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Columbia Accident Investigation Board Report

Responding to the question, “Is the space shuttle an emerging technology?” from NASA’s perspective reveals the attitude of NASA engineers and scientists towards the technology. The answer illuminates one of the key points that the Accident Investigation Board hammers home in its report. As early as 1982, the space shuttle was declared “fully operational” by President Reagan and the perception of the space shuttle as comparable to civilian or military air transport has been pervasive. NASA would not consider the shuttle an emerging technology but a proven one. Instead, the Accident Investigation Board argues that all human spaceflight should be viewed as developmental.

NASA’s failure to view the space shuttle as a developmental vehicle led it to neglect installing or updating feedback mechanisms to track the performance of the shuttle. High resolution and high speed ground-based cameras could have been used to monitor potential damage. Replacing the decades-old sensors would have helped engineers obtain more flight data to verify their calculations and data on past flights. The Board comments that NASA was not a learning organization. It almost seems they were afraid to discover anomalies that they could not explain so they chose not to collect the data and therefore not have to worry about it.

In reading about the development of the space shuttle and the analysis of the foam debris during the Columbia STS-107 flight, I was surprised by how many different ways engineering common sense was compromised by inadequate testing and reliance on poor models. NASA used analytical models rather than flight testing to certify the integrated space shuttle system. Before its first mission, it had never gone on an unmanned orbital test flight. The difficulty obtaining on-orbit pictures of Columbia handicapped the Debris Assessment Team, which had to rely on the inappropriate “Crater” mathematical tool, which had been designed to analyze small cylindrical particles 400 times smaller than the chunks of foam. Because the Crater tool was used so far outside of its experimental limits, its predictions were then disregarded as overly conservative, rendering the tool useless. NASA engineers did not have a solid understanding of the foam properties, which varied widely because of the hand-spraying technique. Because this foam could not be modeled analytically, there should have been greater testing in dynamic conditions, like the impact tests conducted by the Board. It would have been interesting for the Board to delve into why these tests were not done, and perhaps to estimate how much money (or time, human resources) these tests would have taken. They acknowledge that a full-scale, ground-based simulation would not be possible but it is not easy to conceive whether the limiting factors are resources or NASA’s perception that their existing analytical techniques are adequate. Incorporation of anomalies as part of the safety margin rather than wondering why the anomalies occurred was a serious problem. This would be similar to looking at some outliers in a scatter plot of an otherwise straight line and trying to convince people that the data really followed a polynomial curve. Basing analysis on past success rather than probabilistic assessment counters everything we know about statistics.

Ironically, NASA's "can do" culture, which is generally viewed as an asset, became a liability. Business books tout the importance of fostering working environments where employees feel like they can achieve the impossible and are proud of their accomplishments. However, why shouldn't this be the desired state at NASA? Perhaps there needs to be a place for the dreamers and innovators, and then an equally important place for the naysayers and skeptics (i.e. the safety experts). In many organizations, the conservative finance, accounting, and/or quality assurance departments provide an in-house check on over-eager thinkers. In NASA, no one seemed to be carrying this function. The Board frequently describes the safety experts as being silent observers rather active participants. Moreover, the decision to consolidate Shuttle operations under one prime contractor, the United Space Alliance, eliminated NASA's system of checks and balances. Last week, in Rescuing Prometheus, the Big Dig chapter noted that Massachusetts did not allow the same contractor to receive the design and construction bids. Although the state might have done this to encourage more business competition, it is often done to encourage oversight, even if that means more red tape.

The handling of uncertainties about the foam debris was complicated by the muddled use of vocabulary. Foam shedding was initially considered an anomaly, and then either an "accepted risk" or "not a flight or safety issue," depending on which group was asked. The ambiguous and inconsistent definitions made it difficult for anyone to resolve the foam issue. The most frequently used communication medium – PowerPoint slides – failed to properly communicate the seriousness of the uncertainties. On the Debris Assessment Team briefing slide shown on page 191, the Board notes how imprecisely and ambiguously the word "significant" is used. The reliance on PowerPoint slides rather than technical papers, and the tendency to circulate slides to people who have not attended the presentation itself make misinterpretations easy. In the meetings during Columbia's flight, the working engineers and mission personnel were clearly concerned about the uncertainties but the managers focused on the general conclusion that there was no safety-of-flight issue. This is characteristic of typical engineer-manager working relationships. Engineers appreciate the intricacies of the analysis but the underlying assumptions and uncertainties are lost upon management, who are searching for a straightforward answer to guide them to a Yes/No-type decision.

The NASA safety experts were ill-equipped to make judgments about the space shuttle for a number of reasons. The dependence on funding from the very programs that they were hired to oversee compromised their independence. NASA lacked mechanisms to surface minority reports or "weak signals." Lower-ranking staff were set apart from the decision-makers and likely felt too intimidated to bring up their concerns. If NASA cannot foster a Team A/Team B mentality within its own organization, it needs an independent watchdog-type organization to act as a check on its overconfidence. From my experience working on civil infrastructure projects, government inspectors, who monitor safety and quality, were considered an annoyance by contractors but respected for their meticulousness. A slightly confrontational relationship between NASA and its safety experts may actually be desirable because the experts would not be afraid to challenge majority views.

The Board's analysis of the left wing debris was very impressive in its multiple methods, all which contributed to their conclusion that the foam debris could break an RCC panel. Using so many approaches – aerodynamic, aero thermal, sensor, and photographic left little doubt to

what happened. However, in case people were not persuaded by the analytic evidence, the Board used an experiment to demonstrate that the foam could strike the RCC. It seems likely that the Board also used this technique to grab the attention of the media and the public. None of the other methods had the type of powerful visual appeal that shooting a foam projectile at RCC panel assemblies had.

Although many of the problems identified through the fault tree analysis did not necessarily contribute to Columbia's failure, it was very important to go through the entire procedure. The Board took advantage of the investigation to lay bare the space shuttle's and NASA's vulnerabilities, since they had access to the information and staff. For example, there is no saying that in later flights, a bolt catcher might have failed. Also, by eliminating other possible causes of the Columbia accident, the study could be robust against criticism that it had overlooked other problems.