Space shuttle columbia

On February 1, 2003, the Space Shuttle Columbia broke apart during re-entry resulting in the loss of the seven crewmembers and the shuttle. For the next several months an extensive investigation of the accident was performed by the Columbia Accident Investigation Board (CAIB). The board published their final report in August, 2003 and concluded that the cause of the loss of Columbia and its crew was a breach in the left wing leading edge Reinforced Carbon-Carbon Thermal Protection System initiated by the impact of thermal insulating foam that had separated from the orbiters external fuel tank 81 seconds into the missions launch.

During re-entry, this breach allowed hot gas to enter the wing’s leading edge and support structure which ultimately led to the breakup of the orbiter. The CAIB also discovered multiple flaws within the shuttle safety program, the hazard analysis techniques, communicationandleadershipbetween management and engineering, and an obstructive organizationalculture. NASA responded to the Columbia accident by grounding all space shuttle missions for a total of 905 days while they complied with all the recommendations made by the CAIB as well as restructuring their system safety and communication procedures.

Space Shuttle Columbia The Columbia STS-107 mission lifted off on January 16, 2003, for a 16-daysciencemission featuring numerous microgravity experiments. Upon reentering the atmosphere on February 1, 2003, the Columbia orbiter suffered a catastrophicfailuredue to a breach that occurred 81 seconds into the launch when falling thermal insulating foam from the left bipod area of the External Tank struck the Reinforced Carbon-Carbon (RCC) panels on the underside of the left wing.

The orbiter and its seven crewmembers were lost approximately 16 minutes before Columbia was scheduled to touch down at Kennedy Space Center. Within this paper I will discuss the history, mission, and anatomy of Space Shuttle Columbia, the incident and the breakdown in communication and safety practices, as well as information found during the formal investigation by the Columbia Accident Investigation Board (CAIB). History of Space Shuttle Columbia The Space Shuttle Columbia was built in the years leading up to 1981 when it was the first space shuttle to fly into earth orbit on April 12th.

There were four sister ships in the fleet over the next ten years: the Challenger, Discovery, Atlantis, and the Enterprise. The Endeavour was built to replace the Challenger that was destroyed in 1986. Columbia was the first on-line orbiter to undergo the scheduled inspection and retrofit program. It was transported August 10, 1991, after its completion of mission STS-40, to prime space shuttle contractor Rockwell International's Palmdale, California assembly plant.

The oldest orbiter in the fleet underwent approximately 50 modifications, including the addition of carbon brakes, drag chute, improved nose wheel steering, removal of development flight instrumentation and an enhancement of its thermal protection system. The orbiter returned to Kennedy Space Center February 9, 1992 to begin processing for mission STS-50 in June of that year. Primary Mission The primary objectives of this mission was to research in physical, life, and space sciences, conducted in approximately 80 separate experiments, comprised of hundreds of samples and test points.

The crew was divided into two alternating shifts to achieve the most productive use of time for each 24 hour period. The crew’s payload consisted of the following: first flight of SPACEHAB Research Double Module; Fast Reaction Experiments Enabling Science, Technology, Applications and Research (FREESTAR); First Extended Duration Orbiter (EDO) mission since STS-90 (Wilson, 2006). The expected duration of the STS-107 mission was 16 long days. Anatomy of the Space Shuttle The space shuttle is made up of over two million moving parts and 150 miles of internal wiring, making it the most complex machine ever created.

Empty the space shuttle weighs in at 158, 289 lbs and with the main engines installed it tips the scales at over 178, 000 lbs. Once all the fuel and cargo are added, the space shuttle weighs an astounding 4. 5 million lbs. There are three main parts to every space shuttle, the orbiter, solid rocket boosters, and the external fuel tank. The solid rocket boosters and the external fuel tank are ejected from the orbiter while the space shuttle is leaving the atmosphere. The orbiter has enough crew space for eight crew members and a cargo capacity of 50, 000 lbs.

The Incident On January 16, 2003 the Space Shuttle Columbia was launched from Cape Canaveral, FL. 81 seconds into the launch a small piece of thermal insulating foam, the size of a small briefcase, impacted the leading edge of the left wing, damaging the Shuttle's Thermal Protection System (TPS), which protects it from heat generated from the atmosphere during re-entry. The foam had a total weight of 1. 67 lbs which is equal to the weight of 100 marshmallows and originated from the left bipod area of the External Tank.

At the time of the impact the Columbia was traveling at 2300 fps through an altitude of 65, 900 feet. The impact velocity of the foam was 775 fps. While Columbia was still in orbit, some engineers suspected damage as early as day two of the mission, but NASA managers limited the investigation, on the grounds that little could be done even if problems were found and therefore, never informed the crew of any possible damage. The damage to the left wing’s Reinforced Carbon-Carbon (RCC) panel provided a pathway for hot gas to enter the wing’s leading edge and support structure upon the attempted re-entry.

This resulted in major structural and skin damage causing the loss of control and all vehicle data at 207, 135 ft above the Earth while traveling at 12, 500 mph. The Columbia Space Shuttle broke up over north-central Texas just 16 minutes prior to its scheduled landing at Florida’s Kennedy Space Center. The Investigation Soon after the space shuttle disaster NASA created the Columbia Accident Investigation Board (CAIB) with the objective to determine the cause of the Columbia accident and to recommend ways to improve the safety programs and communication procedures within NASA.

The Board published a working scenario along with several preliminary recommendations in advance of the final report which was published on August 26, 2003. Preliminary Recommendations The first of five recommendations the CAIB made was for NASA to develop an inspection plan for the examination of the Reinforced Carbon-Carbon (RCC) system components since the current inspection techniques were not adequate in assessing the structural integrity, its supporting structure, and the attached hardware.

The RCC system is used on the leading edges of the wings, the area aft of the nose cap, and the area around the forward orbiter/external tank attachment structure due to the fact that these are the parts of the orbiter that are subjected to the greatest amount of heat during re-entry. At the time the CAIB conducted their investigation, they discovered and published that NASA did not fully understand the mechanisms that have caused foam loss on almost every space shuttle flight to date. They also found that the original and present day operating design specifications required the RCC components to have essentially no impact resistance.

In order to mitigate future risk to the space shuttles and crew, the CAIB believed that NASA should look into the advanced non-destructive inspection technology and take advantage of it. The second recommendation made to NASA stated that they should amend their existing Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA) to make it a standard requirement for every space shuttle flight to have on-orbit imaging available. The foam strike was first seen during the standard review of the launch video and high-speed photography, by the IntercenterPhotoWorking Group (IPWG) on the morning of Flight Day Two.

The IPWG was concerned about possible damage to the Orbiter since this foam strike was larger than any seen in the past. No conclusive images of the foam strike could be found so the Chair of the IPWG asked management to begin the process of getting outside imagery from the Department of Defense (DOD) to help in damage assessment. This request, the first of three, along with the IPWG’s first report, including a digitized video clip and initial assessment of the strike, was distributed on Flight Day Two and began its journey through the management hierarchy.

Even though the IPWG routed its request through the proper channels used during a mission, the management hierarchy yielded no direction, progress, or results. Therefore, the IPWG then routed its second and third requests for external DOD imagery through institutional, not mission-related, channels which diluted the urgency of the requests and the management viewed the requests as non-critical desires rather than critical operational needs.

Communication did not flow effectively up to or down from the management hierarchy which lead to the three independent requests for imagery being subsequently denied. It was determined by the CAIB that the United States government along with NASA did not utilize every imaging resource it had in order to assess the damage of the Columbia while still in orbit. Recommendation three examined the repair capability of the space shuttle.

The CAIB suggested that for all future missions to the International Space Station (ISS), NASA develop a method to inspect and conduct emergency repairs to the Thermal Protection System (TPS) tiles and RCC while docked at the ISS and recommended that a “ comprehensive autonomous […] inspection and repair capability” be developed for Shuttle missions that do not dock at the ISS. The end goal is to develop a “ fully autonomous capability for all missions”, in the event “ that an ISS mission does not achieve the necessary orbit, fails to dock successfully, or suffers damage during or after docking” (Troxell, 2009).

The last two recommendations addressed the space shuttles imaging systems. The fourth recommendation recommended upgrading the imaging system to provide at least three useful views of the space shuttles from liftoff to at least Solid Rocket Booster separation, and further recommended exploring the possibility of taking additional pictures and observations of the space shuttle during launch using ships and aircraft. Recommendation five pertained specifically to the External Tank (ET) and the Thermal Protection System (TPS) imaging systems examination.

The CAIB recommended modifying one of the two on-board umbilical cameras in order to “ downlink high-resolution images of the ET after separation,” and further recommended that a similar system be put into place to “ downlink high-resolution images of the underside of the orbiter’s leading edge system and the forward section of the TPS” (Troxell, 2009). Organizational Culture Communications procedures between managers and engineers at NASA were also investigated by the CAIB.

The need to communicate effectively and efficiently between the individuals and organizations involved in the space shuttle program were found to be paramount, given the complex and high level of technology along with the extensive risks involved. The CAIB found that the original damage assessments contained substantial uncertainties for a variety of reasons, including management failures, communication breakdowns, inappropriate use of assessment tools, and flawed engineering judgments.

The CAIB also determined that there were lapses in leadership and communication that made it very difficult for engineers and management to raise concerns and understand decisions. Management failed to actively engage and analyze the potential damage caused by the foam strike. Before the accident, flight managers had been under extreme pressure from Congress and the public to maintain launch schedules, and they had not followed established procedures for clearing unresolved problems.

Based on these and other observations, the CAIB concluded that NASA was not a learning organization. Organizational learning is not one but several processes by which organizations seek to improve their performance by searching out the causes behind what they judge to be unacceptable results (Mahler & Casamayou, 2009). The CAIB concluded that the organizational causes to the accident included deficiencies in the command structure and safety monitoring systems, an inability to cope with strong external political and budgetary pressures, and an obstructive organizational culture.

System Safety The CAIB found that NASA's safety program was inadequate of achieving the level of safety necessary for the space shuttle program. As a result, the CAIB recommended that the safety system at NASA be restructured to include the system safety fundamentals. System safety is the name given to the effort to make things as safe as is practical by systematically using engineering and management tools to identify, analyze, and control hazards (Stephans, 2004) throughout all phases of the life cycle.

At the time of the investigation, NASA's definition of system safety was as follows: The optimum degree of risk management within the constraints of operational effectiveness, time, and cost attained through the application of management and engineering principles throughout all phases of a program.

It was a great definition but NASA did not follow or operate under these fundamentals which were proven by the CAIB time and time again.

They found that the system safety engineering and management was not vigorous enough to have an impact on system design, and it was hidden in the other safety disciplines and separated from mainstream engineering which proved extremely ineffective in regards to safety. They also found that the space shuttle safety program had conflicting roles, responsibilities, and guidance. Hazard Analysis The hazard analysis techniques used by NASA at the time of the accident were the Failure Modes and Effects Analysis (FEMA) and the Fault Tree Analysis (FTA).

The CAIB found that the risk information and data from the hazard analyses were not communicated effectively nor could they find adequate application of a process, database, or metric analysis tool that took an integrated, systemic view of the entire space shuttle system. Post Columbia Procedures at NASA Once the investigation into Space Shuttle Columbia’s accident was finished, NASA shut down all space shuttle missions until they felt their system safety and communication procedures where brought up to par.

This space shuttle grounding lasted 905 days and finally ended on July 26th, 2005 when the Space Shuttle Discovery successfully flew the STS-114 mission. System Safety NASA took the recommendation of the CAIB and restructured their system safety program. The purpose of the new system safety program within NASA is to ensure that the optimum degree of safety is achieved through management and engineering practices that minimize the number and magnitude of hazards in NASA systems.

This is coupled with the application of system safety engineering analyses to detect and assess the nature and magnitude of risks so that they may be eliminated, reduced, or accepted depending on project requirements, schedule, and cost. This purpose is reached through the application of management, scientific, and engineering principles during all phases of a system life cycle. The ultimate goal is to avoid loss of life or injury to personnel, damage to or loss of equipment or facilities, project or test failures, and undue exposure to risk and adverse environmental effects.

To date NASA has flown 19 separate space shuttle missions with no incidents under their new system safety program. NASA’s space shuttle fleet is set to retire after just two final missions. Space Shuttle Discovery is expected to launch on November 1st, 2010 and Space Shuttle Endeavour will launch no earlier than February 26th, 2011. Post Columbia Improvements NASA spent $1. 4 billion in an effort to improve the space shuttle after the Columbia incident. The most notable area of improvement was the External Tank.

The bipod foam that caused the Columbia disaster was replaced with an electrical heater to prevent ice from forming. Another notable area of improvement was too the Foreign Object Debris (FOD) procedures which improved safety. They also added over 100 tracking cameras to view launches as well as cameras mounted on the External Tank and Solid Rocket Boosters. NASA also has two aircraft equipped with high-definition cameras which offer the unique perspective of a shuttle flying toward the viewer (Chien, 2006). All of NASA’s improvements seem to have worked so far.

In the years following Space Shuttle Columbia’s accident, NASA reinvented their company from the ground up and is now used as a model company that others look to for advice and operational information. Conclusion The Space Shuttle Columbia accident may or may not have been preventable. There are numerous things that could have gone differently that might have given the crew a different fate, however, the accident happened in the least bad manner possible. The astronauts were able to enjoy themselves the entire mission, complete essential mission experiments, and reach a goal many of them had worked toward their entire lives.

They had no knowledge that the shuttle was damaged and their deaths were mercifully swift. Columbia’s re-entry path over the U. S. made debris recovery far easier than if it had fallen over the ocean. Because so much debris and information was recovered it was possible to determine exactly what happened without any shadow of a doubt. It will certainly always be regrettable that the accident happened, but the fate of the Columbia crew could have been far worse. They will always been remembered as heroes.