Loss of Crew/Loss of Mission Procedures

Presenters: Kush Jani and Robert Haas
Virginia Aerospace Science
and Technology Scholars

Date: 6/17/23
TIME: 8:15-11:15 AM

Table of Contents

Leading Events for Modern Loss of Mission/Crew Procedures

1961-1974
Apollo Program Begins

1966
Event: Apollo 1 Fire Kills Three
Cause: Pure Oxygen Atmosphere

1970
Event: Apollo 13 Oxygen Tank Explosion
Cause: Ground Test Damage, Cascading Failures

1972
Shuttle Program Begins
Flew 1981-2011

1986
Event: Challenger Rocket Explosion Kills Seven
Cause: O-ring Leak, Neglected Reliability

2003
Event: Columbia Heat Shield Failure Kills Seven
Cause: Foam Impact Damage, Neglected Reliability

(Jones, 2015)

History of Loss of Mission/Crew Procedures

The History of NASA's Loss of Mission/ Crew Procedures can trace its roots back to the reliability analysis developed by Rocket Engineers during the Second World War. This form of analysis was later adopted by NASA's Apollo and Shuttle Programs. This theory is usually credited to Robert Lusser, a German scientist who worked alongside Warrener von Braun in Huntsville. Lusser concluded from his research that "the reliability of a system is equal to the product of the reliability of its in-series components"(Jones, 2015). After the Apollo 1 fire, his formula for reliability theory became more important to the space program as an understanding was developed on how a system is only as reliable as its components. With this theory, the potential for a lost mission or crew member became more significantly correlated with the maintenance of proper procedure based around identifying and mitigating risks to avoid loss of mission scenarios.

The concepts of Loss of Mission and Loss of Crew procedure are predicated upon risk management. The ability to predict, analyze and manage risk can help to reduce the chances of a Loss of Mission / Loss of Crew scenario.

Basics of Risk Management

Determining loss criteria for this manned sample collection mission will fundamentally rely on failure mode and effects analysis (FMEA), which itself relies on understanding risks to determine where failures and points of contention could be found (Standard for Performing FMEA, n.d.). In general, risks should be identified and categorized with weight on severity and probability where severity is based on the likelihood of an issue causing mission failure. Since FMEA must be done on all parts of the mission, an understanding of the components and their effect on the system is essential in deriving the subsequent problems a defect in the component could cause. This can also be applied to the human element in terms of having potential defects in the life support systems and even the individual's health itself.

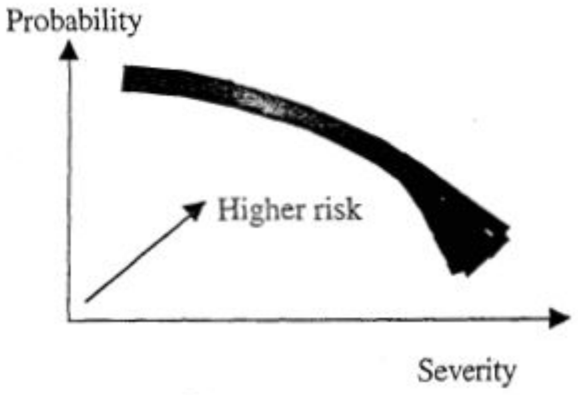


Figure 1. Risk curve.

Table 1. Risk matrix.

		Severity		
		Low	Medium	High
	high		2nd highest	Highest priority
Probability	medium			2nd highest
	low	Lowest priority		

Specifics for a Manned Mission

Beyond the general understanding of FMEA and risk management, this mission will have certain unique characteristics that any failure point determinations need to take into consideration. Since the mission is a manned sample collection mission, a combination of the human element and the mechanical element primarily must be considered for identification of immediate mission failure points. Specifically, any malfunction with sample storage and transportation could result in an immediate and costly failure as the samples become contaminated or defected. Furthermore, the human element also adds layers of complexity as medical issues arising from mechanical or biological issues create large threats by posing risk to the fragile yet critical human element.

For this mission, the FMEA will therefore require an understanding of all of the components involving contact with samples and all of the components involving human life support and safety equipment. Atop these criteria, the analysis done must also consider where unavoid-able failure points lie, such as in launch, and determine the likelihood of failure as different failures have different weights based on severity (Contingency Ops, n.d.).

Points of Contention

Human Factors

- Lack of necessary Provisions
- Illness or Viral Outbreak Among the Crew
- Lack of cooperation among crew members
- Failure to operate and maintain the spacecraft correctly
- Waste Mitigation Systems
- Crew Health Systems, Life Support, and Environmental Control

Mechanical and System Factors

- Equipment Failure (communications, life support system, thrusters, etc…)
- Structural Failure
- Loss of Power
- Decompression of the Spacecraft
- Fire on Board the Spacecraft
- Failure to Launch

Sample Factors

- Contamination of Samples
- Transportation of Samples
- Identification of Samples
- Categorization of Samples

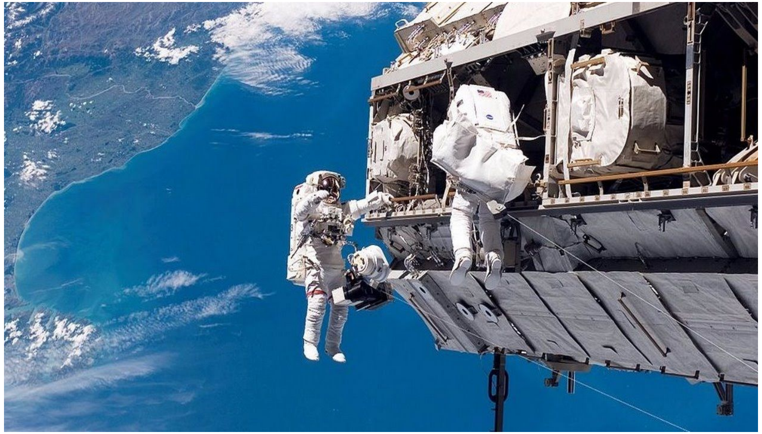
Special Consideration for Samples:
All samples collected must be stored safely without risk of contact to air to prevent contamination. Additionally, they must be contained in such away that prevents the samples from being damaged during transit or unorganized.

Workarounds for Human Elements

Lack of necessary Provisions- Proper mission planning in combination with emergency provisions such as food and water mitigate the risk of running out of supplies

Illness or Viral Outbreak Among the Crew - Quarantining the crew for multiple days before the launch can help to mitigate the risk of a viral outbreak

Lack of cooperation among crew members - Selecting a qualified mission leader and having the crew train together as a team can help to incentivise cooperation among crew members



Importance of Crew Cooperation :

The most important point of contention to address during a space mission is Crew Cooperation. Lack of proper crew cooperation jeopardizes all other mission areas as internal conflicts can lead to neglect of mission critical goals and details.

Failure to operate and maintain the equipment– Prior training with the equipment combined with reference manuals can help to mitigate the risk of equipment failure due to human factors

Waste Mitigation Systems – Having a backup waste management and mitigation system in place can help

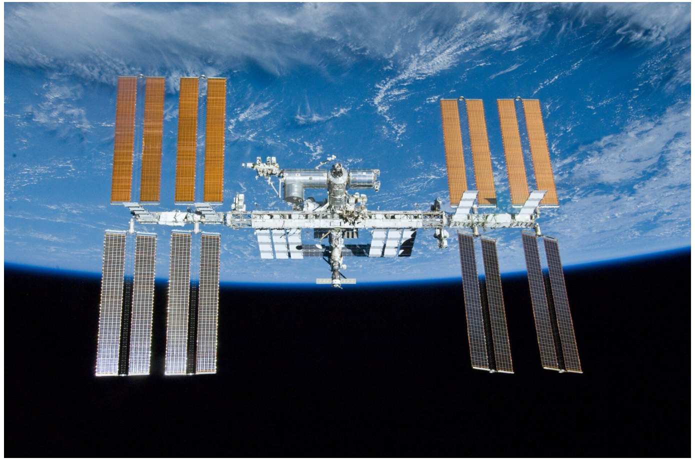
Crew Health Systems, Life Support, and Environmental Control– The inclusion of parallel systems when designing Crew Health Systems can help to reduce the chances of system failure

Workarounds for Mechanical / System Elements

Equipment Failure - Utilizing parallel systems can decrease the likelihood of a catastrophic equipment failure by providing an useable alternative

Structural Failure - The most likely cause of a structural failure on board the spacecraft would be meteoroids that could damage the integrity of the spacecraft. multi-layer insulation (MLI) blankets can be used to help mitigate the damage from these impacts

Loss of Power - The inclusion of a backup power system can add resilience to the spacecraft and mitigate the risk of a catastrophic failure



Definition of Parallel Systems

Parallel systems are systems that operate alongside one another. If one of these systems fail the other will continue to function as normal creating a redundancy that that reduces the likelihood of a major systems failure.

Decompression of the Spacecraft – Utilizing multi-layer insulation (MLI) blankets can help reduce the likelihood of spacecraft depressurization by protecting the body of the spacecraft from micro micro meteoroids impacts

Fire on Board the Spacecraft – The inclusion of on board fire suppression systems can help to mitigate the risk of a fire on board the spacecraft

Failure to Launch – Proper testing of spacecraft components under the expected launch conditions can help to reduce the chances of a failed launch

Information Needed

With the aforementioned emphasis on the manned nature of this collection mission in mind, proper LOC/LOM determinations will undoubtedly require a great deal of information from all parts of the mission as each phase will introduce new potential points of failure and alter the risks that the mechanical and human elements will face. Since the mission revolves around the collection of samples, the method of collection, storage/safekeeping, and transportation of samples will be the most prominent novel factors to be weighed alongside the typical factors of launch, descent, and reentry for the spacecraft itself. On the human-focused side of risk management, an understanding of the crew life support systems in place during transit and the subsequent surface stay will be the more typical factors alongside the novel factors involved in the manned exploration of the surface. Understanding the risks and points of contention found on the surface will require a knowledge of the timing and location of the surface stay, as well as the method of sample collection and surface transport for the crew.

Team Collaboration

Human Factors Team - With special emphasis on Crew Health Systems, Production Systems, and Communication Systems subteams.

Mission Transit Team - With special emphasis on Mars and Earth Entry/Descent/Landing Systems, Mars Ascent Vehicles and Crew and Transit Vehicle Designs subteams.

Science and Surface Operations - With special Emphasis on EVA Operations, Planetary Surface Transportation, and Surface Sampling Operations subteams.

Why Collaborate?

In order to properly analyze points of potential failure, working with the listed teams will be essential in properly understanding all of the components and being able to connect the various effects of the components to one another.

Team Collaboration Contd.

Due to the volume of needed information and weight on details and connections between various components of the spacecraft’s mechanical elements, collaboration aiding our Failure Modes and Effects Analysis shall be essential in ensuring the safety and success of the mission. As standard in industry analysis, collaboration for FMEA will require documentation of designs and decision making such that feedback for lowering risk and catching single point failures can be identified (Making Safety Happen, n.d.). With the human factors team, recognizing points where a loss of crew and mission failure could occur will be determined through the various sub-teams involved in life support, communications, and health. On the mechanical side of failures, the mission transit team will be vital in ensuring mission failures due to transit, common in historical missions, do not occur. Finally, preventing a LOM due to sample mishandeling will be enabled by the Science and Surface Operations team’s sample sub-team. Through careful mitigation-geared review processes, the success and safety of the mission should be as close to guaranteed as possible for such a complex and groundbreaking mission.

The End

THANK YOU FOR YOUR PARTICIPATION!

References

Apollo 1 Patch. (n.d.) NASA. Retrieved June 15, 2023, from https://spaceflight.nasa.gov/gallery/images/apollo/apollo1/hires/s66-36742.jpg

Contingency operations for failures in a generalized Mars Transit ... - TDL. (n.d.). Retrieved June 15, 2023, from https://ttu-ir.tdl.org/bitstream/handle/2346/74189/ICES_2018_235_VERSION2.pdf?sequence=8

Dunbar, B. (2015, June 1). Cancer treatment delivery. NASA. Retrieved June 15, 2023, from https://www.nasa.gov/mission_pages/station/research/benefits/cancer_treatment.html

Hall, L. (2020, November 13). A new doorway to space. NASA. Retrieved June 15, 2023, from https://www.nasa.gov/directorates/spacetech/spinoff/New_Doorway_to_Space

Jones, Harry. Reliability and Failure in NASA Missions: Blunders, Normal Accidents, High Reliability, Bad Luck. 2015. Retrieved June 15, 2023, from http://hdl.handle.net/2346/64314

"Making Safety Happen" through probabilistic risk assessment at NASA. (n.d.). Retrieved June 15, 2023, from https://ntrs.nasa.gov/api/citations/20200001592/downloads/20200001592.pdf

Mars Explorers Wanted Posters. (n.d.). NASA. Retrieved June 15, 2023, from https://mars.nasa.gov/multimedia/resources/mars-posters-explorers-wanted/

NASA. (2022, December 22). NASA's Perseverance Rover deposits first sample on Mars surface – NASA's Insight Mars Lander. NASA. Retrieved June 15, 2023, from https://mars.nasa.gov/news/9323/nasas-perseverance-rover-deposits-first-sample-on-mars-surface/?site=insight

References Contd.

NASA PowerPoint Template. (n.d.). Retrieved June 15, 2023, from https://sbir.nasa.gov/sites/default/files/2017_IndustryDay_Presentations/Day%201-5%20-%20SBIR%20101%20-%20Commercialization%20Rating%20Clarification%20-%20Rich%20Terrile.ppsx

Standard for performing a failure modes and effects analysis - NASA. (n.d.). Retrieved June 15, 2023, from https://rsdo.gsfc.nasa.gov/documents/Rapid-III-Documents/MAR-Reference/GSFC-FAP-322-208-FMEA-Draft.pdf

Table 1 & Figure 1 | Risk of human space - NASA technical reports server (NTRS). (n.d.). Retrieved June 15, 2023, from https://ntrs.nasa.gov/api/citations/20040015098/downloads/20040015098.pdf

Webb, C. (2019, October 25). New research studies on human health during Deep space exploration. NASA. https://www.nasa.gov/feature/space-health-institute-selects-new-research-studies-to-safeguard-human-health-during-deep-space-exploration/