

ESD.85J Class Response Paper on Columbia Accident Investigation Board Report

Three areas that I found significant from reading the CAIB Report are: (1) the growth of importance of incident analysis in complex systems, (2) the difficulties large organizations have in listening to small signals that may cause undetected changes in the overall system behavior and (3) the effect of cultural norms in communication tools on organizational decision making.

Incident analysis has come up as a frequent topic in various discussions lately. Within these discussions, a notion reoccurs that deep-rooted organizational problems have lead to significant system failures where technological, political, organizational, economic, or other forms of complexity mask flaws in the stability of the underlying system. This notion has etched itself into our national consciousness through recent failures within NASA's shuttle program, FEMA's inability to aid distressed citizens in a timely manner after Hurricane Katrina, and countless other incidents known to anyone who has been personally affected or who listens to the media.

At the MIT Engineering Systems Division symposium last year, Sheila Widnall gave an overview of her participation on the Columbia Accident Investigation Board (CAIB). One of my MITRE colleagues, C. Michael Howell, attended and wrote:

Of particular interest to me was her description of a key recurring problem at NASA: "normalizing the deviations they found". In her words, the unexpected became the expected which became the accepted. She used foam coming off the storage tank as just an illustration of a systemic problem. Foam was not supposed to come off; the first few times it did, NASA investigated this as something they did not understand and that should not happen. But as time went on and foam fell off without any safety problems evident, it became viewed as a post flight refurbishment issue - even though it was still not understood. When it was finally implicated in the loss of an orbiter, the initial reaction was "that's crazy; we lose foam on a lot of flights w/out any problem."

From the report, the CAIB started by focusing on the technical problems with foam adhesion, but went on to state very clearly the role it believes the NASA enterprise played in the space shuttle disaster:

In the Board's view, NASA's organizational culture and structure had as much to do with this accident as the External Tank foam. Organizational culture refers to the values, norms, beliefs, and practices that govern how an institution functions. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganizations and the reassignment of key personnel [CAIB Report, 2003, p.177, <http://www.caib.us/default.html>]

At the symposium, Sheila's points were followed by Nancy Leveson's description of the STAMP (Systems-Theoretic Accident Modeling and Processes) approach to accident analysis. "Safety is an emergent system property, it cannot be handled with a reductionist analysis of components alone," according to Nancy. She argued that incident analysis needs to examine the control structure of a system, that accidents are the result of inadequate control of many interacting factors. She pointed out we are dealing with socio-economic systems that are not static; they migrate over time, according to Judy Clapp [MITRE]. For example, a reduction in a budget can cause some part of a well-thought out plan to be compromised, e.g., doing less testing (Hubble Telescope). The loss of foam was never intended, but its occurrence without incident is still a change in the system behavior. So our approach to safety has to track the dynamics of changes in the socio-economic system over time. This is especially relevant to "complex systems of systems" or "Complex Large-scale Integrated Open Systems" (CLIOS), C. Michael Howell points out. Such systems are prone to surprises, and the surprises are rarely good ones. We should spend some effort to "listen to the data", learn from small events (weak signals), and not wait for cascading failures.

To close-out this response paper is a quotation from an interesting article I remember from the November 2003 issue of The Atlantic which cited a NY Times article on NASA's use of PowerPoint and its cultural effect on complexity and decision-making:

At 7:00 a.m. on the ninth day, January 24, which was one week before Columbia's scheduled re-entry, the engineers from the Debris Assessment Team formally presented the results of their numerical analysis...They projected a typically crude PowerPoint summary, based on the results from the Crater model, with which they attempted to explain a nuanced position: first, that if the tile had been damaged, it had probably endured well enough to allow the Columbia to come home; and second, that for lack of information they had needed to make assumptions to reach that conclusion, and that troubling unknowns therefore limited the meaning of the results. The latter message seems to have been lost. Indeed, this particular PowerPoint presentation became a case study for Edward Tufte, the brilliant communications specialist from Yale, who in a subsequent booklet, *The Cognitive Style of PowerPoint*, tore into it for its dampening effect on clear expression and thought. The [Columbia Accident Investigation Board] later joined in, describing the widespread use of PowerPoint within NASA as one of the obstacles to internal communication (see NY Times story at end of this paper). [William Langewiesche, "Columbia's Last Flight," *The Atlantic*, 292:4, November 2003, p. 82.]

The article this quote was based on:

NY Times - PowerPoint Makes You Dumb
December 14, 2003

By CLIVE THOMPSON

In August, the Columbia Accident Investigation Board at NASA released Volume 1 of its report on why the space shuttle crashed. As expected, the ship's foam insulation was the main cause of the disaster. But the board also fingered another unusual culprit: PowerPoint, Microsoft's well-known "slideware" program.

NASA, the board argued, had become too reliant on presenting complex information via PowerPoint, instead of by means of traditional ink-and-paper technical reports. When NASA engineers assessed possible wing damage during the mission, they presented the findings in a confusing PowerPoint slide - so crammed with nested bullet points and irregular short forms that it was nearly impossible to untangle. "It is easy to understand how a senior manager might read this PowerPoint slide and not realize that it addresses a life-threatening situation," the board sternly noted.

PowerPoint is the world's most popular tool for presenting information. There are 400 million copies in circulation, and almost no corporate decision takes place without it. But what if PowerPoint is actually making us stupider?

This year, Edward Tufte -- the famous theorist of information presentation -- made precisely that argument in a blistering screed called *The Cognitive Style of PowerPoint*. In his slim 28-page pamphlet, Tufte claimed that Microsoft's ubiquitous software forces people to mutilate data beyond comprehension. For example, the low resolution of a PowerPoint slide means that it usually contains only about

40 words, or barely eight seconds of reading. PowerPoint also encourages users to rely on bulleted lists, a "faux analytical" technique, Tufte wrote, that dodges the speaker's responsibility to tie his information together. And perhaps worst of all is how PowerPoint renders charts. Charts in newspapers like *The Wall Street Journal* contain up to 120 elements on average, allowing readers to compare large groupings of data. But, as Tufte found, PowerPoint users typically produce charts with only 12 elements. Ultimately, Tufte concluded, PowerPoint is infused with "an attitude of commercialism that turns everything into a sales pitch."

Microsoft officials, of course, beg to differ. Simon Marks, the product manager for PowerPoint, counters that Tufte is a fan of "information density," shoving tons of data at an audience. You could do that with PowerPoint, he says, but it's a matter of choice. "If people were told they were going to have to sit through an incredibly dense presentation," he adds, "they wouldn't want it." And PowerPoint still has fans in the highest corridors of power: Colin Powell used a slideware presentation in February when he made his case to the United Nations that Iraq possessed weapons of mass destruction.

Of course, given that the weapons still haven't been found, maybe Tufte is onto something. Perhaps PowerPoint is uniquely suited to our modern age of obfuscation -- where manipulating facts is as important as presenting them clearly. If you have nothing to say, maybe you need just the right tool to help you not say it.

Questions for class discussion:

1. How do large organizations view safety as an ongoing calibration and assessment issue rather than a box to be checked at a certification point? Safety must focus on prevention rather than investigation.
 2. The notion of small signals being ignored and eventually treated as normal was an important observation about why accidents happen. How do we sift out significant “small signals” from the noise of everything else that is going on?
 3. How can we foster corporate and government innovation in proactively preparing for incidents?
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Incident Analysis Links:

Here is a small sample of URLs put together by MITRE colleague C. Michael Holloway, senior research engineer at the NASA Langley Research Center in Hampton, Virginia, for people interested in research and applications of incident analysis:

C. Michael Holloway, MITRE, <http://shemesh.larc.nasa.gov/people/cmh/cmh-bio-publications.html>

William S. Greenwell, researching incident reporting techniques for failures involving safety-critical software systems: <http://www.cs.virginia.edu/~wsg6p/research.html>

Chris Johnson, heads the Glasgow Accident Analysis Group, our aim is to better understand accidents and incidents involving complex, computer-based systems: <http://www.dcs.gla.ac.uk/~johnson/>

Workshop on the Investigation and Reporting of Incidents and Accidents (IRIA03),
<http://shemesh.larc.nasa.gov/iria03/index.html>

Papers on STAMP (Systems-Theoretic Accident Modeling and Processes),
<http://sunnyday.mit.edu/accidents/index.html>