Chapter 10
Risk Assessment and Management for Space Operations

Qori Halimatul Hidayah
Esa Unggul University, Indonesia

Dewi Setiowati
https://orcid.org/0009-0005-5747-1094
Esa Unggul University, Indonesia

ABSTRACT

Space operations is one of the most advanced and complex technological fields facing humanity with an environment that is very extreme and unfriendly to humans and technology. This activity includes a variety of missions, from satellite launches, planetary exploration, to manned missions into space. The success and safety of these missions relies heavily on the ability to identify, analyze, and manage risks effectively. Risk assessment is based on the evaluation of several criteria, including the severity of a hazard, the probability (frequency) of its occurrence and tolerance for its impact. Integrating and testing space systems is a challenging and complex process involving many technical, operational, and environmental factors. Effective risk management requires coordination across various disciplines, including engineering, biology, physics, geology, and information technology.

INTRODUCTION

Space operations encompass a wide range of activities related to the use and exploration of outer space. These activities include the design, launch, control, and maintenance of spacecraft, satellites, and other space-based systems. Space operations is a complex and dynamic field that requires the integration of advanced technologies, careful planning, and international cooperation to achieve successful outcomes.

Space operations involve a myriad of complex activities, from satellite deployment to manned space missions. These operations are fraught with risks due to the harsh and unpredictable environment of space. Comprehensive risk assessment and management are crucial to ensure the success and safety of these missions. Risk assessment and management assesses these issues by proposing and empirically

DOI: 10.4018/979-8-3693-7939-4.ch010

testing how risk management frameworks designed for direct risks can be extended to include indirect impacts as well.This risk assessment and management is expected to reduce the likelihood of manned space mission failure, improve human safety, minimize costs and ensure missions can continue into the future. All of this can be achieved due to an optimal set of financial, technical, organizational, and human resources.

The development of space operations, space research, and space exploration is one of the key stages in the overall advancement of science. Space exploration is not just a stage in the development of space science, but represents an era of scientific progress across various fields (2018 Wave Electronics and Its Application in Information and Telecommunication Systems (WECONF) : 26-30 November 2018, St. Petersburg State University of Aerospace Instrumentation (SUAI), 2018).

Research in space operations will drive the development of new technologies, one of which is the advancement of satellites that will create network architecture topologies, becoming a key component in the creation of 6G networks. The space-ground integration is a major component of 6G with diverse topologies, evolving over time, with broad geographical and temporal scales, and limited spatial node resources, thus presenting new opportunities for development and coverage in cellular communication (Wang, Jie ., Yuetian Zhou., Bingxin Wang. (2023).

The process of developing space operations will have impacts and risks that occur if not managed with risk management control, so that risk management becomes the main point in creating the development of space operations in order to minimize the effects that will be faced.

To strengthen the introduction, real-world examples of high-profile space missions that faced challenges due to insufficient risk management could be integrated. For instance, the Apollo 13 mission serves as a prime example, where an oxygen tank explosion forced NASA to improvise solutions to bring the crew home safely, highlighting the critical need for comprehensive risk mitigation strategies. More recently, satellite collisions such as the 2009 Iridium-Cosmos collision demonstrate the consequences of inadequate risk assessment in the increasingly congested space environment. These examples not only illustrate the importance of risk management but also anchor the theoretical concepts in practical, high-stakes scenarios.

Integrating quantitative data on the frequency of space mission risks would indeed emphasize the critical role of risk management. For example, launch failures, a common risk in space operations, have occurred in approximately 5-10% of all launches globally, depending on the decade and technology involved. According to the Union of Concerned Scientists and Space Launch Report: From 2000 to 2020, there were around 1,500 orbital launches, of which about 75-100 resulted in complete or partial failures. Satellite malfunctions are also notable. Of the approximately 3,300 active satellites in orbit as of 2021, around 3-5% experience operational issues within the first year of their launch, including communication loss, power failures, or orbital drift. The European Space Agency (ESA) reported that around 26% of all space debris originates from non-operational satellites and failures, underlining the widespread risk posed by insufficient risk management.

By including such statistics, the argument for robust risk management becomes grounded in real data, showcasing the tangible risks that accompany every mission and the necessity of mitigation strategies to protect investments and ensure mission success.

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