

Managing Risk for Cassini During Mission Operations and Data Analysis (MO&DA)¹²

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Abstract— A Risk Management Process has been tailored for Cassini that not only satisfies the requirements of NASA and JPL, but also allows the Program to proactively identify and assess risks that threaten mission objectives. Cassini Risk Management is a team effort that involves both management and engineering staff. The process is managed and facilitated by the Mission Assurance Manager (MAM), but requires regular interactions with Program Staff and team members to instill the risk management philosophy into the day to day mission operations.

While Risk Management is well defined for projects in the development phase, it is a relatively new concept for Mission Operations. The Cassini team has embraced this process and has begun using it in an effective, proactive manner, to ensure mission success. It is hoped that the Cassini Risk Management Process will form the basis by which risk management is conducted during MO&DA on future projects.

TABLE OF CONTENTS

1. INTRODUCTION
2. MISSION OPERATIONS ASSURANCE PROGRAM
3. CASSINI RISK MANAGEMENT PROCESS
4. CASSINI ON-LINE RISK TOOL
5. RISK REPORTING & METRICS
6. CURRENT RISK POSTURE
7. CONCLUSIONS

1. INTRODUCTION

Today's space flight projects are faced with an environment that is driven by both challenging technical and science requirements as well as tight schedules and resource limitations. By nature, these challenges introduce risks that could potentially impact the degree to which today's projects satisfy their high level mission requirements and objectives. A proactive Risk Management Process is not only required by NASA and JPL, but its effective implementation is critical to increasing the likelihood of achieving mission success.

Risk is defined as the likelihood of an undesirable event (programmatic, technical, mission, safety, etc) occurring and

the severity of the consequences of the occurrence. Risk Management is a continuous process that occurs throughout the project lifecycle. The purpose of Risk Management is to proactively identify, assess, track and control risks before they become problems.

Mission Background

The Cassini Mission to Saturn was launched on October 15, 1997 from the Kennedy Space Center and is now in the MO&DA phase of the mission. Since Launch, Cassini has completed one Earth, two Venus and one Jupiter gravity assist fly-by and is now en-route to Saturn, with Saturn Orbit Insertion (SOI) scheduled for July 2004. Cassini will release the Huygens Probe at the moon Titan on 25 December 2004 and will continue on a four year tour of the Saturnian System.

Mission Operations Challenges

Risk Management during Mission Operations is relatively new to missions at NASA and JPL, posing challenges to those who forge ahead with implementation. Programs in the MO&DA Phase have plans that are mature and they are well on their way to achieving their mission objectives. For Cassini, the Mission Plan has long been established, maneuvers have been well thought out and encounters with Saturn's orbiting moons are scheduled. Unlike projects in the Development Phase, Cassini does not possess risk mitigation options to slip the launch date, trade resource margins such as mass, power and performance or delay a critical test to deal with hardware problems. Plans for the Cassini Mission and Saturn Tour Operations are in place and any alterations at this point in the mission would pose potentially serious impacts to other resources.

Risk Management in Mission Operations

Due to the nature of MO&DA, Risk Management becomes a crucial element for ensuring mission success. Cassini began the initial planning for Risk Management in October 2000, some three years after launch. The Futron Corporation was hired in November 2000, as a consultant, to assist in the planning process and in training the flight

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team. A series of planning workshops and training exercises were conducted from November 2000 to February 2001, with program and engineering staff, to ensure that the process in development became an integrated team effort.

Following the planning and process development, a series of brainstorming workshops were conducted with the Program Staff and team members to start identifying risk areas. This effort resulted in the development of an initial Significant Risk List (SRL), which is being used as the basis to start managing risk for the Program. Risks have been categorized and ownership assigned to the appropriate offices for disposition and resolution. A JPL institutionally supported web-based tool has also been tailored to facilitate risk identification, assessment, tracking, control, reporting and metrics generation. Cassini has a very low tolerance level for risk and as such, takes this process very seriously. The remainder of this paper will describe the Cassini Risk Management Process and how it will be used to manage risks in mission operations, before they become problems.

2. MISSION OPERATIONS ASSURANCE PROGRAM

Mission Operations Assurance (MOA) is a key process implemented during MO&DA, facilitated by the MAM. MOA engages the mission operations team in assurance related functions such as risk management, reviews, anomaly reporting / resolution and configuration management. Two of the key objectives of the Cassini Mission Assurance Program are to 1) improve the operational reliability during Mission Operations and 2) provide independent risk assessment to Program Manager & Office of Safety and Mission Assurance. Consistent with the operations assurance function, the MAM on Cassini is responsible for the development and implementation of an effective, value added Risk Management Process.

As reviews are also used to identify and assess risk areas, the Cassini Review and Risk Management processes are tightly coupled, under the cognizance of the MAM. Regular risk assessment reviews have been strategically scheduled throughout the project lifecycle. During Mission Operations, particular attention is paid to Critical Mission Events, thus Critical Event Readiness Reviews (CERR) will be conducted. They are held at times appropriate in the mission, to assess readiness and residual risk prior to a Mission Critical Event. For Cassini there will be two CERRs, one for SOI and one for the Probe mission.

3. CASSINI RISK MANAGEMENT PROCESS

Risk Management is a requirement, levied on Programs and Projects by both NASA and JPL. This section describes the processes, methodologies, tools and metrics that the Cassini Program has developed to implement a risk management program that is in compliance with NPG 7120.5A, NASA Risk Management Process Requirements. Figure 1 illustrates the risk management requirements as defined in NPG 7120.5A.

In response to NPG 7120.5A, Cassini has established a Risk Management Process to do the following:

- Identify the potential sources of risk and identify risk drivers
- Qualitatively assess risk impacts and likelihood
- Determine the sensitivity of these risks to program assumptions and the correlation among the risks
- Determine and evaluate alternative approaches to mitigate moderate and high risks
- Take actions to avoid, control, assume or mitigate each risk
- Ensure that risk is factored into decisions on selection of specification requirements and solution alternatives

Risk Management is a continuous, circular process, that is conducted throughout the lifecycle of the Project. The Cassini Risk Management Process is illustrated in Figure 2.

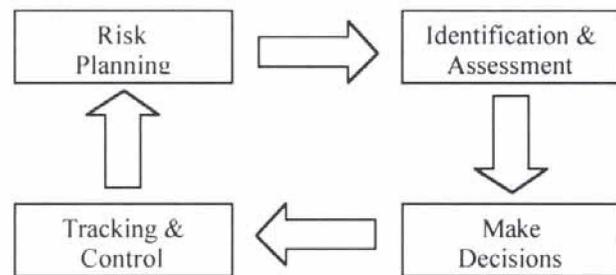


Figure 2 Cassini Risk Management Process Flow

Roles & Responsibilities

The Cassini Program Manager is responsible for the successful guidance of the Program, in the presence of technical and programmatic risk, as well as the Program's overall risk exposure. Responsibility for development and implementation of the Cassini Risk Management Process was assigned to the Mission Assurance Manager, who in turn also coordinates all risk management activity.

Risk Management on Cassini is a team effort and all team members are included in the process. Everyone is responsible for identifying risk items and ensuring they are included in the SRL. Typically, the Cassini Office Managers are designated as the risk owners, although in some instances ownership may be delegated to a subsystem lead. Table 1 illustrates the functions, responsibilities and products produced during the process.

Table 1 Risk Management Roles & Responsibilities

Function	Who	Product
Risk Planning	MAM	Risk Mgt Plan
Identification	All	ID & Initial Assess't
Assessment	Risk Team	Likelihood/Impact
Quantification	MAM	Quantitative Analysis
Decision Making	Risk Team	Actions Assigned
Decision Making at Program Level	Program Manager	Mitigation/contingency plan approval. Redesign / descope decisions.
Tracking & Control	MAM	Ongoing Risk Assm't, Status & Metrics

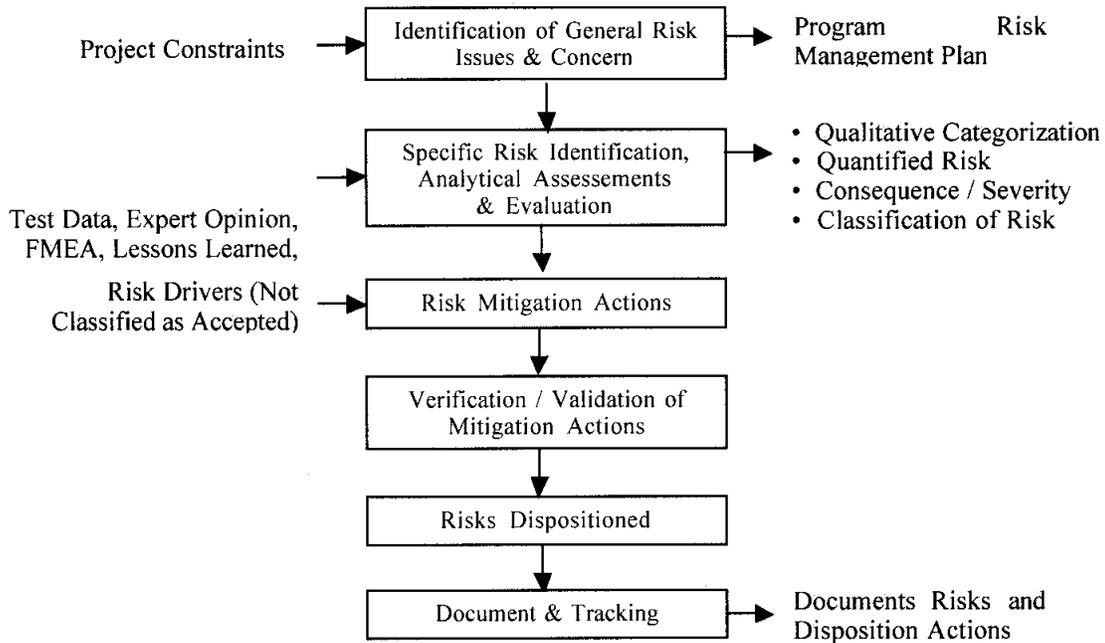


Figure 1 NPG 7120.5A Risk Management Process Flow

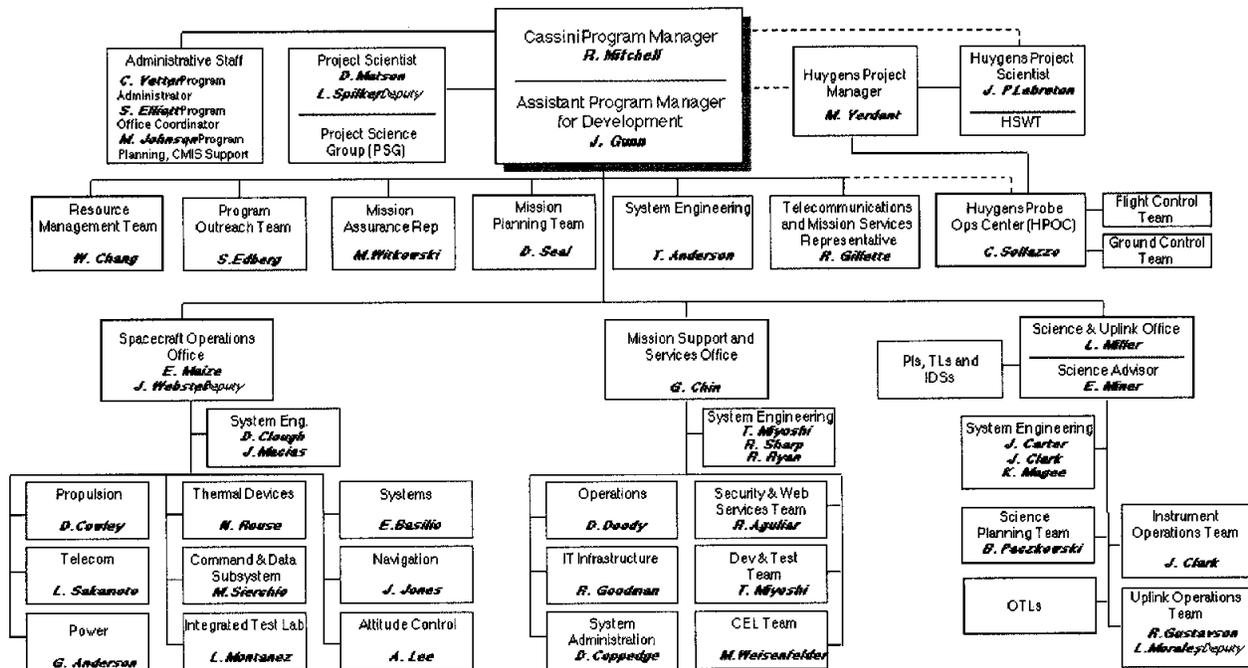


Figure 3 Cassini Program Organization / Risk Team Membership

Cassini Risk Team

The Cassini Risk Team is composed primarily of the persons responsible for individual Work Breakdown Structure (WBS) items and is chaired by the Cassini MAM. This decision making team is comprised of the Program Manager and Staff, Office Managers, Team Leads, Sequence Virtual Team Leads (SVTL) and Science

Planning Virtual Team Leads (SPVTL). Figure 3 illustrates the organizational structure of the Cassini Program.

Risk Planning

Before Risk Management can be effectively conducted, plans must be put into place to document how the process will be implemented.

Risk management planning for Cassini involved:

- Defining the programs's overall risk policy and objectives
- Defining roles, responsibilities, resources, schedules and documentation required for Risk Management Activities
- Defining the tools and techniques that will be used for risk identification & assessment, risk analysis and mitigation, tracking and control
- Defining the relationship Risk Management has with respect to systems analysis, configuration control, anomaly reporting / resolution and reviews, etc.

The results of the Cassini planning process are documented in the Risk Management Plan, which focuses exclusively on events that may occur in the future. This enables the project to proactively identify and manage risk, rather than respond to problems later on. The plan documents roles and responsibilities, establishes timing guidelines and describes how risks are analyzed, responded to and tracked.

Identification & Assessment

Risk Identification is the process for understanding what uncertainties or risks the project might face during the course of the mission and documenting their characteristics. The Cassini Project performs Risk Identification and Assessment utilizing: 1) Risk Management Training and Brainstorming Workshops, 2) Expert Interviews (as required), 3) Fault Trees and 4) Flight Team Member solicitation for input. Any and all Flight Team members may submit risks at any time during the life cycle of the project. On Cassini this input is solicited and encouraged.

Risk Assessment is the process of prioritizing risks to determine which risks require greater management attention and/or resources. Assessment typically includes both a qualitative and quantitative analysis of risks and conditions to determine their effects on project objectives.

As Cassini's budget and schedule are well established, risks are only assessed quantitatively. If desired, the capability for qualitative analysis is available via modifications to the online tool. As risks are identified, they are also assessed and triaged according to likelihood and impact of occurrence.

Detailed definitions for likelihood and impact criteria are specified in the Cassini Risk Management Plan. The Cassini Triage Matrix is illustrated in Figure 4. As a trend setter, and deviating from typical risk management practices, Cassini decided to adopt a 3x5 matrix, versus the symmetrical 3x3 or 5x5. This decision was made due to the fact that no matter how unlikely an event is to occur, Cassini expends resources addressing those with significant and/or high impact ratings. This decision

further illustrates the risk tolerance, or rather risk intolerance, of the Program.

In addition to being triaged, risks are also categorized by Mission Phase on Cassini. This serves to better illustrate where and when the Program's exposure to a given risk is present. Risks are categorized into Cruise, Tour, Saturn Orbit Insertion (SOI) and Probe groupings.

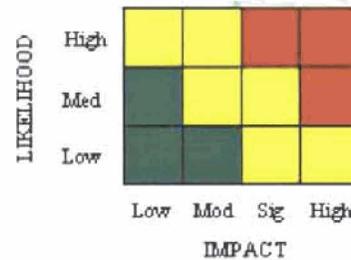


Figure 4 Risk Triage Matrix

Following completion of a mission phase, risks associated with it are retired, as the window of vulnerability will have expired. This enables the team to effectively work and prioritize risk mitigation measures depending on the mission phase and criticality.

Inputs to the identification and assessment process are consolidated by the MAM and presented to the Cassini Risk Team for disposition. Risk identification, assessment and disposition occurs quarterly, when the risk team convenes.

Make Decisions

The Decision Making process is utilized to determine which risk response type will be invoked for each risk on the SRL. It involves assembling each risk item and aggregate risk data to identify which risks require mitigation, which will be tracked and which will be accepted or retired. During the process, risk mitigation approaches are introduced, trade-offs conducted and decisions are made to determine the response necessary. A cost-benefit analysis may be conducted for each proposed mitigation approach to ensure that the cost of the proposed action is less than the expected risk outcome. Trade studies are performed for competing options and potential for introducing new risks by application of mitigation measures is also addressed.

Decisions as to whether to avoid, mitigate, accept or retire risks are first proposed by the risk owners. Following review by the MAM, these decisions are brought before the Cassini Risk Team for discussion and disposition.

Tracking & Control

Risk Tracking and Control involves regular reassessments of all risk items in the SRL. This process includes: identifying residual as well as new risks, executing risk mitigation measures and evaluating their

effectiveness through the project life cycle. The MAM re-assesses the SRL monthly, updating the SRL and metrics as necessary. The Cassini Risk Team meets quarterly to evaluate changes to the SRL and project risk posture, as well as assess the effectiveness of mitigation measures that have been implemented.

These regular re-assessments enable Cassini to determine if:

- Risk responses have been implemented as planned
- Risk response actions are effective
- Risk exposure of the project has changed or remains constant
- A risk trigger has occurred
- New risks have arisen that were not previously identified

As risks are retired, they are placed into an archive and no longer tracked. It is expected that most risks on Cassini will be retired following completion of a given Mission Phase (e.g. SOI), as that is how they are categorized.

4. CASSINI ON-LINE RISK TOOL

To facilitate risk record keeping and configuration control, Cassini has adopted web-based, on-line risk management tool that is also institutionally supported by JPL. This tool has previously been utilized on JPL's Mars Exploration Rover (MER) Project and is currently in use on Space InfraRed Telescope Facility (SIRTF). Tailoring for Cassini has been completed and the tool has been rolled out to the Cassini Flight Team. The tool was developed by Keevin Fisher, a Ratheon contractor working for JPL. It is hosted and maintained on a server at the Ratheon facility in Pasadena, alleviating the Cassini workforce from administration efforts. Changes, updates and additions are worked easily and directly with Keevin and his team.

The tool consists of a Microsoft Access database system and web-based front end. It enables all Cassini team members to easily input risks into the system for MAM and Risk Team evaluation. Cassini risk management encourages any and all team members to identify risks that they feel are present. The risk tool is easily reached via a link from the Mission Assurance website, within the Cassini Portal. The environment and process enables anyone on the flight team to push the alert button. As risks are entered into the system they are reviewed by the MAM and brought before the Cassini Risk Team for further evaluation.

Risks are stored, triaged and tracked via the on-line system, enabling the MAM and Risk Team to concentrate on the risks themselves, not the record keeping. Tight version control enables the MAM to track changes and progress over time. This version control also facilitates metrics that track and trend the history of risks. To facilitate status reporting and metrics, modifications to the system have been proposed and are currently being implemented. These modifications, when completed,

will produce status reports and metrics for the MAM at the push of a button. Cassini is working closely with Keevin and his team to tailor this tool into a valuable resource for projects managing risk during mission operations. A sample Risk Summary from the on-line tool is given in Figure 5.

5. STATUS REPORTING & METRICS

A Risk Management agenda item is included for all project level Monthly and Quarterly Management Reviews, as well as any other review at the Program Level. Reporting is done by the MAM and includes:

- Risk Summary
- Risk Status and Action Plans (for Red risks)
- Changes Since Last Reviews
 - Updates to Mitigation Plans
 - Updates to the Risk Database
- Metrics

The MAM and Program Manager have together defined metrics to be collected for the purpose of tracking risks and measuring the effectiveness of risk responses. At a minimum the following metrics are expected to be maintained:

- Green, Yellow, Red risks vs. time
 - Assessment of how risk exposure changes with time in each of the classifications
- Project's aggregate risk exposure vs time
 - Aggregate risk assessment of the Project's total risk exposure vs. time. This metric sums the number of active risks times a weighting factor for each risk exposure color. The sum is then normalized and forms the basis for the aggregate risk exposure comparisons vs.time.
- Risk Status Change - risks added, change in status and retired vs. time
 - Assessment of how risk status has changed, due to risks being added, deleted, mitigated, accepted, retired etc., vs time
- Liens against project resources (cost, schedule, performance budgets) vs time
 - Assessment of the resource reserves required to cover an accepted yellow or red risk.
- Aging Metrics
 - Aging assessment of how long the project has taken to react and disposition new risk items/faults are active mechanical or electrical component potential failures.

6. CURRENT RISK POSTURE

Risk Management planning has been completed, but implementation has just begun on Cassini. The initial SRL has been developed and to date 59 risks to mission objectives have been identified by the process. Of these risks identified and assessed in the initial round, 3 were rated red (high likelihood / high impact). Yellow risks currently number 36, with 20 green risks remaining. By

Cassini Risk Table Summary - All Risks

	High	0	0	1	0
Likelihood	Medium	0	8	3	2
	Low	0	0	15	10
		Low	Moderate	Significant	High
		Impact			

Risk Classifications		Pending	Under Review	Evaluated	Total
Not a mission threat	Green	0	20	0	20
Potential threat to mission success	Yellow	0	36	0	36
Significant and likely threat to mission success	Red	0	3	0	3
	Total	0	59	0	59

* Pending risks are not included in Under Review and Evaluated risk table given above

- Risks without Impact Categorization: 0
- Risks without Likelihood Categorization: 0
- Risks with a Pending status: 0
- Retired Risks: 0
- Rejected Risks: 0

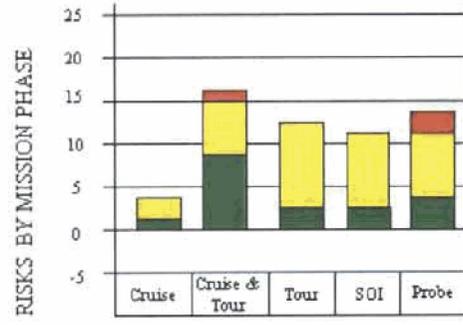
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Figure 5 Risk Summary

risk category, there were 5 Cruise Risks, 16 Cruise/Tour Risks, 13 Tour Risks, 12 SOI Risks and 13 Probe Mission Risks identified. The risk assessment / break down of risks by category and is given in Figure 6. The results of the integrated initial risk assessment and triage activity is illustrated in Figure 7. All risks will now be tracked and monitored on a regular basis, with the MAM reviewing new risks, updates and changes as they are input. It is anticipated that mitigation efforts will be put into place, that when implemented, will reduce red risks to yellow and yellow risks to green. This will be an activity to occur in the future.

The initial SRL is in the process of being scrubbed by those assigned ownership of the individual risks. Following the scrubbing, risk ratings will be compared with initial ratings, to obtain a measure of how effective our initial mitigation efforts have been. Once this is done, a quarterly metric will continue on this parameter to illustrate the Program's risk posture over time.

Risk awareness by the Cassini Flight Team is on the forefront. Flight Team members continue to identify,



HIGH	0	1	0	0	2
MED	4	7	10	9	7
LOW	1	8	3	3	4

Figure 6 Risk Summary by Mission Phase

assess and control risks. Risk items will begin to be dispositioned quarterly by the MAM and Risk Team. Contingency planning will be reviewed regularly by the team where measures to reduce, mitigate, or eliminate/retire are necessary.

7. CONCLUSIONS

Cassini has put into place a risk management process that is proactive in identifying, assessing and mitigating risks before they become problems. Cost effectiveness is achieved by:

- Comprehensively identifying risks
- Rapidly assessing which risks require the expenditure of project resources
- Taking early actions to mitigate these risks
- Iterating the process frequently, to be responsive to the dynamic internal and external environments

The Cassini Program has successfully implemented a Risk Management Process for mission operations. The initial SRL has been developed and input into the online tool. The Risk Management web-based system has been rolled out for use by the flight team and risk owners are working

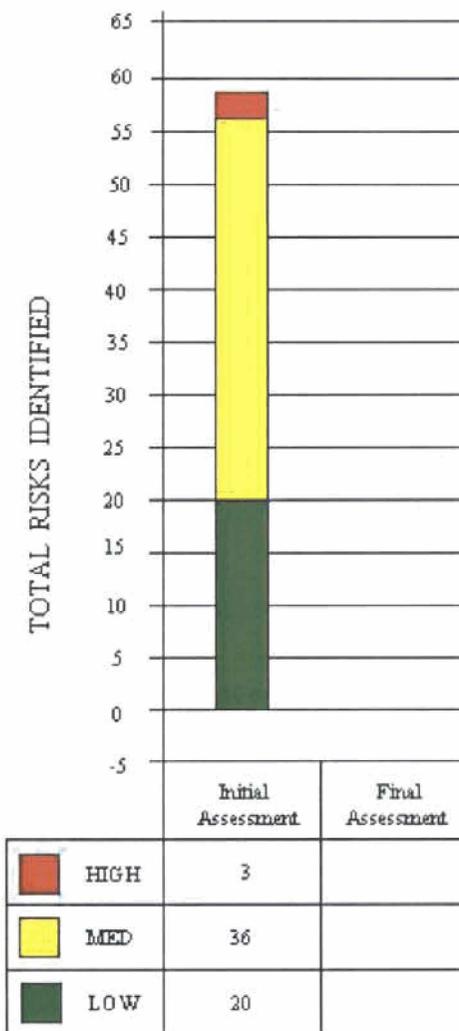


Figure 7 Cassini Initial Risk Assessment Results

their assigned risks. While the process and system are relatively new to the Program, the philosophy has taken hold and flight team members are proactively assessing risk on a daily basis. As time goes by, results of what has been

put into place will become visible and will be illustrated in future papers.

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