National Aeronautics and Space Administration
Marshall Space Flight Center
Space Transportation Directorate

Risk Management Implementation Program

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Abstract

The U.S. civil aerospace program has been a great contributor to the creation and implementation of techniques and methods to identify, analyze, and confront risk. The National Aeronautics and Space Administration (NASA) has accomplished mission success in many instances, but also has had many failures. Anomalies have kept the Agency from achieving success on other occasions, as well. While NASA has mastered ways to prevent risks, and to quickly and effectively react and recover from anomalies or failures, it was not until few years ago that a comprehensive Risk Management (RM) process started being implemented in some of its programs and projects. A Continuous Risk Management (CRM) cycle process was developed and has been promoted and used successfully in programs and projects across the Agency.

The Space Transportation Directorate at NASA's Marshall Space Flight Center has been a strong advocate of this process. In January 2000, the RM implementation process started and was made available extensively to all programs and projects within the Directorate. The RM Operations Office, reporting to the Director, was created. A plan and definition of general guidelines were presented and discussed with the Director and the program and project managers. A teams training program and related NASA standards training and familiarization were defined and implemented. The RM Toolbox was installed on an internal site through the World Wide Web, which is available to all the Directorate's personnel. The Toolbox includes: an RM template, tools and techniques (fault tree analysis, failure mode and effect analysis, probabilistic risk assessment, hazard analysis, etc.), links to key standards and NASA investigation reports, and lesson's learned, as well as other useful references and documents.

Having a series of programs and projects in different points of their life cycles, it was quite challenging to keep them all on track. Risk identification, analysis, planning, tracking, control, and communication/ documentation are the basic steps of the CRM process, which has been successfully implemented within the Directorate. Comprehensive utilization of algorithms, RM grids, risk mitigation waterfall charts, stoplights, etc., and efficient periodic technical and programmatic management reviews of top issues, have enhanced the health and performance of programs and projects.

Implementation of CRM is now required for all new programs and projects, and it has been gradually and successfully extended to existing ones. CRM has been included within the top 10 actions listed in the Directorate's Strategic Plan. The ultimate goal is to have the CRM process as an integral part of program and project management to enhance overall mission success.

Introduction

The Marshall Space Flight Center (MSFC) is the National Aeronautics and Space Administration's (NASA) Center of Excellence for Space Propulsion, and its mission areas include Space Transportation Systems Development, Microgravity Science, and Space Optics Manufacturing Technology. From the Apollo Program through the Space Shuttle and beyond, revolutionary "leapfrog" technologies, as well as numerous worldwide-recognized successful programs and projects, have been led and supported by the Center.

The Space Transportation Directorate is responsible for MSFC's designated role as NASA's Center of Excellence for Space Propulsion and the NASA Lead Center for Space Transportation Systems Development. As such, it plans, directs, and executes research, technology maturation, and advanced design and development, as well as advances science and engineering excellence for NASA's space transportation systems, including Space Shuttle main

propulsion elements and other Earth-to-orbit and in-space transportation systems for travel beyond low-Earth orbit (LEO).

The Directorate is product oriented, having several programs and projects within several objectives and goals. NASA's Integrated Space Transportation Plan (ISTP) is the heart of the organization. Three components define the Plan: Space Shuttle Safety Upgrades; 2nd Generation Reusable Launch Vehicles (RLV); and the Advanced Space Transportation Program, which includes 3rd Generation RLVs and beyond and In-Space Transportation Systems. There were several experimental (X) vehicle technology demonstrators within the Directorate, aimed at validating advanced technologies to enable development of vehicle architectures for future LEO and in-space vehicles. These are described below to give perspective on the types of programs and projects that the Space Transportation Directorate manages, as well as on the importance of RM to mission success.

The X-33 project was begun to demonstrate in sub-orbital flight the technologies needed for a single-stage-to-orbit RLV serving as the "technology pull," with private industry as the operator and NASA as the customer. It was the first project to combine the many elements necessary to reduce launch costs, focusing on structures, materials, engines, computers, operations, and maintenance considerations.
The X-34 project was created both to provide a sub-orbital low-cost test bed with streamlined operations and rapid turnaround, and to test the tenets of the "faster, better, cheaper" management theories as applied to developing a launch vehicle.
The X-37 project is an ongoing initiative with important technology goals. It is the first of NASA's fleet of RLV experimental technology demonstrators intended to operate in both the orbital and reentry phases of flights. This vehicle will demonstrate dozens of advanced airframe, avionics, and operations technologies that will directly contribute to the 2nd Generation RLV goals outlined in the ISTP. Although still supported by the Directorate, this project was recently transitioned to the newly formed 2nd Generation RLV Program office at MSFC.

Content

This paper is not a scientific paper, nor is it an engineering report. Rather, it is a project management description that includes lessons learned, project management responsibilities, and upper management requirements for implementation of a comprehensive RM process to effectively manage projects.

Identification and assessment of risks have been key elements in project management and have been considered throughout the history of projects managed by the Center. However, a structured RM process included as an integral part of project management had not been formally implemented. During the 1999 – 2000 MSFC reorganization, RM and Systems Engineering were included as two of the project management elements needing immediate attention and continuous improvement, within the guidelines for managing programs and projects. Later on, the Mars Climate Orbiter Mishap Investigation Board, headed by the MSFC Center Director, stated in its March 13, 2000 report that "Risk Management should be employed throughout the life cycle of the project, much the way cost, schedule and content are managed. Risk, therefore, becomes the 'fourth dimension' of project management treated equally as important as cost and schedule."

Subsequently, the Space Transportation Directorate developed a plan to implement the RM process within its programs and projects. At the time, only major projects of four major programs were included in the plan: (1) Advanced Space Transportation Program, (ProSEDS, Rocket Based Combined Cycle/Integrated Systems Test of an Air-Breathing Rocket), (2) 2nd Generation RLV, (3) Pathfinder Program (X-34, X-37, Flight Experiments), and (4) Advanced Development Projects (International Space Station Propulsion Module; Interim Control Module; X-38 Deorbit Propulsion Stage) and X-33.

With the creation of an office in charge of the Risk Management Operations within the Space Transportation Directorate, reporting directly to the Director, the RM initiative hit the ground with strong, solid, and well-defined support from upper management. Immediately after, a comprehensively defined implementation plan was drafted. It included:

- Directorate-level guidelines and policies for RM process implementation.
- The RM process in the top 10 items for Fiscal Year 2000 within the Directorate's Strategic Plan.
- The RM process to be implemented beginning with the formulation stage of a project.
- Required Continuous Risk Management (CRM) training for all project teams, individually.
- Memorandums of charter and implementation for RM teams.

• Requirement for programs/projects to identify RM as a function within their organization.
• Requirement for each program/project to incorporate the RM process as an integral part of the management structure.
• Training for managers, Systems Engineers, and Risk Managers (CRM, Standards).
• Provide guidance and assistance in writing an RM plan for programs/projects.
• Instruct, educate and demonstrate to project managers relative how to use the Plan in the managing of the project as a tool to improve cost, schedule and performance.
• Initiate review and approved of RM plans for programs/projects at the Directorate level.
• Implement periodic RM reviews.
• Incorporate RM as part of the Directorate periodic Technical issues Reviews.
• Identify and defines RM reviews at the upper management level (as an integral part of periodic program/project management reviews).
• Provide total upper management support for the RM process.
• Creation of an RM Toolbox with key tools to assist program/project-level implementation of RM processes.

The RM Toolbox is available to personnel through the Space Transportation Directorate's internal Web site (see Figure 1). It includes:
• Space Transportation Directorate RM guidelines/ideas
• NASA Lessons Learned
• Recently Released Reports on NASA Programs
• Program/Project Risk Management — MWI 7120.6
• Risk Management Plan Template (including all the elements required in the NPG 7120.5)
• Administrator's Requirements for RM
• Risk Management Procedures and Guidelines
• Risk Management Tool Description
• Risk Management Tools
• Failure Mode and Effects Analysis (FMEA).
• Fault Tree Analysis (FTA)
• Probabilistic Risk Assessment (PRA).

Figure 1. The RM Toolbox on MSFC's intranet.

The Space Transportation Directorate based its RM implementation plan on the CRM process concept developed by the Carnegie Mellon University's Software Engineering Institute; it was adapted to NASA's needs by the MSFC Safety and Mission Assurance Office. It is based on the "open communication" core principle: "Risk Management can not simply succeed without the constant attention to fostering open communication." This includes:

• Encouraging free flowing information at and between all project levels.
• Enabling formal, informal, and impromptu communication.
• Using a consensus-based process that values the individual's voice.

In simple terms, risk is the possibility of suffering loss, whereas risk management is defined as the discipline for living with the possibility that future events may cause adverse effects (Kloman 90, p. 203). CRM is an engineering practice with processes, methods, and tools for managing risks in a project. Briefly, it is based on a set of functions that are identified as continuous activities throughout the life cycle of the project defined within a paradigm (Figure 2). Those functions are: Identify, Analyze, Plan, Track, Control, and Communicate/Document. Understanding project life cycle, for our purposes, as defined in the NPG 7120.5, NASA's program and project management processes and requirements also include: formulation, approval, implementation, and evaluation.

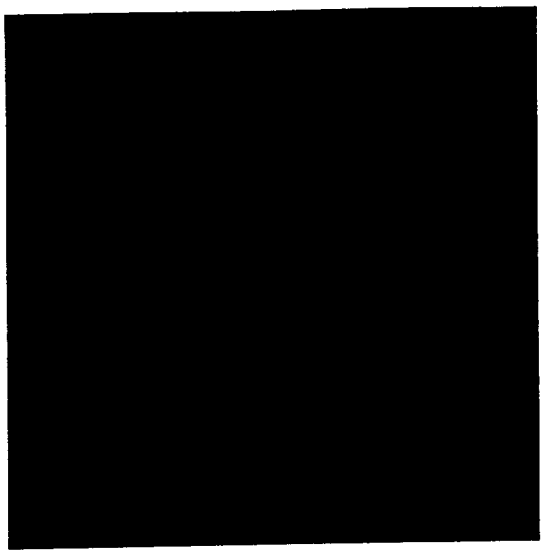

Figure 2. CRM process throughout project life cycle.

Findings

As expected, each project had evolved with characteristics that made it unique in management style, level of maturity, procurement instrument, national interest, roadmap, technologies, definition of mission success, etc. Because of this, and in accordance with the relevance of the various projects to NASA's goals, it was required to tailor the plan to fit each individual project.

The general set of guidelines and a specific policy were prepared, discussed, and implemented. Sound resistance was encountered. In addition to management and engineering resistance, legal and procurement limitations were the dominant and critical elements dealt with. Constraints framed in contractual agreements and requirements, teams of contractors with a wide variety of management styles and cultures, budget constraints, and specific milestones underway, were some of the main obstacles faced during implementation of the RM process. Perseverance, patience, and tenacity were required, as well as bringing forth not only managerial justification, but the inherent benefits and advantages of investing in a systematic RM approach.

Although some of the programs/projects had an RM process in progress, the majority of them had either partial or complete absence of some requirement elements outlined in the Directorate's plan, and did not adequately reflect utilization of the guidelines and pertinent NASA standards. To highlight some deficiencies, the following list is a sample of discrepancies found in various projects:

- Absence or non-utilization of the RM plan.
- Absence of an RM professional in charge.
- Lack of understanding the criteria for mission success at the team level.
- Lack of a rigorous risk identification and assessment process.
- Lack of support from upper management.
- Lack of risk "ownership".
- Inadequate or non-utilization of RM tools (FMEA Critical Items List, Hazard Analysis, FTA, PRA, etc.) which had not been considered in the formulation of some projects.
- Lack of process for risk identification, analysis, and tracking.
- Lack of an active/serious list of risks.
- Lack of adequate risk mitigation plans.
- Lack of a milestone schedule for risk accomplishments.
- Risk mitigation plans not integrated in managing the project.
- Lack of an RM budget.

More than a requirement, the RM process has to be considered as a fundamental tool to manage a project. It was found that several projects in the Directorate had identified and included an RM process in their organizations and requirements. Furthermore, some projects showed perfectly updated project plans and risk mitigation plans. However, in several of them, managers were not using these tools to manage their projects, only to fulfill a requirement or a perceived gap. Extensive RM plans, schedules, risk mitigation plans, etc. are worthless unless the manager includes them in his/her daily management style. All the effort resulting in comprehensive paper blocks can turn into a waste of time and resources. In other words, a comprehensive RM process will not succeed unless championed by the project manager.

Interestingly enough, while some projects had indications of having an RM process in place, their corresponding programs did not have one at that higher level. Several projects were reacting to their own project management cultures, styles, and approaches. So the program was joggling for a stable RM process from as many projects as they had. Once a program is started, it must develop Systems Engineering and RM processes to be able to execute them through their corresponding projects in a systematic and consistent fashion.

Structured programs require adequate resources for adequate implementation within a project. Resources, including skills, plans, infrastructure, budget and management support, etc., need to be thought through and comprehensively planned within the formulation phase of a project. The deeper into the life of the project, the more complex it becomes. This factor, combined with the number of team members in a contract (i.e., contractors), elevates the RM implementation process exponentially. It is a fact that government contracts have a tendency to be proposed by teams of corporations, agencies, universities, small business organizations, etc. Therefore, a variety of cultures, management styles, and policies are distinct elements in these types of teams. When writing a proposal, there are very few opportunities to discuss and agree upon terms and conditions beyond the requirements in the Request for Proposal (RFP). The focus on winning is to meet the RFP requirements, while using the fewest resources possible in the shortest amount of time.

Management approach, details, and planning are scarce. Although the proposal usually includes a management plan and approach, a fundamental lack of comprehensive steps for team integration and a plan to develop and implement System Engineering and RM processes are usually ignored or approached superficially.

Major contracts often include up to eight or more direct contractors and, depending on the type of procurement instrument used, all of them may be "prime" contractors. Once the contract is awarded, a number of cultures collide, bringing into play their own concepts and approaches; integration is usually very cumbersome and, in some cases, never achieved.

But being more categorical in the assessment, it is important to emphasize that the responsibility starts on the shoulders of the RFP writers and approval cycle teams because they set the requirements. This responsibility then follows to the proposal review and selection team as well.

These teams are responsible for assuring that the requirements are clearly stated in the RFP, then comprehensively submitted and, furthermore, negotiated and specified in the contract clauses. However, this is not usually the case. Teams are primarily focused on technical content and dollars proposed. Historically, one of the lowest priorities is project management approach and, subsequently, the RM process.

The proposing contracting team must make a commitment to define and implement a unique management approach for the program/project in question and toimplement a comprehensive and compliant RM process. Adjustments to the "culture" must be "intended" and "committed" at the proposal stage. So, when at the negotiation table, the management and RM terms must be discussed and a well-structured RM process submitted. With it, the contract can then be signed and team members can implement the plan, thereby adjusting their work cultures to fulfill the agreement.

Program and project managers with knowledge and experience in RM are relevant to a successful RM process implementation within a project. Therefore, it is a fundamental requirement to have program and project managers with open minds toward innovative and revolutionary management techniques. Although RM has been around for many years, it is often new to many mangers.

Risk mitigation plans were identified for many risks within various projects. However, they were generally lacking in method, schedule, milestones, etc. Some projects that had risk mitigation plans were not actively involved in the tracking/monitoring of the risk progress. Rather, it allowed the system to become a bookkeeping exercise rather than a tracking tool and viable management element.

While some projects appeared to be acting as teams, they were not really working as such. Having continuous meetings is not enough if the parties do not discuss the risks. Some project team members were not aware of the existence of an RM plan or process within the project. Furthermore, some of them were not involved in risk analysis or identification.

It was necessary to take each project one by one and dedicate time to understanding the process they were using for assessing risks and resolving them. Several individual characteristics and deficiencies were found in each of them, which required special and specific attention and corrective actions. Following are some general illustrations:

- Work as a team within the project team. This means be an active part of the team, understand the project, status, goals, and the management approach. Identify real potential solutions when implementing the RM process and do some hands-on training in RM plan and mitigation plan proposals.
- Demonstrate real benefits from managing with a structured RM process versus a traditional approach.

• Since projects want to invest minimally in non-tangible items, it is required to help the project to set the system at the lowest possible cost, always showing advantages and providing tools to solve paths, trends, and budget decisions.
• Coaching and providing criteria for adoption of risk mitigation approaches (avoidance; assumption, retention; control, reduction, prevention; knowledge and search; transfer, deflection).
• Identifying needs for adequate risk mitigation plans. Risk mitigation plans are fundamental in the RM process. Coaching and enforcing implementation of risk mitigation plans which include some type of schedule planning (waterfall mitigation) with clear identification of "inch-stones", decision making points, off-ramps, contingency plans, and milestones tied to the main schedule, as a minimum.
• Assuring requirements for a comprehensive RM process at the early stage of the process, starting with the RFP. Then follow it in the proposals submitted to a procurement competition. And, subsequently assuring that the RM process is an integral part of the project management system that will be used in the execution of a project.

The 2nd Generation RLV Program is one of the largest initiatives within the Agency and the largest in the civil space transportation field. Their RFPs were out for bids around the third quarter of 2000. This Program has successfully implemented the steps outlined above and their projects are currently being managed based on the implementation of a strong RM process at the program level. This is one example where NASA has embraced RM from RFP formulation and has made this mandate an integral part of the overall contracting effort.

Conclusions

1. The RM process was successfully implemented in the Space Transportation Directorate at NASA MSFC.
2. The RM process is more efficient and effective when implemented at early stages in the life of the project. The RM process must be implemented at the formulation phase.
3. The Project Manager is ultimately responsible for implementing and adequately utilizing the RM process to manage the project.
4. The intent of some project managers was to show the existence of an RM process within their project management approach. However, very few were using it as a tool to manage.
5. The Project Manager must define the process, incorporate it into the Project Plan, and implement it. The RM process is only as good as the Project Manager wants it to be.
6. Some projects were not operating as true teams. Therefore, project risk information was not available to all members at the same time. Inputs from key players were collected either late or never.
7. The RM process may be implemented at any stage of the life cycle of a project. However, within government programs/projects it is very complex to do it after RFP formulation because of procurement limitations.

Recommendations

The following are specific recommendations to be implemented in any government program/project:

1. The RM process must be implemented at the program level first, so the policies and requirements flow down to the projects. It shall include as a minimum: policy, guidelines, RM Plan, and details regarding risk mitigation plans.
2. RM is an element of the project management and must be considered as an inherent part of any sound management activity. Therefore, it must have budget, RM Plan, and be represented in an organization within the project.
3. The project team must believe in the RM process to support it and execute it. So, the team must be intimately familiar with the process to freely speak and make open recommendations for improvement of the process and the course of the project itself.
4. The project team must be risk reduction/control minded. Therefore, the project team members must be oriented toward a similar RM philosophy and approach beginning at the early stages and continuing throughout the life of the project. Common training (e.g., CRM), continuous team risk discussion meetings, and welcoming any risk mitigation from any team member, must be met with the same level of interest and enthusiasm.
5. Training is not enough. Teamwork, application, and management style based on the RM process are required.

6. Upper management's full and impartial support of RM is required. Project Management leadership sets the tone.
7. The RM process must be pro-active and neither reactive nor a simple bookkeeping process.
8. Government programs and projects are generally ruled by standards that have been very well structured and only need to be brought to the procurement scenario as part of the proposal and negotiation stages.
9. RFPs must include clear and well-defined requirements for an RM process as part of the management approach proposed.
10. The government proposal review team is responsible for selecting proposals that include a comprehensive and well-structured project management approach. Furthermore, a contract must be signed with the total conviction that a comprehensive RM process will be implemented as an integral part of the project management approach offered.
11. Periodic program and project reviews at the Directorate and Center levels must emphasize and direct special attention to the structure of the RM process, its progress, results, status and short and long term comprehensive risk mitigation plans. Now, where Technical Reviews are held, separately from management reviews, this forum must include RM details for each issue, as listed above, and limit the RM summary, approach schedule and cost for the management Reviews.
12. Risk mitigation plans properly developed, implemented and closely monitored are fundamental for a robust RM process. These plans must include: clear description of the risk; detailed water fall schedule plan (including "inch-stones", decision making points, off-ramps, etc., and shall be tied to the overall project schedule), contingency plans, and relevancy or impact within the project

As NASA strives for excellence in all aspects of business, the Risk Management process has become an integral part of its commitment to safety and mission success.

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