Protecting the General Public From Launch Hazards is Very Challenging/Expensive for Many Users

Should the Government or an Industry Group Ease the Pain?

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The Board found that dangerous aspects of NASA's 1986 culture, identified by the Rogers Commission, remained unchanged. The Space Shuttle Program had been built on compromises hammered out by the White House and NASA headquarters.[14] As a result, NASA was transformed from a research and development agency to more of a business, with schedules, production pressures, deadlines, and cost efficiency goals elevated to the level of technical innovation and safety goals.[15] The Rogers Commission dedicated an entire chapter of its report to production pressures.[16] Moreover, the Rogers Commission, as well as the 1990 Augustine Committee and the 1999 Shuttle Independent Assessment Team, criticized NASA for treating the Shuttle as if it were an operational vehicle. Launching on a tight schedule, which the agency had pursued as part of its initial bargain with the White House, was not the way to operate what was in fact an experimental vehicle. The Board found that prior to *Columbia*, a budget-limited Space Shuttle Program, forced again and again to refashion itself into an efficiency model because of repeated government cutbacks, was beset by these same ills. The harmful effects of schedule pressure identified in previous reports had returned.

Prior to both accidents, NASA was scrambling to keep up. Not only were schedule pressures impacting the people who worked most closely with the technology – technicians, mission operators, flight crews, and vehicle processors – engineering decisions also were affected.[17] For foam debris and O-ring erosion, the definition of risk established during the Flight Readiness process determined actions taken and not taken, but the schedule and shoestring budget were equally influential. NASA was cutting corners. Launches proceeded with incomplete engineering work on these flaws. *Challenger*-era engineers were working on a permanent fix for the booster joints while launches continued.[18] After the major foam bipod hit on STS-112, management made the deadline for corrective action on the foam problem *after* the next launch, STS-113, and then slipped it again until *after* the flight of STS-107. Delays for flowliner and Ball Strut Tie Rod Assembly problems left no margin in the schedule between February 2003 and the management-imposed February 2004 launch date for the International Space Station Node 2. Available resources – including time out of the schedule for research and hardware modifications – went to the problems that were designated as serious – those most likely to bring down a Shuttle. The NASA culture encouraged flying with flaws because the schedule could not be held up for routine problems that were not defined as a threat to mission safety.[19]

The question the Board had to answer was why, since the foam debris anomalies went on for so long, had no one recognized the trend and intervened? The O-ring history prior to *Challenger* had followed the same pattern. This question pointed the Board's attention toward the NASA organization structure and the structure of its safety system. Safety-oriented organizations often build in checks and balances to identify and monitor signals of potential danger. If these checks and balances were in place in the Shuttle Program, they weren't working. Again, past policy decisions produced system effects with implications for both *Challenger* and *Columbia*.

Prior to *Challenger*, Shuttle Program structure had hindered information flows, leading the Rogers Commission to conclude that critical information about technical problems was not conveyed effectively through the hierarchy.[20] The Space Shuttle Program had altered its structure by outsourcing to contractors, which added to communication problems. The Commission recommended many changes to remedy these problems, and NASA made many of them. However, the Board found that those post-*Challenger* changes were undone over time by management actions.[21] NASA administrators, reacting to government pressures, transferred more functions and responsibilities to the private sector. The change was cost-efficient, but personnel cuts reduced oversight of contractors at the same time that the agency's dependence upon contractor engineering judgment increased. When high-risk technology is the product and lives are at stake, safety, oversight, and communication flows are critical. The Board found that the Shuttle Program's normal chain of command and matrix system did not perform a check-and-balance function on either foam or O-rings.

The Flight Readiness Review process might have reversed the disastrous trend of normalizing O-ring erosion and foam debris hits, but it didn't. In fact, the Rogers Commission found that the Flight Readiness process only affirmed the pre-*Challenger* engineering risk assessments.[22] Equally troubling, the Board found that the Flight Readiness process, which is built on consensus verified by signatures of all responsible parties, in effect renders no one accountable. Although the process was altered after *Challenger*, these changes did not erase the basic problems that were built into the structure of the Flight Readiness Review.[23] Managers at the top were dependent on engineers at the bottom for their engineering analysis and risk assessments. Information was lost as engineering risk analyses moved through the process. At succeeding stages, management awareness of anomalies, and therefore risks, was reduced either because of the need to be increasingly brief and concise as all the parts of the system came together, or because of the need to produce consensus decisions at each level. The Flight Readiness process was designed to assess hardware and take corrective actions that would transform known problems into acceptable flight risks, and that is precisely what it did. The 1986 House Committee on Science and Technology concluded during its investigation into *Challenger* that Flight Readiness Reviews had performed exactly as they were designed, but that they could not be expected to replace engineering analysis, and therefore they "cannot be expected to prevent a flight because of a design flaw that Project management had already determined an acceptable risk."[24] Those words, true for the history of O-ring erosion, also hold true for the history of foam debris.

The last line of defense against errors is usually a safety system. But the previous policy decisions by leaders described in Chapter 5 also impacted the safety structure and contributed to both accidents. Neither in the O-ring erosion nor the foam debris problems did NASA's safety system attempt to reverse the course of events. In 1986, the Rogers Commission called it "The Silent Safety System."[25] Pre-*Challenger* budget shortages resulted in safety personnel cutbacks. Without clout or independence, the

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Overview

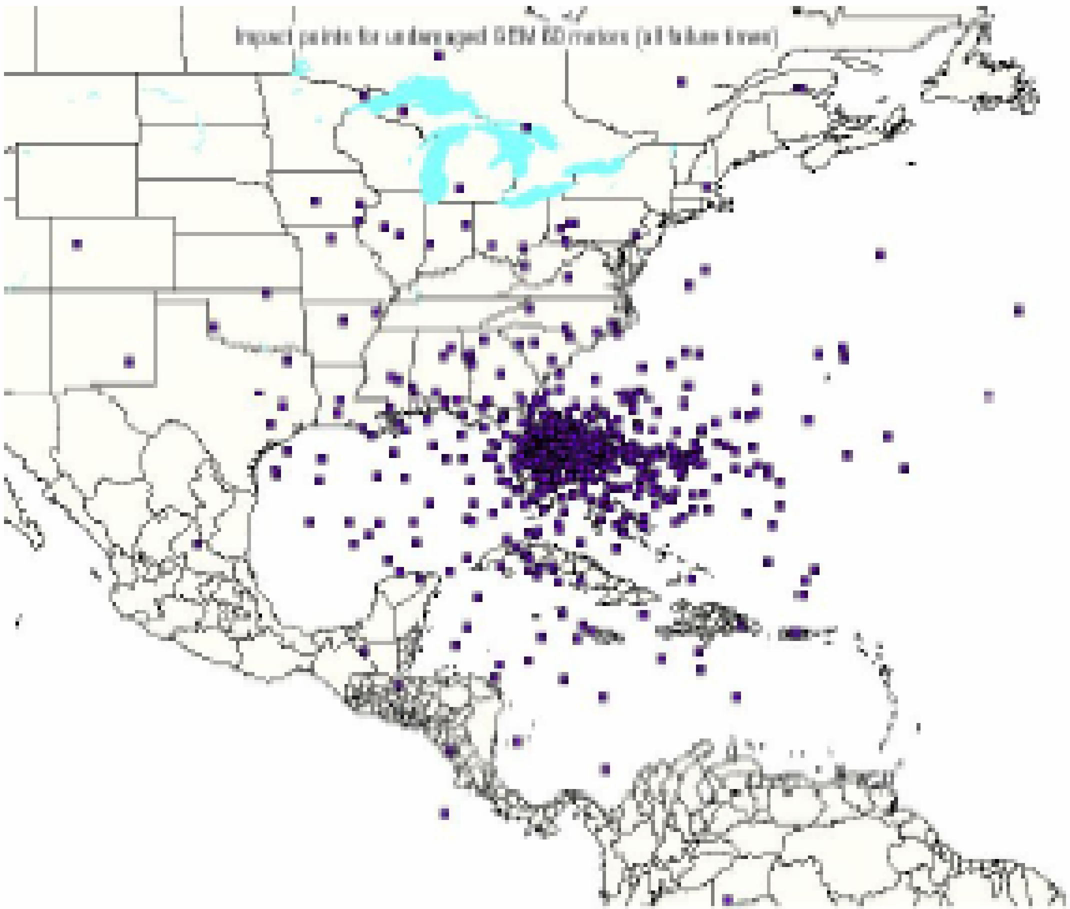
- Flight Termination System – Why?
- Cost Drivers
- ROM Costs for Typical FTS
- Notional Options
- Conclusions
- Recommendation

Flight Termination System

WHY?

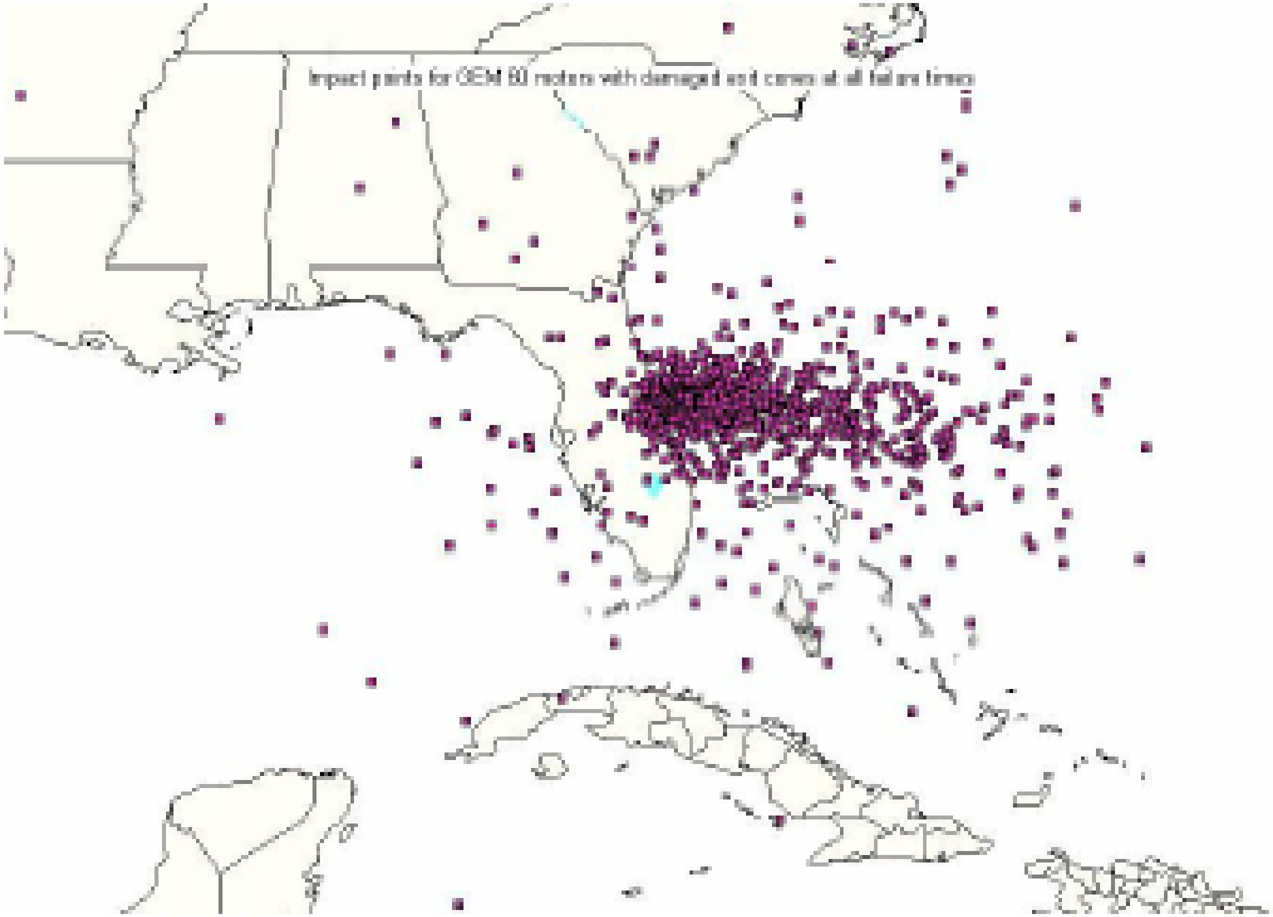
Random (Monte Carlo) Impact Locations - Undamaged Free Flying GEM60s

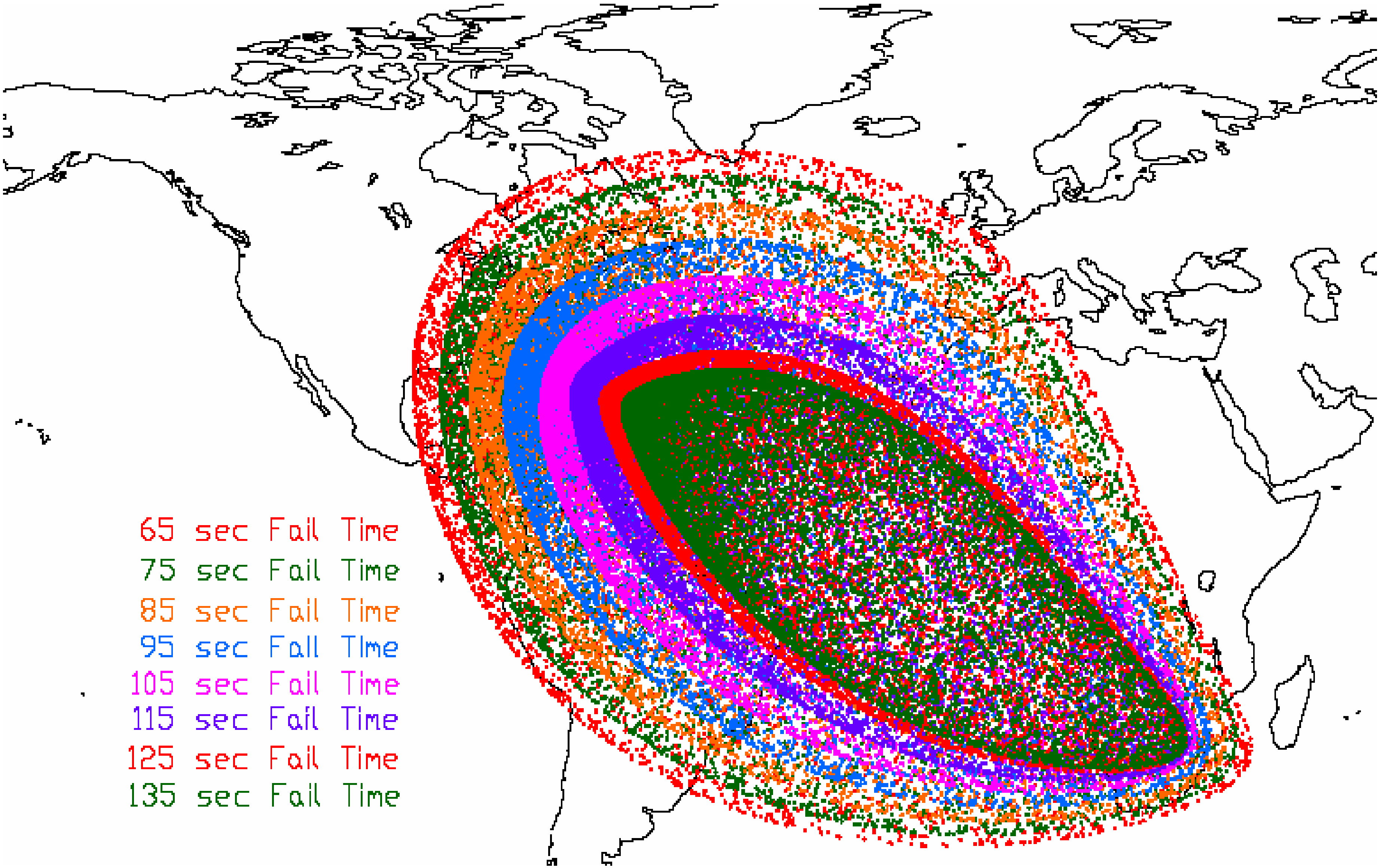
- The potential impact range of the undamaged GEM60s from avionics failures is very large
  - 2000 impact points (1000 for each GEM60) are plotted for each of the 22 failure initiation times



Random Impact Locations - Free Flying GEM60s with a Damaged Nozzle Bell

- The potential impact range of GEM60s with a damaged nozzle bell from avionics failures is smaller than for undamaged GEM60s but is still very large
  - 2000 impact points (1000 for each GEM60) are plotted for each of the 22 failure initiation times





65 sec Fail Time
75 sec Fail Time
85 sec Fail Time
95 sec Fail TIme
105 sec Fail Time
115 sec Fail Time
125 sec Fail Time
135 sec Fail Time

Cost Drivers

- *Flight Termination System* ***must*** *function reliably when vehicle is breaking-up*
  - *Single Fault Tolerant*
  - *Highly reliable piece parts*
  - *Extensive development, qualification and acceptance testing*

Typical Launch Vehicle Flight Termination System Costs (ROM)

Note: Does not include FTS Needs Analysis, system design, integration, or vehicle testing

Component	Quantity (Typical)	Recurring Cost Per Unit Including ATP	Development and Qualification Testing Note 1	Delta Qualification Testing Note 2	Margin/Gap Testing	Lot Acceptance Testing Note 3	Age Surveillance Testing Note 3
Antenna	2	$10K - $14K	TBD	TBD	NA	NA	NA
RF Coax Cable	AR	$100 - $200	TBD	TBD	NA	NA	NA
RF Power Divider	1	$5K - $7K	TBD	TBD	NA	NA	NA
Secure Destruct Receiver	2	$60K - $100K	$1M - $3M	$70K - $100K	NA	NA	NA
Non-Secure Receiver	2	$10K - $100K	$0.5M - $3M	$70K - $100K	NA	NA	NA
Battery	8	$8K - $10K	$0.5M - $1M	$70K - $100K	NA	NA	NA
ADS Logic Box	8	$40K - $75K	$1M - $3M	$70K - $100K	NA	NA	NA
S+A with EED	2	$10K - $25K	$250K - $1M	$70K - $100K	$250K	$70K-$100K	$70K-$100K
S+A Interrupter	8	$10K - $25K	$250K - $1M	$70K - $100K	NA	NA	NA
Lanyard Pull Initiator	8	$2K - $4K	$250K - $1M	$70K - $100K	$250K	$70K-$100K	$70K-$100K
Explosive Transfer System	AR	$0.5K - $1K	$250K - $1M	$70K - $100K	$250K	$70K-$100K	$70K-$100K
Shaped Charge	AR	$2K - $4K	$250K - $1M	$70K - $100K	$250K	$70K-$100K	$70K-$100K

Notes: 1) New Design 2) Existing Design, New Environment 3) Does Not Include Component Data

Options

- Option 1
  - Government or Industry Group contract with various manufacturing vendors to develop, qualify, and build a variety of unique, cutting-edge technology FTS components (e.g., space based, autonomous) IAW Government requirements
  - User (DOD, NASA, Commercial) Responsibility
    - Design Flight Termination System IAW government requirements
    - If desired, purchase unique FTS components from government/industry group and perform delta qual/acceptance testing IAW government requirements
    - Develop, qualify, build, and test remaining FTS components as required, IAW government requirements
    - Perform FTS integration/testing on vehicle IAW government requirements

Options (cont.)

- Option 2
  - Government or Industry Group contract with various manufacturing vendors to develop and qualify a variety of unique, cutting-edge technology FTS components (e.g., space based, autonomous) IAW Government requirements
  - User Responsibility
    - Design Flight Termination System IAW government requirements
    - If desired, purchase unique FTS components from pre-qualified manufacturing vendors and perform delta qual/acceptance testing IAW government requirements
    - Develop, qualify, build, and test remaining FTS components as required, IAW government requirements
    - Perform FTS integration/testing on vehicle IAW government requirements

Options *(cont.)*

- Option 3
  - Government or Industry Group purchases “rights” to qualification data for legacy FTS components and makes it available to all
- Options 4 - 10
  - Permutations and combinations of above options and others not yet offered

Conclusions

- Significant cost reduction for users (while maintaining high FTS reliability) can only be accomplished by solutions that are very much out-of-the-box
- Concept is radical and has risks for all involved (Gov't/Users)
  - Safety
  - Political
  - Contractual
  - Technical
  - Legal
  - Mission Assurance
- Cost/Benefit for each player is unknown at this time

Recommendation

- Government (federal or state) should fund a feasibility assessment with following objectives:
  - Survey all ranges and range users (DoD, NASA, Commercial) and determine level of interest in government or industry group developing, qualifying, and possibly fabricating high end FTS components
  - If level of interest is high enough perform cost/benefit analysis for all reasonable/rational options and all users