

HOW IT HAPPENED AGAIN – LESSONS LEARNED FROM THE SPACE SHUTTLE COLUMBIA ACCIDENT

Kendra L. B. Cook
Owner
C² International, LLC

**This presentation is dedicated to the men and
women who perished on the Space Shuttle
*Columbia***



Rick D. Husband
Commander

William C. McCool
Pilot

Michael P. Anderson
Payload Commander

David M. Brown
Mission Specialist

Kalpana Chawla
Mission Specialist

Laurel Blair Salton Clark
Mission Specialist

Ilan Ramon
Payload Specialist

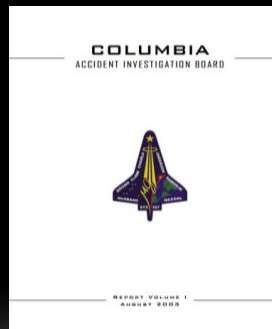
OVERVIEW

- Background – From *Challenger* to *Columbia*
 - Reduction of Workforce
 - Space Shuttle Program Management – Who's Responsibility Is It?
- The Accident
- The Cause of the Accident
- Case Study
 - NASA's Organizational Culture
 - Decision-Making and the Normalization of Deviance
 - Silent Safety Program
 - The Return of Cost and Schedule Pressure
- How Could It Happen *Twice*?
- Recommendations
- Conclusions

3

DISCLAIMER

- Much of the material in this presentation came directly from the *Columbia* Accident Investigation Board Report, Volume I, August 2003.



4

BACKGROUND – FROM CHALLENGER TO COLUMBIA

- The *Challenger* Accident Investigation Board Report (aka Roger's Commission Report), issued June 6, 1986 concluded:
 - NASA's culture had gradually begun to accept escalating risk
 - NASA's safety program was largely silent and ineffective
 - The drive to declare the Shuttle operational had put enormous pressures on the system and stretched its resources to the limit
 - NASA should create an independent Office of Safety, Reliability, and Quality Assurance
 - NASA should implement structural and program management changes

5

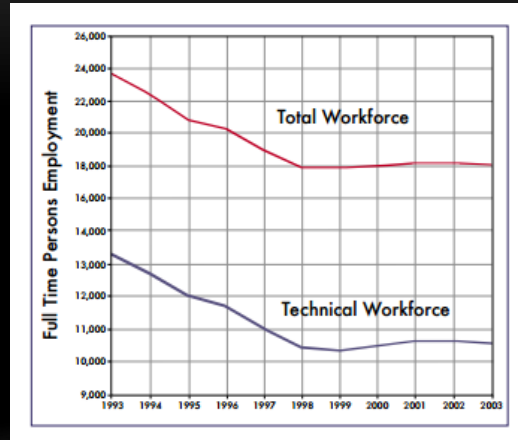
BACKGROUND – FROM CHALLENGER TO COLUMBIA

- It was 32 months after the *Challenger* tragedy before another Shuttle mission was launched
- NASA made significant organizational changes and revised the Shuttle manifest to reflect a more realistic flight rate
- NASA created a HQ Office of Office of Safety, Reliability, and Quality Assurance
- In the 17 years between the *Challenger* and *Columbia* accidents, the Space Shuttle Program achieved vital successes
- Things were not necessarily as they appeared...

6

REDUCTION OF WORKFORCE

- During the 1990's NASA was under immense pressure to lower shuttle operating costs
- Reducing the size of the workforce was the primary means to lowering costs



7

REDUCTION OF WORKFORCE

- 1995 letter from Kennedy Space Center engineer Jose Garcia to President Clinton stated:
 - *"The biggest threat to the safety of the crew since the Challenger disaster is presently underway at NASA."*
- By 2000, NASA leadership realized that downsizing had led to a serious skill imbalance and an overburdened core workforce
 - Increased workload and stress on those remaining
 - Increase in potential impacts to operational capacity and safety
- In 2000 NASA announced they would stop their workforce downsizing and they would start hiring immediately

8

SPACE SHUTTLE PROGRAM MANAGEMENT – WHO'S RESPONSIBILITY IS IT?

- Management of the Shuttle Program was moved from Johnson Space Center to NASA HQ per the Challenger Accident Investigation Board's recommendation
- In 1996, Johnson Space Center was designated as "lead center" for the Shuttle Program
- The head of the Shuttle Program at NASA HQ, Bryan O'Connor, fought the return of the Shuttle Program management back to Johnson Space Center
"It is a safety issue," he said, "we ran it that way (with program management at HQ, as recommended by the Roger's Commission) for 10 years without a mishap and I didn't see any reason why we should go back to the way we operated in the pre-Challenger days."
- In 2002, NASA Administrator Sean O'Keefe transferred management of both the Shuttle Program and the ISS from Johnson Space Center back to NASA HQ.

9

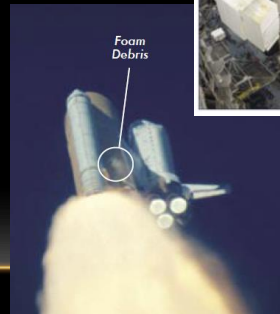
THE ACCIDENT – FEBRUARY 1, 2003



10

THE CAUSE OF THE ACCIDENT

- Breach of the Thermal Protection System on the leading edge of the left wing caused by a piece of insulating foam that separated from the External Tank
- During re-entry, the breach allowed superheated air to penetrate the leading edge insulation and gradually melt the aluminum structure
- Increasing aerodynamic forces caused loss of control, failure of the wing, and breakup of the Orbiter



11

NASA'S CULTURE

- NASA is a highly successful organization capable of achieving seemingly impossible feats
- NASA underwent many organizational and managerial changes after the Challenger accident but their culture endured
- Their culture manifested a self-confidence that NASA possesses unique knowledge about how to safely launch people into space
- This led to “flawed decision making, self deception, introversion, and a diminished curiosity about the world outside the perfect place.”

12

NASA'S CULTURE

Findings:

- Organizational culture strongly influences people's actions
- According to the *Columbia* Accident Investigation Board Report:
 - Cultural resistance was a fundamental impedance to NASA's effective organizational performance and undermined effective decision-making
 - By the eve of the *Columbia* accident, institutional practices that were in effect at the time of the *Challenger* accident – “such as inadequate concern over deviations from expected performance, a silent safety program, and schedule pressure” – had returned to NASA

13

DECISION- MAKING AND THE NORMALIZATION OF DEVIANCE

- The “decision to launch the Challenger was flawed...Communication failures, incomplete and misleading information, and poor management judgments all figured into a decision-making process that permitted internal flight safety problems to bypass key Shuttle managers.”

~ *Challenger* Accident Investigation Board Report

- “Management decisions made during Columbia's final flight reflect missed opportunities, blocked or ineffective communications channels, flawed analysis, and ineffective leadership”.

~ *Columbia* Accident Investigation Board Report



14

DECISION- MAKING AND THE NORMALIZATION OF DEVIANCE

- Leading up to both the *Challenger* and *Columbia* tragedies, NASA personnel exhibited:
 - Blocked or ineffective communication
 - Missed opportunities
 - Flawed analysis
 - Poor judgments
 - Inadequate / incomplete information
 - Uninformed decision-making
 - Ineffective leadership
 - Normalization of deviance

15

DECISION- MAKING AND THE NORMALIZATION OF DEVIANCE

- Managers' tendency to accept only opinions that agree with their own blocked effective communication
 - Mission managers were not as concerned about the foam strikes
 - Engineers' were unable or unwilling to challenge the managers
- Flawed analysis
 - Personnel knew that the monitoring of tile damage was inadequate and that clear trends could be more readily identified if monitoring was improved, but no such improvements were made
 - Flying with deviations from design specifications became viewed as normal and acceptable
 - => Normalization of deviance

16

DECISION- MAKING AND THE NORMALIZATION OF DEVIANCE

- “Normalization of Deviance” = the acceptance of events that are not supposed to happen
- Early in the Space Shuttle Program foam loss was considered a dangerous problem
 - Baseline design requirements precluded shedding by the External Tank
- With each successful landing, NASA engineers and managers increasingly regarded foam-shedding as inevitable and an acceptable risk
- What was originally considered a serious threat came to be treated as a reportable problem that was within the known experience base and was believed to be understood
- With no engineering analysis, Shuttle managers used past successes as a justification for future flights

17

DECISION- MAKING AND THE NORMALIZATION OF DEVIANCE

Findings:

- NASA did not follow its own rules and requirements on foam-shedding
- Foam-shedding, which initially raised serious safety concerns, evolved into a routine maintenance / turn-around issue
- NASA failed to adequately perform trend analysis on and provide engineering attention to foam losses resulting in the inability to make informed decisions
- Ineffective leadership and channels of communication made it difficult for engineers to raise concerns or understand decisions
- “Lack of institutional memory in the Space Shuttle Program”

18

SILENT SAFETY PROGRAM

- 1986 - NASA created an Office of Safety, Reliability, and Quality Assurance
 - Responsible for agency-wide safety-related functions
 - Associate Administrator did not have direct authority
 - Safety, reliability, and mission assurance activities across NASA remained dependent on other programs and centers for funding
- 1990 - GAO report questioned the effectiveness of the Office
 - Questioned ability to be successful because they're funded from activities whose safety-related performance they are responsible for overseeing
- NASA did not institute centralized funding in response to the GAO report, nor has it since.

19

SILENT SAFETY PROGRAM

- While *Columbia* was on orbit, NASA knew there had been a foam strike and there may be an issue
- Debris Assessment Team members had to prove that a safety of flight issue existed before management would obtain images of the left wing
- DAT members did not raise contrary points of view about mission safety for fear of being singled out and ridiculed

20

SILENT SAFETY PROGRAM

Findings:

- The dependence of safety personnel on Shuttle Program support limited their ability to oversee operations and communicate potential problems
- Safety personnel failed to adequately assess anomalies and frequently accepted critical risks without qualitative or quantitative support, even when the tools to provide more comprehensive assessments were available
- Safety personnel were present at meetings with the Debris Assessment Team, Mission Evaluation Room, and Mission Management Team, but were passive and did voice concerns or dissenting views
- The silence of the safety processes undermined oversight; when they did not speak up, safety personnel could not fulfill their stated mission to provide “checks and balances”
- NASA’s safety culture has become reactive, complacent, and dominated by optimism

21

SILENT SAFETY PROGRAM

Findings:

- Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including:
 - Reliance on past success as a substitute for sound engineering practices
 - Organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion
 - The evolution of an informal decision-making processes that operated outside the organization’s rules

22

THE RETURN OF COST AND SCHEDULE PRESSURE

- The schedule for completing the ISS was the primary driver of the shuttle's launch schedule
- By 2001, the ISS was \$4B over budget
- The WH and Congress put NASA, the Shuttle Program, and the ISS on probation
 - NASA had to prove it could meet its schedules within cost, or they would be forced to halt the ISS at "core complete" status
 - With the probation came a fixed launch schedule
 - NASA was given a deadline: Feb 19, 2004 = the line in the sand
 - If they didn't meet that date, NASA would risk losing support for subsequent Space Station growth


23

THE RETURN OF COST AND SCHEDULE PRESSURE


- Meeting the 19 Feb deadline meant preparing and launching 10 flights in less than 16 months
- The focus was on retaining the ISS program; little attention was paid to the effects the aggressive schedule would have on the Shuttle Program
- Both the workforce and the budget had been reduced by over 40% in the past decade
 - Less experienced staff and older equipment
- NASA was using funds "intended for Space Shuttle safety upgrades to address operational, supportability, obsolescence, and infrastructure needs"

24

THE RETURN OF COST AND SCHEDULE PRESSURE



Summary



- Critical Path to U.S. Core Complete driven by Shuttle Launch
 - Program Station assessment: up to 14 days late
 - Program Shuttle assessment: up to 45 days late
- Program **proactively managing** schedule threats
- **Most probable launch date is March 19-April 19**
 - ✓ Program Target Remains 2/19/04

- Work was scheduled on holidays
- A third shift of workers was hired and trained
- Future crew rotations drifting beyond 180 days
- Some tests previously deemed “requirements” were skipped or deferred

- Program Managers estimated that Node 2 launch would be 1-2 months late
- NASA's legendary “can do” attitude meant to one wanted to be the one to stand up and say “we can't make that date”

25

THE RETURN OF COST AND SCHEDULE PRESSURE

Findings:

- The interdependencies between the shuttle and the ISS programs significantly increased the complexity of the schedule
- The countdown to Feb 19th and the importance of maintaining the schedule influenced managers' decisions
- The four flights scheduled in the 5 months from Oct 2003 to Feb 2004 would have required a processing effort comparable to the effort immediately before the Challenger accident
- There was no schedule margin to accommodate unforeseen problems
- The capabilities of the system were being stretched to the limit to support the schedule
- During STS-107, managers were concerned with the foam strike's possible effect on the launch schedule

26

HOW COULD IT HAPPEN TWICE?

- NASA's political and budgetary situation remained the same
- NASA's culture remained unchanged
- NASA's history encouraged a pattern of flying with known flaws
- NASA's structure and management did not encourage efficient communication
- NASA's safety program was, and remains ineffective
- NASA had the same conflicting goals: cost, safety, or schedule?
- The accident investigation board report concluded that there is a "lack of institutional memory in the Space Shuttle Program" and that "NASA is not functioning as a learning organization"

27

RECOMMENDATIONS

Enterprise	Individuals
Adopt and maintain a schedule that is consistent with available resources	Be involved in discussions with peers and subordinates
Regularly evaluate deadlines to ensure additional risk incurred to meet that schedule is recognized, understood, and acceptable	Pay attention to subordinates and offer them encouragement
Implement an ethics program and enforce policies & procedures that reward ethical behavior	Communicate – both formally and informally to ensure all relevant people are informed
Require ethics training to provide a practical foundation to build on and to reference	Maintain ongoing attention and dialogue regarding values
Emphasize Lessons Learned in training – both good and bad	Encourage alternate perspectives, critical questions, and "bad news"

28

CONCLUSION

“Awareness guides action.”

Warren Blank

January 28, 2010

29

IN MEMORIAM

“This cause of exploration and discovery is not an option we choose; it is a desire written within the human heart...We find the best among us, send them forth into unmapped darkness, and pray they will return. They go in peace for all mankind, and all mankind is in their debt.”

President George W. Bush

February 4, 2003



30

QUESTIONS?



REFERENCES

- Columbia Accident Investigation Board Report, Volume I, August 2003.
- Sunseri, Gina. "Sense of Loss': Columbia Space Shuttle Crew Remembered 10 Years After Accident". ABC News website: <http://abcnews.go.com/Technology/columbia-space-shuttle-crew-remembered-10-years-accident/story?id=18360615>. Accessed 1 February 2013.
- Cowen, Ron. "Columbia Disaster: Why did the space shuttle burn up?". Science News Online: http://www.phschool.com/science/science_news/articles/columbia_disaster.html. Accessed 12 July 2013.
- NASA-submitted material appended to the statement of NASA Administrator Daniel Goldin to the senate Subcommittee on Science, Technology, and Space, March 22, 2000.
- Beck, Richard (Director, Resources Analysis Division, NASA), "Agency Budget Overview, FY2003 Budget", February 6, 2002, CAIB document CAB070-0001.