How an Effective Contract and its Enforcement Could Have Prevented the Challenger Disaster[1]

By Nana Kwabena Osei

ABSTRACT

Over the years, a lot of investigations and research have been conducted to better understand and highlight the causes of the Challenger Disaster in order to improve space programs as well as put in place measures to prevent such disasters. Extensive rational has been offered as the root cause of the disaster led by NASA as well as independent investigative committees such as the Rogers Commission and the Committee on Science and Technology House of Representatives of the 99th Congress of the United States. The main cause has been rooted in the failure of the primary O-ring on the right Solid Rocket Booster Motor which was as a result of a fundamental faulty design. Other causes have been linked to the poor risk management practices and flaws in the decision-making processes at NASA at the time. However, available reports on the incident have failed to investigate contractual failures during the program, between NASA and their prime-contractors, to address the importance of contracts and their effective management in the success of projects and programs.

This paper utilizes a multi-attribute decision making tool to compare effective contract signing and enforcement with different solutions as recommended by the Rogers Commission, and to determine which of the solutions eliminates the problem through the application of root cause analysis. Based on the results, the paper suggests an effective contract, its enforcement and compliance to all details could have been the key to the prevention of the Challenger Disaster and loss of its crew members.

Key Words: *Challenger Disaster, Space Shuttle, NASA, Space Exploration, Project Contract Failure, Decision-making, Root Cause Analysis, Dispute Resolution.*

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INTRODUCTION

In the 1970's, the National Aeronautics and Space Administration (NASA) was tasked with developing a manned reusable space vehicle for transporting crew and cargo to and from space called the space shuttle. North American Rockwell was selected on July 26, 1972 to construct the shuttle whiles Morton Thiokol was awarded a $710 million contract to design and build the solid rocket boosters (SRBs) in 1974.

Figure 1 Challenger Disaster (Source: www.history.com)

The SRBs are key elements in the operation of a space shuttle as it provides the shuttle with the required thrust to overcome the earth's gravitational force to reach orbit.

Morton Thiokol's design was an up-scaled version of the Titan Missile which had been successfully used in previous years with the only major difference being the addition of a secondary O-ring. The O-rings prevented the pressurized combustion gasses from the boosters from escaping by forming an airtight seal. The O-rings were assigned a "Criticality 1", meaning their failure during launch will result in the destruction of the Orbiter, However, later tests will indicate a potential compromise in design as the O-rings which were designated malfunctioned especially at low temperatures.

After 6 days of delay as a result of bad weather conditions and technical issues, the Challenger space shuttle was finally launched on 28th January, 1986, from Kennedy Space Center at Cape Canaveral, Florida. Despite several attempts by engineers from Morton Thiokol to boycott the launch insisting that certain components especially the rubber O-rings that sealed the joints of the shuttle's solid rocket boosters were vulnerable to failure at low temperatures, the shuttle was given go ahead for launch by NASA managers.

The 25th mission took off at 11:39 a.m. igniting into a fireball after 73 secs through a chain of reactions which included failure of the primary O-rings in the rocket boosters causing collapse of the shuttle's external tank, releasing all its fuel into combustion and killing the entire crew. This traumatizing event was watched live by the families of the crew and all onlookers, throwing NASA's shuttle program into disarray.

Even though the direct cause of the disaster was determined to be the failed O-rings, investigations concluded that the decision-making process at NASA was ineffective, that together with its contractors, NASA failed to proactively resolve the increasingly evident malfunction in the rocket booster joints resulting in the loss of life.

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OBJECTIVE/PROBLEM or OPPORTUNITY STATEMENT

The best approach to any problem resolution investigation is an in-depth understanding of the problem, as it imperatively clarifies what information exactly is to be gathered during the analysis. This sets the right tone in identifying our corrective actions and at the same time ensuring the effectiveness of the solutions to implement. To help us define our problem, we will answer the questions of when did it happen? Where did it happen and how it impacted the goals/benefits of the project?

The main problem of the Challenger disaster was the loss of all seven crew members and the challenger shuttle itself, contrary to the main objective of the program.
Most projects and programs typically have multiple goals which includes ensuring the safety of all employees and stakeholders involved, delivering the intended purpose efficiently, all within the constraints of time, cost and quality.

NASA's space program regards safety as top priority since a manned mission cannot be considered a success unless all of the astronauts launched into space come back in one piece. The safety deliverable of the program was not achieved as a result of the deaths of all the seven astronauts aboard the shuttle. In addition to that, the space program was extremely expensive with cries for its shutdown due to waste of the tax payers' money. This led NASA to develop the reusable shuttle for multiples missions therefore its total destruction dealt an immense blow on the technical and financial objectives of the challenger mission. As a direct result of the shuttle disintegration, the who mission was a complete loss; the teacher in space program and launching of a space satellite were unachievable affecting the educational and scientific goals of the flight. Finally, the analysis and investigations in the wake of the disaster led to lose of faith by the general public in the program as well as lose of time and labor.

What	Problem(s)	Loss of Crew and the space shuttle
When	Date	January 28, 1986
	Time	11:39:12 AM EST
	Different, Unusual, Unique	100-year freeze (Cold Weather)
Where	State, City	Cape Canaveral
	Facility, Site	Challenger (STS 51-L)
	Task being performed	First stage ascent (~46,000' altitude)

Impact to Goals

Safety	Loss of 7 astronauts (Entire Crew)	
Education	Teacher in space lessons not achieved	
Scientific	Satellite for data collection not launched	
Technical	Total loss to Challenger STS	$1,000,000,000
Social	Loss of faith in program	
		$1,000,000,000

Table 1 Challenger Disaster Problem Definition, Source: thinkreliability.com

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The objective of this paper is to investigate the Space Shuttle Disaster from a contractual perspective between NASA and one of their key stakeholders to the space program: Morton Thiokol, which was a direct contributor to the disaster. More specifically:

1. We will first suggest a contractual solution amongst the recommendations of the Rogers Commission relating to risk management, decision-making as well as testing and certification programs will be analyzed against the well tested and proven industry practices to determine their effectiveness and viability.
2. Secondly, we will analyze the various solutions to determine which one offers the most practical yet feasible means of eliminating the root cause of the incident.
3. Finally, the paper will explore ways in which contractual enforcements of the roles and responsibilities, risk assessment, testing and quality criteria as well decision making matrices could have potentially prevented the disaster from occurring.

FEASIBLE ALTERNATIVES

Taking into consideration the findings of the Rogers Commission and the Committee on Science and Technology House of Representatives of the 99th Congress of the United States with their reports on the Challenger Disaster, we will include the effective use and enforcement of a contract among the main recommendations of action items as possible solutions to the program failure.

From there, we will build a Cause Map through the utilization of Apollo Techniques to identify the root cause or causes of the disaster and try to ascertain which of our alternative solutions better offers a feasible solution to eliminate or worst case scenario, mitigate the impact of the failure on the program objectives. The main areas of solutions recommended by the various commissions included:

1. Re-design: development of a new design or re-designing of the faulty Solid Rocket Motor Joint and seal
2. Reorganization of the Shuttle Program Management Structure.
3. Establish a safety organization to manage over-all safety of the program
4. Enforcement of all contract clauses including design, safety, roles and responsibilities

DEVELOPMENT OF OUTCOMES

Design: Development of a new design or correcting the faulty SRM Joint and Seal

Despite the availability of information and evidence from prior missions on the flaws in the joint design, neither NASA nor Morton Thiokol technical managers understood the severity and urgency of the malfunction. The disaster could have possibly been eliminated if the then fleet were grounded and a change in the SRM joint and seal were ordered by way of a new design to eliminate the joint or a redesign to prevent the possible blow-by of gases or resilience-

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dependency of the joint on temperature. This would have come at high cost due to the significant tax payer's money that had gone into the program however could have saved the lives of the crew and the image of the program.

Reorganizing the Shuttle Program Management Structure

Flaws in the decision-making process at NASA was made possible by the hierarchical management structure with unclear roles and responsibilities as well as unequal authority allowing key stakeholders to halt a launch when a component is deemed unfit for purpose. A more linear structure would have facilitated the movement of vital information such as shuttle funding, work packages to ensure accountability at all levels. Management of Morton Thiokol finally approved the launch contrary to the opinions of their engineers because they were not empowered by the management structure to stand their grounds and object the launch.

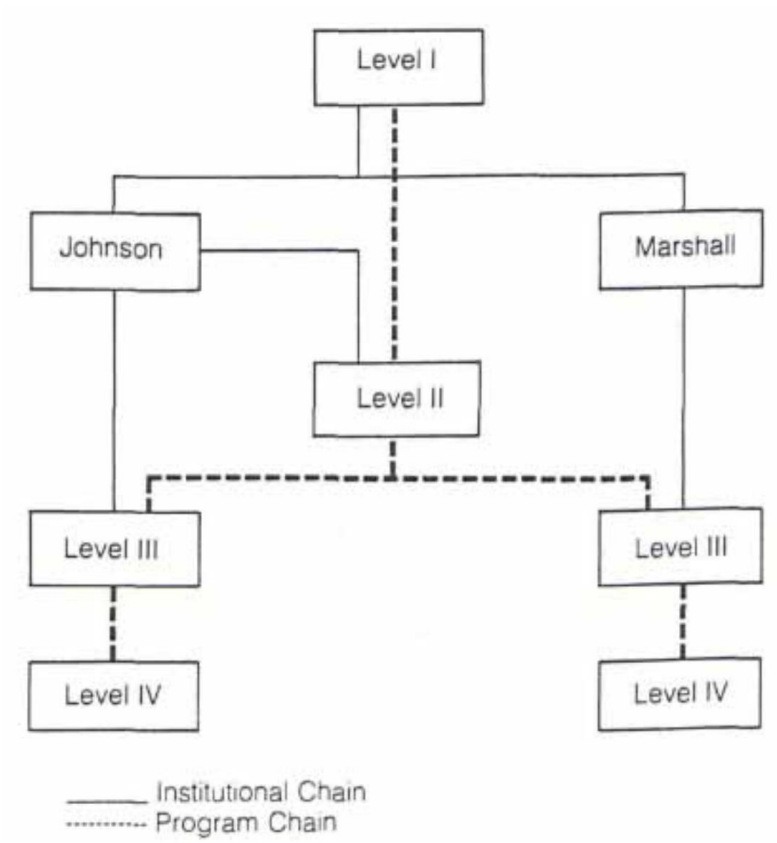

Figure 2 Shuttle Program Management Structure, Source: pmi.org

LEVEL I: *Flight Associate Administrator*
LEVEL II: *Manager, National Space Transportation Program*
LEVEL III: *Program Managers for Orbiter, SRB, External Tank and Shuttle Main Engine*
LEVEL IV: *Contractor to Shuttle Elements*

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Establish a safety organization

The commission recommended the establishment of an independent organization tasked with the role of overseeing all safety, reliability and quality assurance related issues within all NASA programs. A rigorous approach to accident prevention and flight system safety requirements combined with processes that ensure components and systems meet quality standards enabling functionality as planned would have gone a long way to prevent the occurrence of the incident. The compromise in the O-rings due to temperature would have been flagged as unfit for purpose therefore aborting the launch.

Contract Enforcement

A contract is a written or oral legally-binding agreement between the parties identified in the agreement to fulfil the terms and conditions outlined in the agreement. Although there are a lot of plausible solutions for the disaster as suggested by the commissions that investigated the incident including redesign of the solid rocket booster motor joint as well as restructuring the decision-making and safety process at NASA, it is clear that the use and enforcement of a contract between NASA and its key stakeholders in the program clearly outlining the below points would have provided a fundamental framework for the elimination of the various chain of failures that finally led to the disaster.

- The contract awarded to Morton Thiokol for the design of the Solid Rocket Booster was based on a Development and Verification Plan (D&V Plan) which was used to demonstrate that the conceived design reliably meets all requirements for safety, design and performance. Therefore, any malfunction should have rendered the contract between NASA and Morton Thiokol void requiring going back to basics to fix the issues before proceeding.

- A contract could have been used to redefine the roles and responsibilities of all key stakeholders granting requisite authority to approve or reject shuttle launch should they deem any process/component unfit. Clearly stating this in the contracts would have given the managers at Thiokol the legal power to stand their grounds and rejecting the launch thereby preventing the disaster.

SELECTION CRITERIA

In order to select the best option that provides a solid foundation which effectively eliminates the causes of the Challenger disaster, we analyze the overall objectives and deliverables of the program from different perspectives to better understand what our best option should entail in ensuring all deliverables are met within the constraints of the program.

Therefore, from below strategic wheel of the program, and multi attribute decision-making tool, our final option should result in

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- A successful launch and return of all 7 crew members from a 7-day space satellite deployment. and teacher in space mission onboard the Challenger Shuttle.
- 100% elimination of the root cause of the disaster as per the root cause analysis.
- Aids or facilitates the achievement of the other solutions.
- Cost effective solution to secure funding from the tax payer.

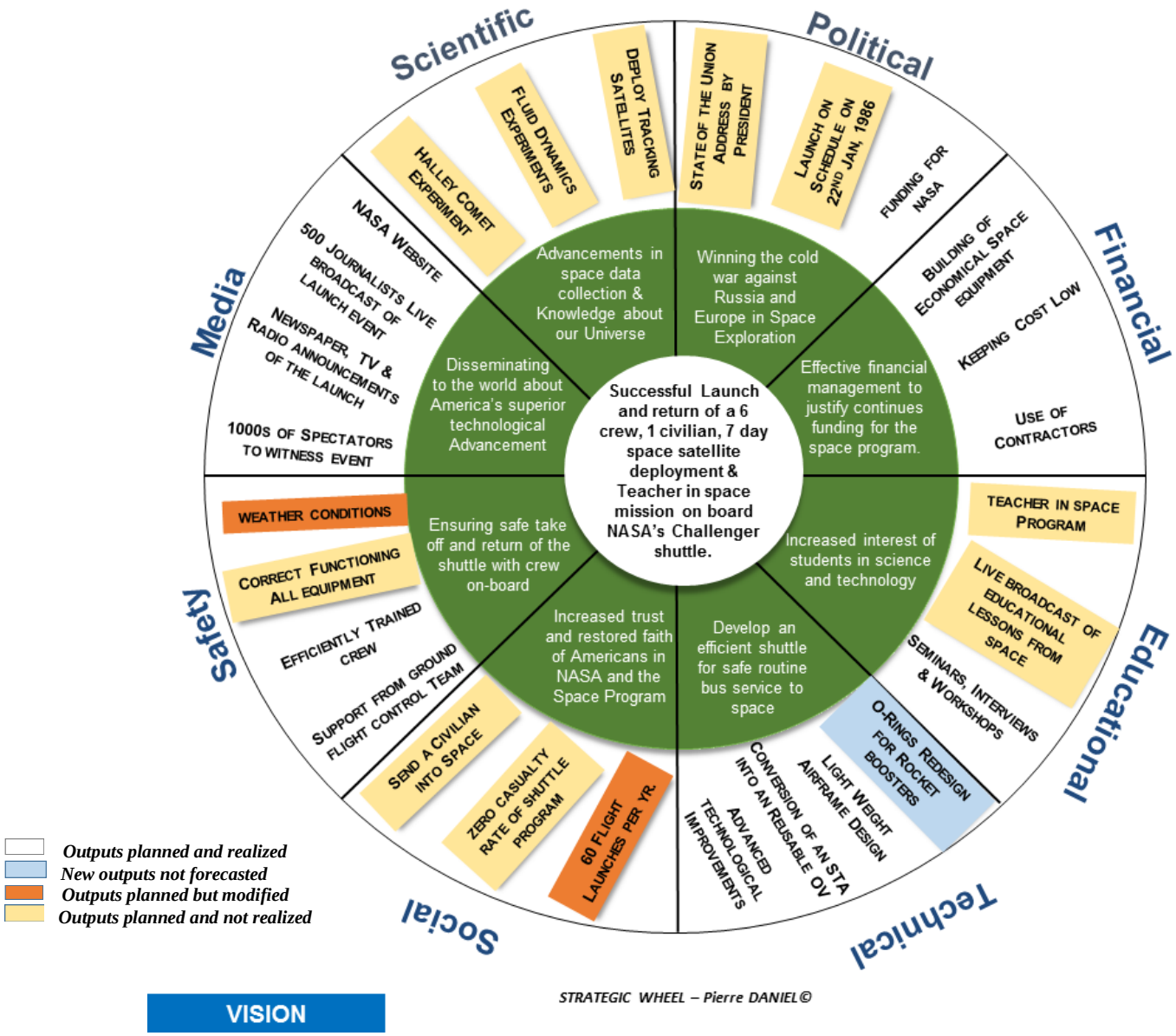

Figure 3 Strategic Wheel of the Challenger Program

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Attribute	Re-design of RSBs	Organizational Re-structure	New Safety Organization	Contract Enforcement
Cost	High	Medium	Medium	Low
Facilitation of the other solutions	Medium	Medium	Medium	High
Elimination of Root Cause	100%	50%	75%	100%
Achievement of Program Goals	Likely	Likely	Likely	Most Likely

Table 2 Multi Attribute Decision-Making Tool, By Author

FINDINGS

Analyzing the root cause of the challenger accident will assist in determining if our final solution provides a frame work for the elimination of the root cause of the disaster thereby averting the incident. The ultimate goal of safety was not achieved with all the seven crew members losing their lives, therefore this is our starting point in our analysis. Asking, "Why?" in a progressive manner, we can say the deaths were as a direct result of the loss of the space shuttle which was caused by explosion of the external tank of the shuttle. Prior to that, the external fuel tank had exploded due to the excape of combustible gases from the right rocket booster. Why this was possible was because the seal around the O-ring failed to prevent the leak of gases from the rocket booster.

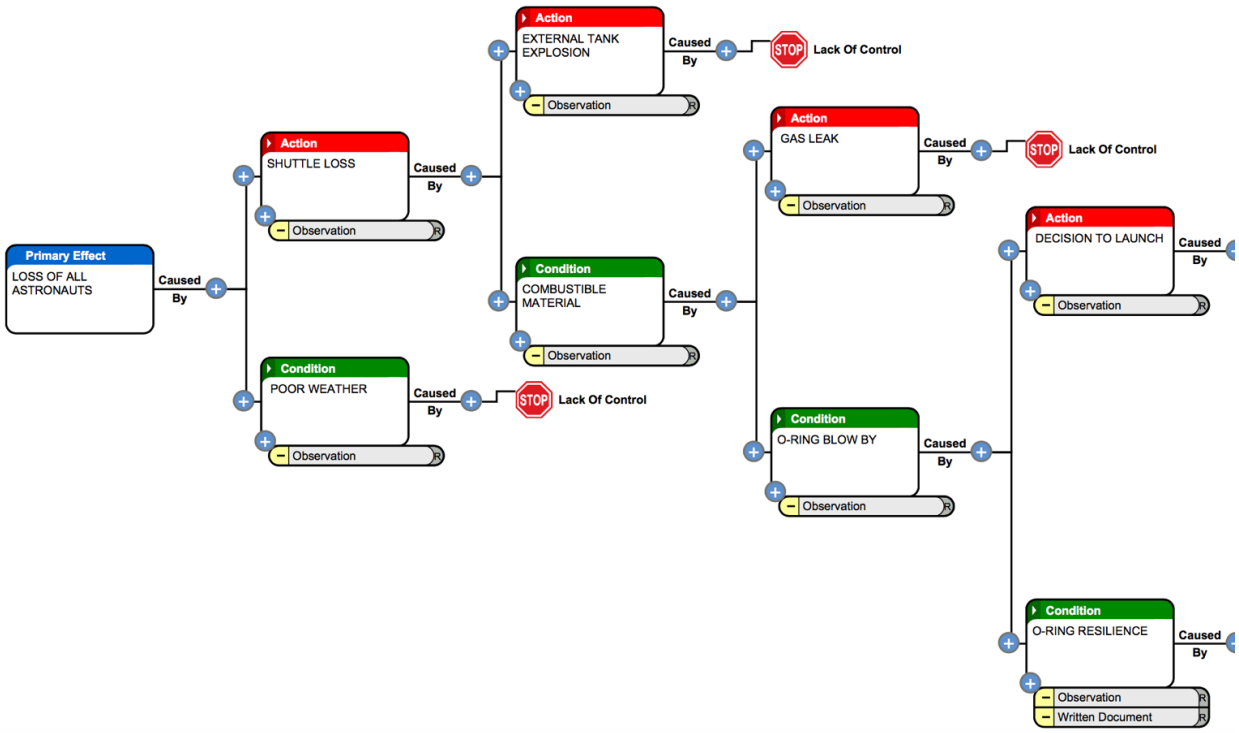

Figure 4 Reality Chart of Challenger Disaster-1, Software: RealityChart v7.9 By Author

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The process progresses with the analysis of why the primary O-ring failed? As per the finding of the Rogers Commission, the two main reasons for the O-ring failure was a structural design flaw in the joint which had been identified and documented previously by Morton Thiokol. The other major factor was the decision made by NASA officials to launch the shuttle despite calls for postponement by engineers from Morton Thiokol due to low temperatures and possible malfunction of the O-rings. Both causes can be traced to contractual failures. If the roles and responsibilities of both the project owner(NASA) and the contractor(Morton Thiokol) were clearly highlighted by way of effective clauses in the signed contracts with significant authority going to all key stakeholders with the power to halt the launch at any time if they deem the condition any component as compromised. Also acceptance criteria and quality standards had to be quantifiable and measurable making it ineffective to operate any component if testing and previous data prove there are unfit for purpose

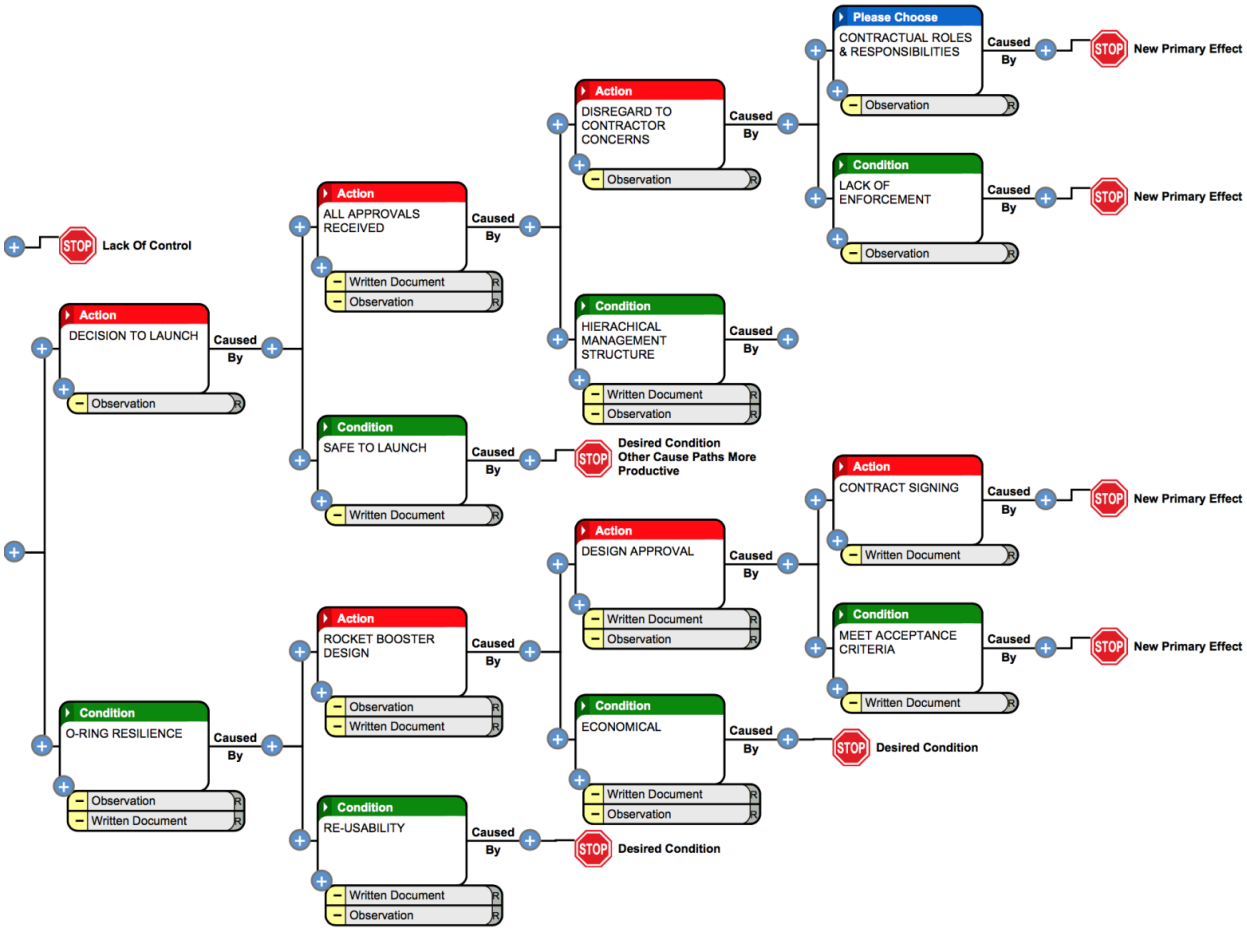

Figure 5 Reality Chart of Challenger Disaster-2, Software: RealityChart v7.9 By Author

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CONCLUSION

The importance of an effective contract signing and its efficient management cannot be over-emphasized in today's fast paced and uncertain project world. At the time of the challenger disaster, the space shuttle was the most complex machines ever built by man with over 2 million separate components and parts, requiring meticulous testing and planning to the teeth to ensure successful execution. Due to the diverse nature of such projects involving several stakeholders, there always arises the issue of roles and responsibilities in relation to quality management, safety and compliance. In this paper, we have through the use of multi-attribute decision making techniques as well as Apollo root cause analysis linked the root cause of the Challenger disaster to contractual failures. A contract is legally binding and clearly outlines the needs of the buyer to be executed by the contractor under foreseeable constraints. Therefore, absolute compliance to all contract terms and conditions including principles, technical specifications, testing and administrative processes in accordance with industry contractual best practices throughout the total life cycle of a project creates an enabling environment providing reasonable assurance for the achievement of the project goals.

FOLLOW ON RESEARCH

It is evident from the Challenger Disaster that only the signing of a contract does not assure the success of a program. Contract management and enforcement is a key aspect in ensuring the overall success of the process. Most often than not contracts are sub-contracted several times requiring monitoring by the contracting agency as well as the prime contractor to ensure compliance to performance standards.

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