Disastrous High-Tech Decision Making:

From Disasters to Safety

Preface

The space shuttle program is now history. Tokens of that era, four of the shuttles' winged orbiters, can be viewed in museums.[1] They remind us of technological achievement and of new frontiers imagined and explored. Behind the achievements, however, were two technical and human failures, the *Challenger* and *Columbia* shuttle disasters. Because those whose deliberations caused these two disasters survived, unlike many other high-tech disasters, a rich record is uniquely available in their testimony that traces how decision-making participants interpreted events and how they reacted. Decision participants' own testimony, including their commentary on their own and each other's actions, offered a rare opportunity to examine closely participants' perceptions, presumptions, and prior commitments. The official investigation of the *Challenger* disaster provided in its *Report*[2] both complete assessment of the physical cause of the accident and extraordinarily open availability of information about its human causes, but the Commission's own examination of the human causes fell far short of probing how and why the participants thought, felt, and acted the way they did. Probing the how and the why remained an open task.

The immediate *physical* cause of the *Challenger* disaster was identified by the investigating Commission accurately.[3] Most academic analysts of the accident, however, misidentified the technological dynamics that caused the disaster. Those are reported in a remote appendix of volume II of the Presidential Commission *Report,* in dense engineering language.[4] Engineers gave pronounced warnings about that actual danger hours before *Challenger's* fatal launch. The recently arrived cold weather, they warned, could well cause critical protective devices (O-rings) to fail. Managers at the time, and virtually all analyses of the accident since that time, focused not on temperature dynamics but on O-ring erosion, whose threat had actually been proven negligible, and on other distracting pressures.

The complex *human* causes of missing or denying the *real* danger of cold temperatures, therefore, have entirely escaped attention—the engineers' and managers' conflicting interpretations of data, the development of key individuals' mental models, the shaping forces of organizational culture and of leadership style, individual managers' fears and situations, interorganizational complexity, sensitivities to production schedule and market, and even the form of argument that the engineers and managers fell into.[5] Those are among the human causes that produced the wrong diagnosis of the shuttle's actual situation on that cold morning of launch. Those causes are explored in this book.

A perspective not before applied to this type of accident, macroergonomics, brings to light new dimensions of causality in such disasters. Ergonomics is the study of *persons,* using their available mental and manual *tools* and working from their *past experience*, who are attempting to accomplish a *task* in a particular social and physical *environment*. Macroergonomics is ergonomics applied to complex organizations, where "persons" translates to individuals, groups, and roles operating at different levels of authority and organization, and where "task" translates to organizational (or inter-organizational) function and mission. Delving into the causes of this disaster with this more differentiated and grounded framing than earlier analyses have employed has yielded two new dimensions of disastrous decision processes.

First illuminated is the unfolding sequence of a social psychological process in which deliberations of the decision participants (engineers and managers), traced from the first suggestion of a possible problem to the disastrous decision, proceed in the form of an evidencebased argument. This micro-history of a decision shows how sequence matters. It also pinpoints places where errors of various kinds were made.

The second new dimension of disastrous decision making revealed is a cluster of four previously unnoticed dangers that imperil the decision process itself. These four dangers coincide and seem to form something of a new *syndrome* of causes. This cluster of dangers appears to be shared with other high-tech disasters. It has not before been recognized in the considerable literature on accidents and their causes. Besides the *Challenger* disaster the *Columbia* shuttle disaster (Lighthall, 2014a) is another exemplar of this quartet of causes. The most recent and different kind of high-tech exemplar was the financial and credit meltdown of 2008.[6]

These dangers lie in the human understanding and control of complex technology. They are the dangers of human functioning presented by people who are selected for their experience and competence trying, individually and collectively, to respond effectively to an infrequent but inevitable situation in these high-tech enterprises. It is a situation where *new technical information arises during ongoing operations and warns of a dangerous possibly disastrous operating condition affecting the entire enterprise.*

Why, more than a quarter century after the *Challenger* accident and after not only official investigations but also scholarly books and dozens of scholarly articles, should yet another analysis of causes of that accident be published or, if published, be read? The answer is simply that the human roots of this apparently technological disaster are tangled and deep. Its human complexity requires new, more differentiated perspectives and dimensions of analysis to reveal clearly the actual physical and human causes. Vaughan's (1996) study, widely cited and relied upon for an accurate account of both physical and human causes of the *Challenger* accident, was the only study that made extensive use of primary documents. It examined the shaping of the *Challenger* launch decision through a sociological lens. Unfortunately, it is seriously flawed.[7] I examine the deliberations leading to the *Challenger* accident through a macroergonomic lens that combines perspectives from psychology, sociology, anthropology, and, surprisingly, rhetoric and argumentation. This lens is adjustable, providing at one level the verbal contents of an argumentative exchange unfolding among persons with different backgrounds and motives. At a more macroscopic level, it brings into focus varying practices distributed across two collaborating organizations—practices that reflect a dominant underlying, unrecognized cultural value.

Revisiting the deliberations leading up to the *Challenger* disaster at levels not before examined, therefore, reveals entirely new views of the realities at work—at work in that particular fatal event, yes, but much more. We also get a new, ground-level view of naturalistic decision making under stress, of how engineers and managers communicate effectively and ineffectively, and of how a leader's ideology of data and proof can be highly adaptive in one phase of production and a source of blindness in a second phase. Most significantly for high-tech safety-critical projects generally, however, is the discovery in the complexities of the *Challenger* accident a new syndrome of conditions lying at the center of the *human* causes of not only the *Challenger* accident but of other high-tech disasters also. They are the causal conditions that shape time-pressured assessments of a new danger during ongoing operations.

I have allocated time over more than twenty years to studying the many layers of cause in the *Challenger* disaster, conducting my own interviews early on of major and supporting participants.[8] It should not be surprising, then, that I reveal new views of a high-tech organization at work: how decision makers, in this case engineers and managers, work at crosspurposes, how styles of leadership influence the content of decisions, how collaboration between private enterprise and government can shift from productive to disastrous, and how one basic value of an organization's culture preempts another basic value and creates a dangerous, extreme corporate form of what David McClelland (1953, 1961) called a "need for achievement."

This book's messages of human and technological complexity, challenge, and hidden dangers will be of interest to four groups of readers. First are the managers and engineers—and the students and professors of management and engineering—who are concerned with managing, monitoring, or teaching about high-tech projects such as space exploration; operating nuclear power plants, submarines, or nuclear-waste sites; or conducting deep-water energy exploration. The second group comprises professors and students of social and organizational psychology, of ergonomics, of the sociology of organizations, and of the burgeoning field of the anthropology of organizations. Third are the scholars and professionals who study the human causes of disasters and the officials who investigate disasters. Fourth is the growing group of retired professionals with backgrounds or interests in the underlife, opportunities, or dangers of high technology.

> *[T]eam structure effective for routine operations could break down in non-routine circumstances.* *Barry Strauch*

> *None are more hopelessly endangered than those who falsely believe they are safe.*
> Johann Wolfgang von Goethe

End Notes

1. Shuttle *Enterprise*, the first orbiter built, was moved from the Smithsonian's National Air and Space Museum at the Steven F. Udvar-Hazy Center in Virginia to the Intrepid Sea, Air & Space Museum in New York. The Udvar-Hazy Center became the new home for shuttle *Discovery*, which retired after completing its 39th mission in March 2012. Shuttle *Endeavour* went to the California Science Center in Los Angeles. *Atlantis* is displayed at the Kennedy Space Center Visitor Complex in Florida.
2. Presidential Commission on the Space Shuttle Challenger Accident. 1986. *Report*, Volumes I–V, Washington, DC: United States Government Printing Office.
3. Ibid, vol. I.
4. Ibid, vol. II, Appendix L, L37–L49.
5. When I refer to “engineers” from this point on I mean to include all those who are technically trained to monitor and report on an enterprise’s technological dynamic states and changes – engineers, technicians, technical operators, etc.
6. For two accounts of front-line technical experts warning of the disaster, see Jaffe (2012) and McCuistion (2012). See also National Commission on the Causes of the Financial and Economic Crisis in the United States (2011), especially Part One, “Crisis on the Horizon.” The BP *Deepwater Horizon* Oil Spill in the Gulf of Mexico in contrast was an exemplar of a warning signaled by display instruments whose information was misinterpreted. See the report, National Commission on the BP *Deepwater Horizon* Oil Spill and Offshore Drilling (2011).
7. See my critique of Vaughan’s analysis of the disaster at www.high-techdangers.com .
8. My search of primary documents at both the National Archives and the History Department at Marshall Space Flight Center includes not only copies of the Commission’s interviews with every teleconference participant but also an important Thiokol-NASA contract document as well as inter-center reports calling for and describing corrective steps taken in the wake of an extended and “unnecessary” launch delay of the flight immediately preceding *Challenger*, flight 61C. I also have interviewed key engineers and managers at both Marshall and Thiokol about their participation in the decision and about the boosters’ technical dynamics—including phone conversations, correspondence, and recorded sessions at the home or office of both Larry Mulloy and Allan McDonald over many years (10 years with Mulloy, 22 years with McDonald). My

own lack of engineering education has been mitigated by corrective engineering guidance by key participants at both Marshall and Thiokol (again, including both Mulloy and McDonald).

My account of the dynamics that caused the O-rings' failure to seal the booster's joint is also the only account that is informed by two post-accident investigations reported in Appendix L of Volume II of the Presidential Commission *Report* (see note 4). The results of both investigations, carried out by different sets of engineers independently, agree in their findings—and validate the prelaunch warnings by Thiokol's Roger Boisjoly and Arnold Thompson—that O-ring temperature, not O-ring erosion, caused the booster's joint to remain unsealed for the booster's hot (5700 °F) gases to escape and erode or melt everything in their path.

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