



Killing “Death Star:” be persistent in advocating for safety

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In July of 1982, Congress mandated a Shuttle/Centaur Program to launch Galileo and Ulysses satellites by May of 1986 and subsequently to collaborate with the U.S. Air Force for Department of Defense (DOD) missions. In order to pair these two existing programs, the shuttle liquid hydrogen (LH2) and liquid oxygen (LOX) propellant fill/drain/dump system had to be modified, as shown Fig. 1, because the Centaur propellant was loaded at the same time as the External Tank and Centaur propellant had to be dumped for a launch abort or failure for Centaur to deploy prior to Orbiter landing. The Centaur also required multiple design changes to integrate with the shuttle payload bay, including modifications of the tank, the fill/drain/dump system, the integrated support system, and software updates, Fig. 2 compares the external physical dimensions the Atlas Centaur versions. The only similarities to the uncrewed Centaur were the RL-10 engines, and that cryogenic LOX and Hydrogen were only separated by a single bulkhead.

I became the Deputy Director of Safety Reliability & Quality Assurance (SR&QA) in October 1985. In November a senior safety engineer informed me of significant safety concerns about the Shuttle/Centaur Program, which no one in management had addressed. One concern was the tank and propellant systems not meeting the required factors of safety. Another was the over-pressurization of the liquid oxygen system from excessive surge pressure, such as a water hammer effect from liquid oxygen loading termination.

The Space Shuttle Program Payload Safety Panel Chairman had disapproved the Shuttle/Centaur payload non-compliance reports, but that the decision was overturned by NASA Headquarters after an appeal by the NASA Lewis Research Center (LeRC). Other safety-critical, single-point failures existed in this program as well, with credible concerns as to the reliability of the system. The Shuttle/Centaur Program management relationship was that the NASA LeRC/USAF Space Division Shuttle/Centaur Joint Project Office was hardline reporting to NASA Headquarters and dash line reporting to the NASA JSC Space Shuttle Program Office.

In preparation for the Shuttle/Centaur Program Level 1 (NASA Headquarters) Review on January 16, 1986 at Kennedy Space Center (KSC), I wrote a memorandum [1] to the manager of the National Space Transportation System regarding the JSC SR&QA position on Centaur. This memorandum stated the following safety problems that have been identified to SR&QA to date must be resolved prior to the first Centaur flight:

- Design change to dump valve or control system to reestablish single fault tolerance in valve actuation. Design fix that was incorporated to provide confidence that valve will operate negated valve actuator redundancy. This is a criticality 1 item.
- CISS control unit relay Criticality 1 single-point failure mode (short to ground) must be eliminated. Required action would be to remove crosstie (cause of failure being Criticality 1) or put in isolating diodes. Flight hardware with fix should be checked out during one of the tanking tests.
- Lack of configuration control, verification, testing, and shelf life on Centaur software. For example, Centaur software not incorporated in OMI S0046 Count Down Demonstration Test (CDDT) tanking test wet/dry under review at KSC. Software to be put under configuration control with only mandatory changes being made. Vehicle integrated testing such as CDDT to be run with flight software. Level of rigor for verification and testing to be the same as for Orbiter because of the Criticality 1 nature of this software.
- Waiver WARC 3 Centaur/CISS fill, drain, dump system ultimate factor of safety pressure surges is being forwarded with a recommendation of disapproval. The first Centaur flight was scheduled to launch approximately four months later.

At the Level 1 Program Review I presented the JSC SR&QA position, and the NASA Headquarters Head of Human Spaceflight directed me to coordinate with LeRC. This was discouraging, since JSC SR&QA and the Payload Safety Panel had been working with LeRC with no agreement to correct the safety non-compliance reports.

In early January 1986, the commander for one of the Centaur missions, Rick Hauck, was working on an issue with redundancy in the helium actuation system for the liquid oxygen and liquid hydrogen dump valves. This concern is the same as what I had listed as item a) in my memorandum. Hauck believed that the program was willing to compromise on the margins in the propulsive force being provided by the pressurized helium, which concerned him enough that he raised the issue with the Chief of the Astronaut Office, John Young. “John Young called this mission, ‘Death Star’ ” [2] recalled Hauck. “That was his name for this mission, which he said with humor, but behind humor, there’s a little bit of truth. I think it was conceded this was going to be the riskiest mission the shuttle would have flown up to that point.”

John Young and Rick Hauck “went to a board [Space Shuttle

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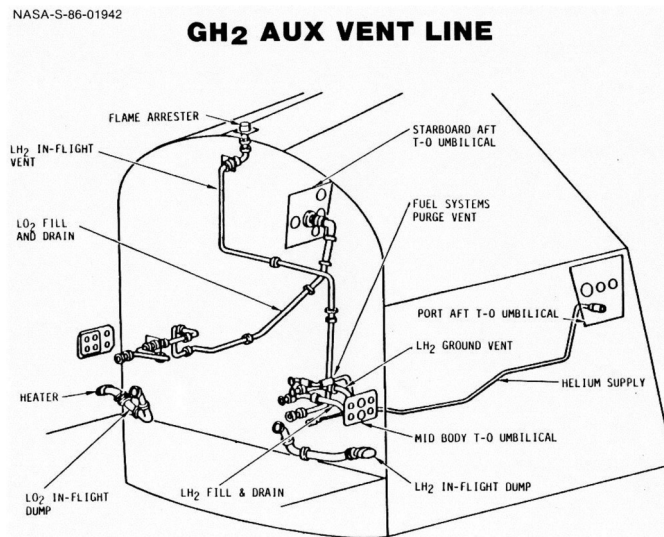


Fig. 1. Modified shuttle propellant system.

SHUTTLE/CENTAUR USES PROVEN ATLAS/CENTAUR SYSTEMS

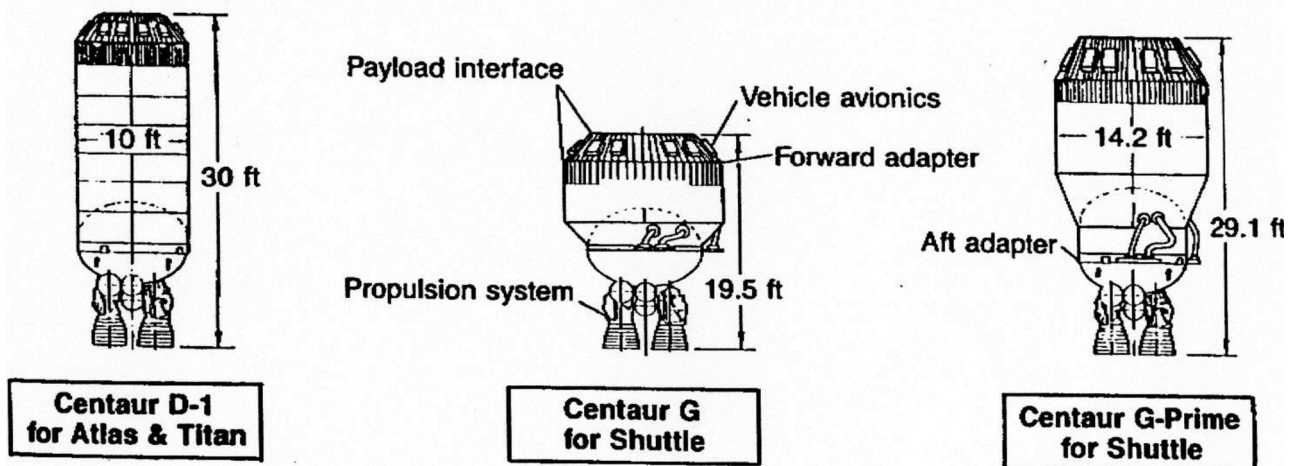


Fig. 2. Centaur design variants.

Program Control Board] to argue why this was not a good idea to compromise on [the helium actuation system], and the board turned down the request.” Back in the Crew Office, Hauck told the other crew members, “NASA is doing business different from the way it was done in the past. Safety is being compromised, and if any of you want to take yourself off this flight, I will support you.” [3]

On January 28, 1986, Space Shuttle Challenger was on the launch pad at the Kennedy Space Center (KSC). The decision was made to proceed with the launch, and Challenger and its crew of seven were lost after 73 seconds of flight. Unfortunately, the planned launch of the Ulysses, and its Shuttle-Centaur in May, a little over three months later, on-board the Space Shuttle Challenger, became a major factor in deciding to launch Challenger on January 28, in the face of the accumulated ice and the cold temperatures. The program felt it was essential to launch that day to avoid impacting the short turn-around time of Space Shuttle Challenger after its return from its January mission, to support a May planetary launch window.

I was surprised and disappointed that even after the Challenger

accident and the Rogers Commission Report on the Challenger accident, the managers involved still wanted to fly the Centaur. The next scheduled mission, this “Death Star,” with all of the open safety concerns was delayed but not canceled. On March 4 John Young wrote to the Centaur mission commanders Rick Hauck and Dave Walker about the Centaur mission. The handwritten note said, “But also never forget that: a. Running the pressure up & down during ascent, b. Venting H₂ during ascent, c. pressurized stabilized pressure vessels, d. spot-welded pressurized propellant tanks are not good ideas...Please do NOT invite me to any more briefings on Centaur. The engineering logic in them makes my head hurt.” [4] Despite this sentiment, Hauck reported that John Young would ask him about the “Death Star” at the Monday morning status meetings.

On March 6 General Dynamics made a presentation to the Payload Safety Review Panel covering actions being worked and items considered closed. JSC insisted on redesign of the safety-critical dump valve to provide redundant actuation. LeRC stated that a redesign would create schedule problems that NASA Headquarters would have

to direct. [5]

On March 17 I conducted an SR&QA audit of the safety-critical avionics. [6] Significant findings included:

Acceptance testing without released test procedure.
Automatic test equipment used on checkout often indicated "Test Passed" when parameters were out of limits.
Control unit tested on unreleased software.
Critical avionics box certified for flight with open failures and waivers.

When I asked the responsible engineer why he signed off on the flight certification with open failures, he said his manager directed him to sign. LeRC told me this was not true. I did not mention this in my written report, because I did not want the engineer to be disciplined for what he conveyed to me in private.

On April 8 three members of the House Appropriations Committee Surveys Investigation Staff met with me regarding Centaur safety concerns. They asked me questions about my audit results and the problems I had reported. They also requested copies of the other two memos, documenting the SR&QA position and the concerns raised at the Level 1 Program Review at KSC.

The JSC Engineering Propulsion and Power Division Systems Branch Deputy Chief had concerns about Centaur's compatibility with the shuttle. He believed that the inherent Centaur design, with common bulkhead pressure-stabilized tanks combined with a highly active cryogenic vent and pressurized duty cycle, did not meet human spacecraft standards and represented an undue hazard to the shuttle [7].

On May 22, 1986 Rick Hauck presented [8] the concerns to management, that even after the proposed safety modifications had been implemented, the Shuttle/Centaur flight still represented significant additional risk to the orbiter and crew. Attempts to integrate an uncrewed upper stage into the shuttle resulted in compromises which created undue risk, and the ability to reduce the risks to an acceptable level was questionable.

On June 6, 1986 a draft of a Shuttle/Centaur presentation [9] destined for the NASA Administrator was reviewed in a meeting chaired by the Space Shuttle Program Office (Level 2) at JSC with personnel from Headquarters, LeRC, KSC, and the Jet Propulsion Laboratory. The briefing highlighted two significant hazards:

Loss of pressure control of oxygen or hydrogen tanks would be a catastrophic failure, and end-to-end pressure control could not be verified by testing.
Rupture of lines/components due to pressure surges during normal system transients, and pressure surges due to system malfunction or inadvertent operations not included in design requirements.

The presentation concluded that even with the best possible solutions, Centaur represented significant additional risks to the shuttle. This was the JSC position, not LeRC's position, and the word "significant" was ultimately deleted. The safety assessment stated, "No technical barriers have been identified which prevent Centaur integration into [the shuttle] with minimal additive risk." I spoke up to say that this was not safety's position, but the chart was not changed.

On June 13, 1986 NASA Headquarters sent out this Shuttle/Centaur presentation for review and comment, in preparation for its presentation to the NASA Administrator on June 19. I recommended adding the wording "tank rupture hazard increased during dumps." Regarding tank pressure control, I added "end-to-end pressure control is highly sensitive to assumptions regarding fluid dynamics which cannot be test verified." On the summary chart I added, "additive safety risks are inherent to Centaur, cannot be eliminated, and represent significant increase over that accepted for previous payloads." None of my comments

were incorporated into the presentation.

On June 16 a telecon was held with NASA Headquarters regarding Centaur. I wrote a memo to document that I had communicated the JSC SR&QA position that "even if all the proposed safety modifications are made...the program must accept a safety risk greater than any previous shuttle payload and most shuttle systems...The overall position of this office is not to fly Centaur on the space shuttle." [10]

On June 19, 1986 the revised charts were presented to the NASA Administrator, and I attended this meeting sitting next to Commander Rick Hauck. [11] At the meeting DOD, LeRC, the JSC Engineering Propulsion and Power Division Chief, and planetary representatives favored continuing Shuttle/Centaur, but I stated that the risk was too high. Many arguments were made under much scrutiny, but I held my position regarding the safety hazards. The astronauts also expressed concerns, but were somewhat resolved to flying the mission. The Administrator left to have a separate, closed-door meeting. I felt very discouraged, as it seemed the program would continue, based on the presentation and the position of the other organizations.

Later that day I learned that the Administrator had canceled the program. That made my day! Hard work and persistence had paid off.

It is important to note the Ulysses Probe was safely launched from Space Shuttle Discovery, utilizing two solid rocket propulsion stages, the Inertial Upper Stage (IUS) and the Propulsion Assisted Module (PAM), on 6 October 1990, from the Kennedy Space Center for an unprecedented journey of discovery.

Lesson: If you believe something is unsafe, be persistent in reporting your concerns, again and again if necessary. Advocating for the cancellation of this program was an extraordinarily difficult task that faced considerable opposition. Even with the recent loss of *Challenger*, significant safety hazards were not receiving enough attention, influenced in part by schedule pressure. Although other organizations had concerns with the Shuttle/Centaur Program (Payload Safety Panel, Engineering, Crew Office), I as the SR&QA representative voiced opposition to the mission at the Administrator's review.

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