Point of View

listen to your engineer

Gail D. Baura

On 24 August 2007, the National Aeronautics and Space Administration (NASA) announced that it had determined the cause of space shuttle external tank foam loss, during launch, as well as its solution. The external tank carries liquid propellant for the launch and is coated with a composite foam for heat dissipation and a lighter foam for high-insulation efficiency. Apparently, composite foam atop the metal brackets that hold fuel lines on the tank may develop microscopic cracks, which cause the lighter foam above it to fall during the stress of launch. On the basis of the results of testing, NASA believes that only the lighter foam is required for bracket coating. This foam modification will be tested during the next Discovery launch on 23 October 2007 [1].

While the shuttle manager, N. Wayne Hale, Jr., believes that the foam loss problem is solved, I prefer to wait for data from the inevitable next dozen launches to support his conclusion. In 1973, NASA's original specifications included a requirement that debris during launch be prevented.

> **3.2.1.2.14 Debris Prevention:** The Space Shuttle System, including the ground systems, shall be designed to preclude the shedding of ice and/or other debris from the shuttle elements during prelaunch and flight operations that would jeopardize the flight crew, vehicle, mission success or would adversely impact turnaround operations. [2]

In 1980, the External Tank Component End Item Specification reiterated this requirement [3]. Nevertheless, the inaugural 1981 flight of Columbia sustained damage from debris, causing 300 thermal protection tiles to be replaced. Later, external tank foam struck the left wing during Columbia's launch on 16 January 2003. During subsequent reentry on 1 February, this breach in the thermal protection system led to progressive melting of the aluminum structure of the left wing, failure of the wing, and breakup of the Columbia orbiter [4]. For the next two and one-half years, NASA researched and implemented safety improvements for orbiters and external tanks to prevent foam loss. However, when Discovery was launched on 26 July 2005, four pieces of foam still fell from the external tank. The largest chunk weighed 0.9 lb, more than half the weight of the foam that doomed Columbia. This chunk barely missed hitting the orbital. During this flight, Hale sent an e-mail to the Discovery crew confessing that he was "absolutely mortified by the performance of the external tank foam" and that they were not going to fly again until it was fixed [5]. After this Discovery flight, space shuttles flew five additional times, with external foam loss during each launch.

Risk involves the probability of occurrence of harm and the consequence of that harm.

NASA does not understand risk analysis. Even though it created its Office of Safety, Reliability, and Quality Assurance per the recommendation of the Rogers Commission after the Challenger exploded during launch in 1986, NASA's culture continues to maximize risk rather than let schedules significantly slip. After Discovery flew again with foam loss in 2005, after two and one-half years of safety work, seven of the 25 voting members of the Stafford-Covey Task Group, tasked for certifying that the Columbia Accident Boards' recommendations had been met, issued a minority report. In this 19-page annex to the main report, they observed that "NASA's leaders and managers must break this cycle of smugness substituting for knowledge" [6].

Risk involves two components: the probability of occurrence of harm and the consequence of that harm. As shown in the classic risk chart (Figure 1), if the risk associated with a current product design occurs in the intolerable region of high probability of occurrence and

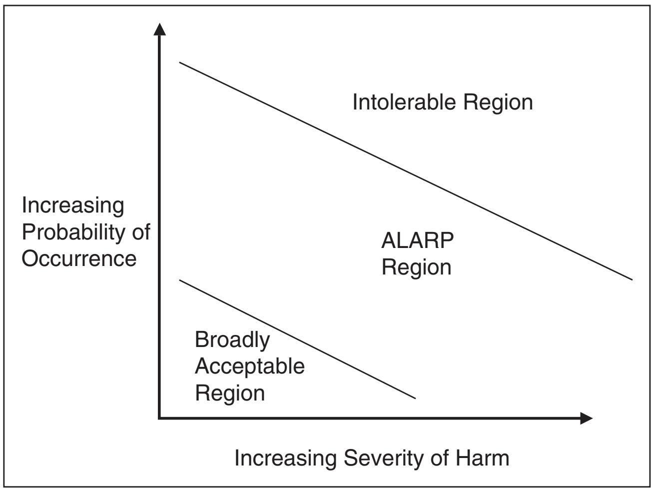

Fig. 1. Three region risk chart (7).

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high severity, then the design should be modified to reduce risk to as low as reasonably possible.

Even though foam loss occurred during the inaugural flight, which demonstrated that an external tank requirement was not being fulfilled, NASA classified and continues to classify foam loss as being within the broadly acceptable region of risk.

When risk analysis is conducted in the medical device industry, developers and users meet for endless hours to document all known risks and to mitigate them. Development engineers are critical to this process. Similarly, NASA should have listened to engineer Roger Boisjoly when he tried to prevent Challenger from launching during the coldest launch temperature to date, which he believed would cause O-ring failure. NASA should have granted chief engineer Rodney Rocha's request to obtain a detailed video of the Columbia launch to assess foam damage before reentry. Finding a solution in 2007 to a problem that first occurred in 1981, against a specification requirement written in 1973, and after seven deaths in 2003 remains unacceptable.

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References

[1] W. E. Leary, "NASA believes it has found reason foam fell on shuttle," *NY Times*, p. A3, 25 Aug. 2007.
[2] NASA National Space Transportation System, "Space shuttle program description and requirements baseline," NASA, Houston, TX, NSTS-0700, vol. 1, book 1, 1973.
[3] NASA National Space Transportation System, "External tank component end item specification," NASA, Houston, TX, NAS8-30300, 1980.
[4] G. D. Baura, *Engineering Ethics: An Industrial Perspective*. Burlington, MA: Academic Press, 2006.
[5] J. Schwartz and W. E. Leary, "Return to space: The overview; shuttle docks; shield damage is called minor," *NY Times*, p. A1, 29 July 2005.
[6] Stafford-Covey Task Force, "Return to flight task group," NASA, Houston, TX, final rep., July 2005, p. 197.
[7] Association for the Advancement of Medical Instrumentation, "Medical devices—Application of risk management to medical devices," AAMI, Washington, DC, ANSI/AAMI/ISO 14971:2000, p. 20.

Book Reviews (continued from page 11)

This text is divided into three broad sections. Part 1 is aimed at delivering the necessary nuts and bolts introduction to relevant topics in biology, mathematics, and experimental techniques. The range of topics covered is relatively comprehensive with corresponding concise and useful clarifications. The explanation of molecular bonds and forces covers three pages, as does differential equations and DNA libraries.

Part 2 introduces the fundamental details that qualify the systems descriptor to this field. This includes descriptions of processes, cycles, and expressions as well as modeling tools and approaches. Many engineers will be comfortable with the mathematics associated with computational and modeling approaches, even if they are not familiar with it. This may not be the case, however, for the descriptions of biological systems. These include applications to cellular processes and functions, including self-organization and self-replication as well as gene expression/regulation including time delays. The authors specifically seek to explain how different models are used to approach distinct classes of simulations. Particularly revealing is the use of these models and interpretations to cellular systems including regulation, cascades, oscillations, and even aging. The application of modeling to the understanding and explanation of these intercellular and intracellular processes is a familiar engineering approach. Part 2 concludes with examples of how systems biology affects medical systems and biotechnology, and it specifically addresses text mining, drug development, food production, ecology, nanotechnology, and even the design of new organisms.

Discussions and examples of Internet resources for information retrieval and examination are the focus of Part 3. The authors focus more specifically on available modeling tools and the databases they use in their specific investigations, although all the prominent databases and modeling software are covered. Specific databases addressed include KEGG, BRENDA, and others from the National Center for Biotechnology and European Bioinformatics Institute. The modeling tools include general purpose, mathematical, and Math lab (including examples) tools and specialized tools such as Gepasi, E-Cell, PyBioS, as well as the Systems Biology Markup Language, and the Systems Biology Workbench.

Overall, this text successfully achieves its goal of providing a survey of contemporary systems biology approaches. The review materials are useful as few individuals are adept at the broad range of the topics presented. The treatment, or practice, of systems biology covers an extremely broad range of cellular systems and potential applications. Computational Internet tools are ever evolving in the number of applications and their complexity, and this shared resource continues to provide insight and holds great promise. Engineers other than those working in bioinformatics and computational biology may initially be uncomfortable and unfamiliar with some of the topics and applications addressed. This resource does an admirable job of bringing the readers to a level where they can pursue more advanced study and research.

—Benjamin S. Kelley
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