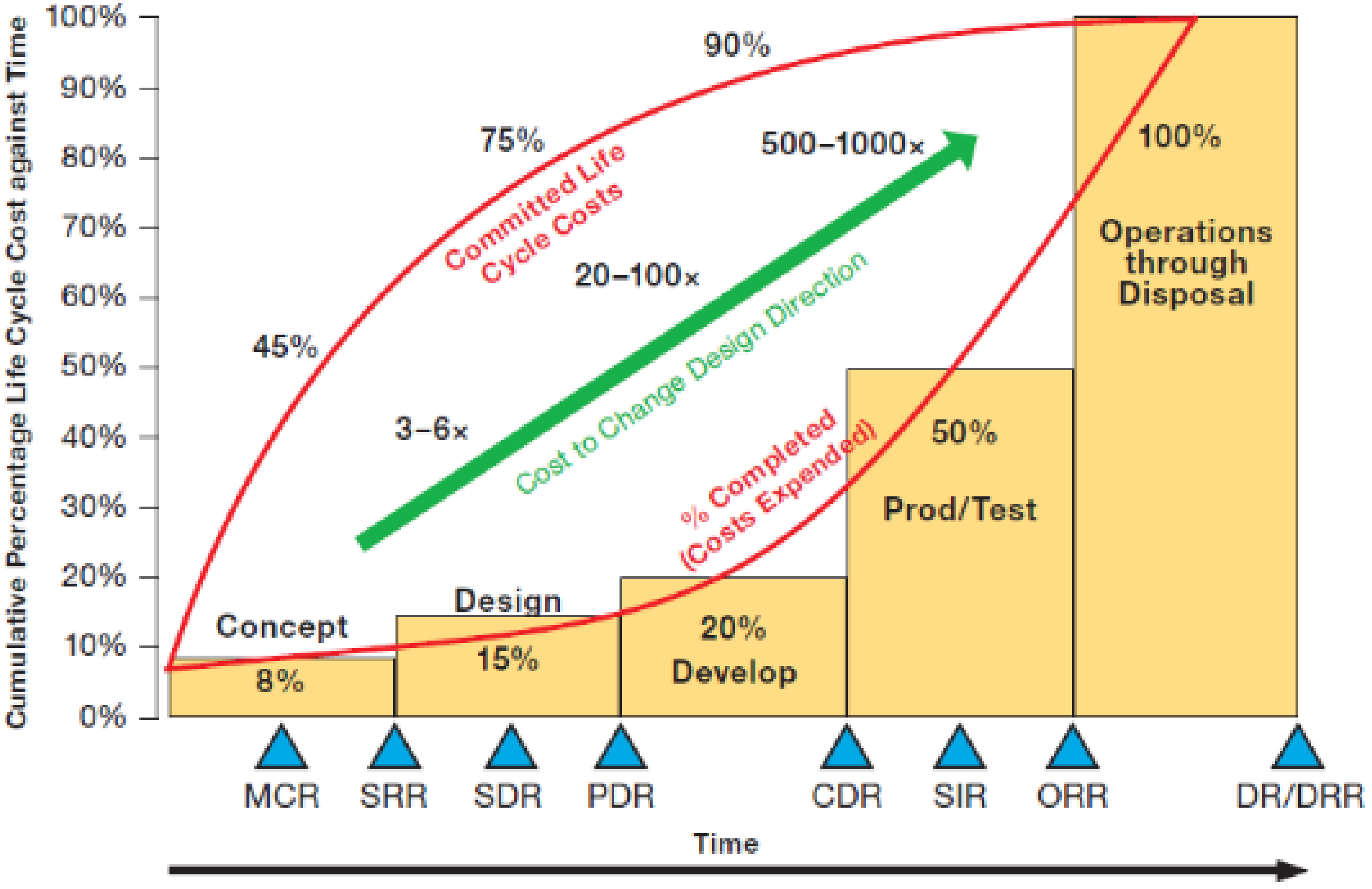
Habitability and Environment
Ensure design supports crew human health and performance for all living and working conditions

Maintainability and Supportability
Design to simplify and optimize human resources for M&S with given mission constraints

Training
Efficient and effective training systems and training design

Human System Integration and Testing

How do we know we are getting it those designs right?



MCR	Mission Concept Review	**CDR**	Critical Design Review
SRR	System Requirements Review	**SIR**	System Integration Review
SDR	System Definition Review	**ORR**	Operational Readiness Review
PDR	Preliminary Design Review	**DR/DRR**	Decommissioning/Disposal Readiness Review

Getting it wrong happens in real life

Littoral Combat Ships: Automation will save us!

The Navy Basically Just Admitted That The Littoral Combat Ship Is A Floating Garbage Pile

By Jared Keller | August 12, 2018 at 03:55 PM

MILITARY TECH

Share Share Share Share

Manpower reduction effort:

- **Planned: From ~200 to 45 sailors based on “smart” technologies**
- ***Unplannned: E5 and up, avg age 30, multiple accidents and incidents***

How do we tell if we are getting it right?

Analog testing and simulation

We test…

Can our crews effectively use systems as designed?

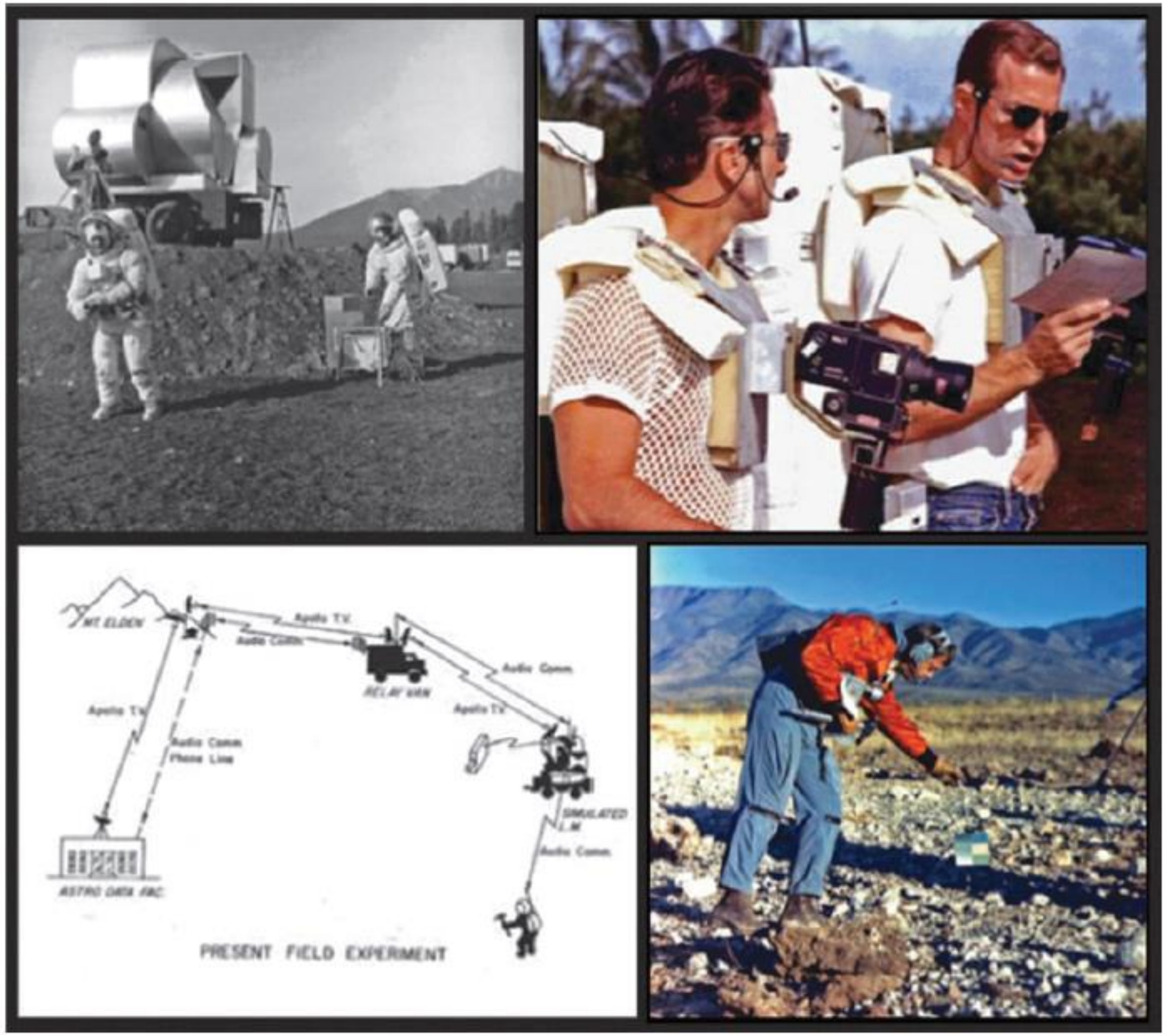
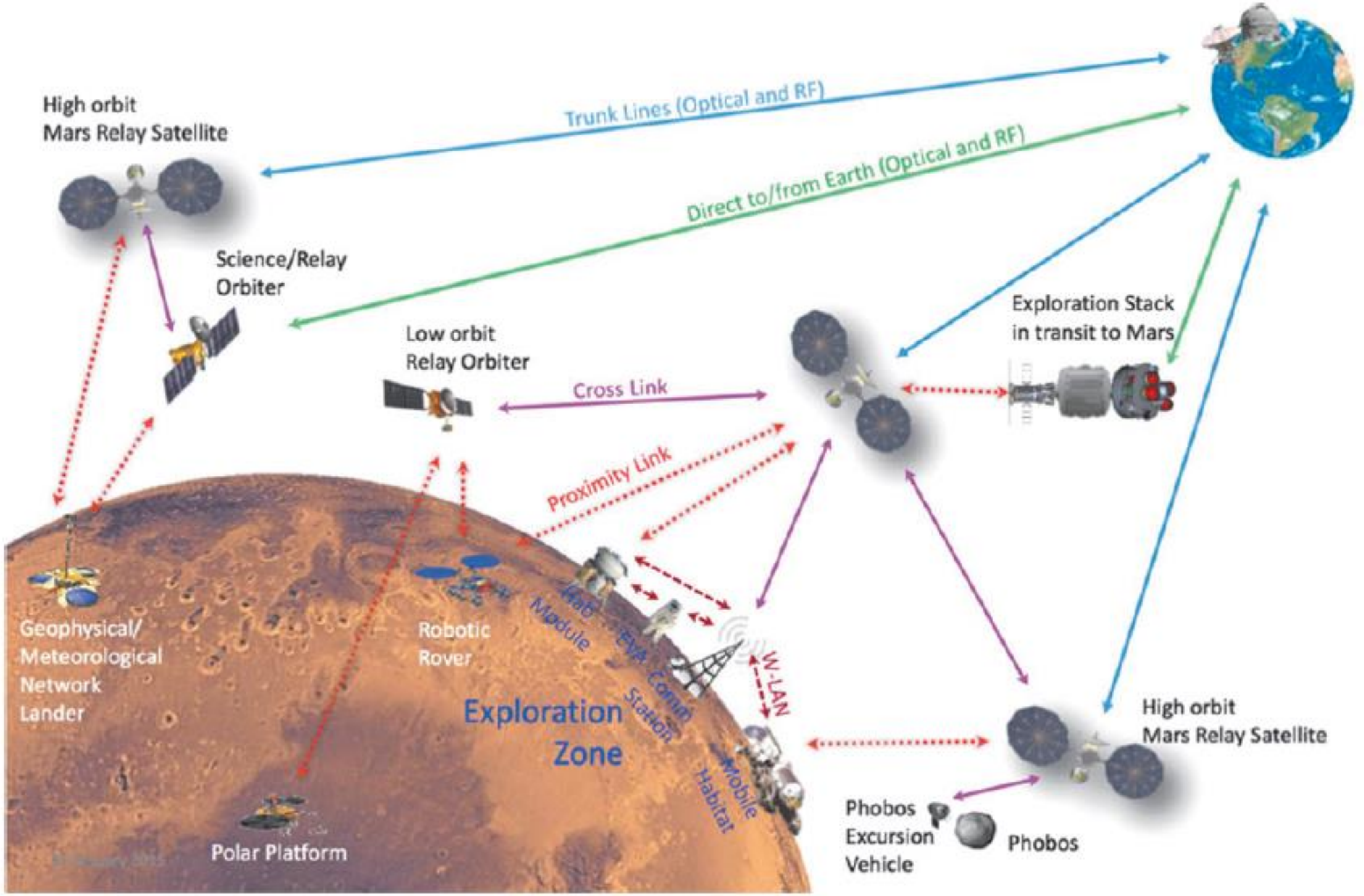


FIG. 1. Top row and lower right: Apollo crewmembers performing what we today call analog missions, for testing procedures, concepts, equipment, and training crews. Lower left: Apollo-era telecommunication link diagram closely resembles modern field test telecomm link diagrams (Schaber, 2005).

Siebert et al., Astrobiology Vol 19 (3) 2019 DOI: 10.1089/ast.2018.1915

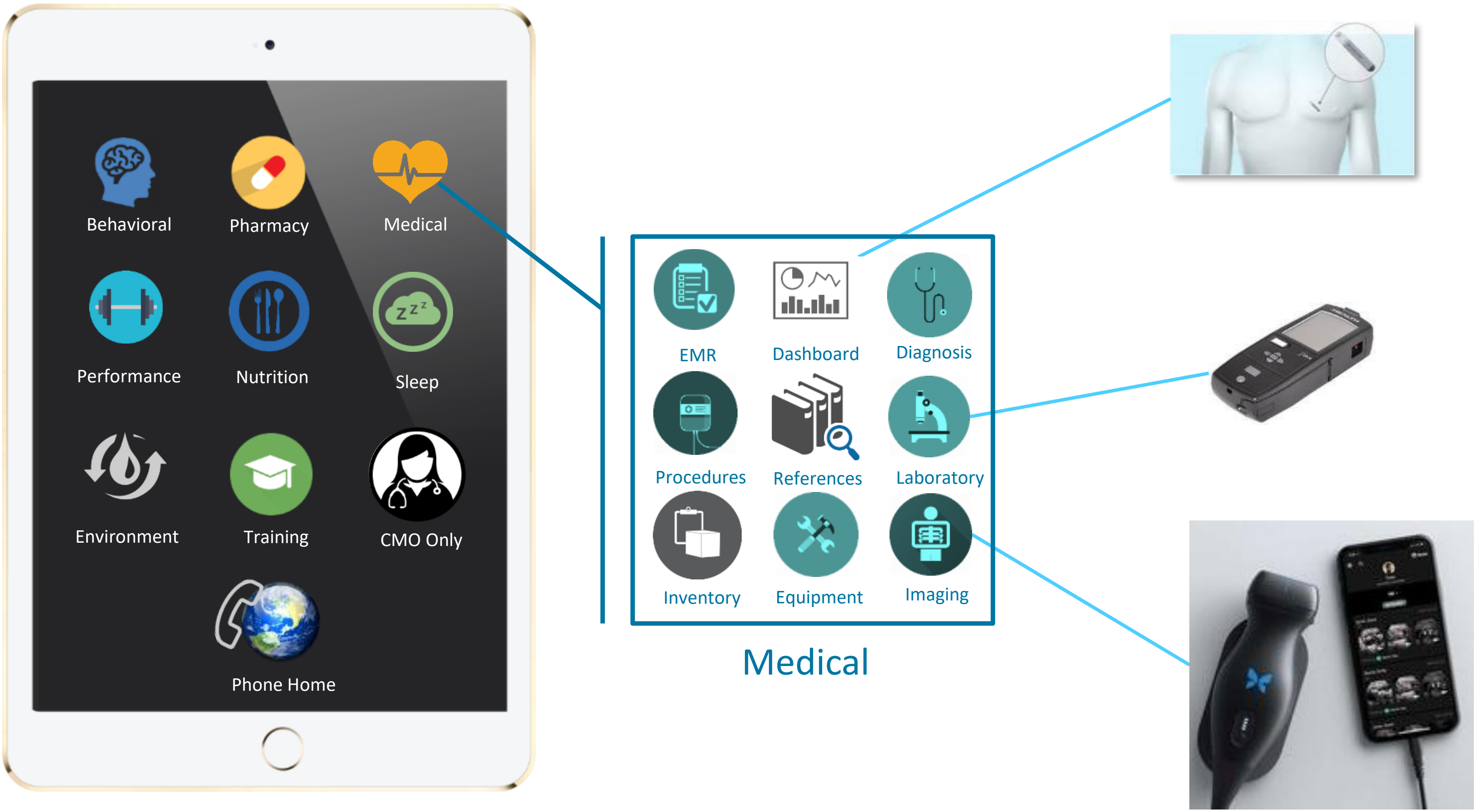
And we test…



Siebert et al., Astrobiology Vol 19 (3) 2019 DOI: 10.1089/ast.2018.1915

And we test…

Do our systems do what we claim they will do?



Are we systematic in learning?

Acceptability Ratings should reflect the extent to which the condition overall was considered an "Acceptable" approach to conducting human exploration given the following definitions:
Operational Acceptability: *Able to effectively, efficiently and reliably conduct operations with accurate exchange of all pertinent information and without excessive workload or (in-sim) avoidable inefficiencies or delay.*
Scientific Acceptability: *Able to effectively and reliably complete and record scientific observations, measurements, and/or sampling with sufficient quantity, distribution, resolution, accuracy, and/or integrity to test the scientific hypothesis/hypotheses. Note: Efficiency, or lack thereof, is addressed by Operational Acceptability.*
Task Acceptability: *Able to effectively, efficiently and reliably complete a task without significant discomfort, exertion, fatigue, or avoidable inefficiencies, and without risk of injury to self or damage to equipment.*

Examples of deficiencies: inefficiency, high mental workload, increased physical exertion,

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

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

A.F.J. Abercromby et al. / Acta Astronautica 91 (2013) 34–48

And we test…

Do they work under the most challenging conditions?

How do we know we aren’t making it worse?