# The Commercial Launch Industry, Reusable Space Vehicles, and Technological Change

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On October 31, 1997, NASA announced that the X-33 Program had just successfully completed its five-day-long Critical Design Review. The X-33 is a technology demonstrator for NASA's "next generation" of space launch vehicle. It will flight test a range of technologies needed for single-stage-to-orbit reusable launch vehicles, such as thermal protection systems, composite cryogenic fuel tanks, and the aerospike engine. Test flights are now scheduled to begin in July 1999. Eventually, based on the X-33 experience shared with NASA, Lockheed Martin may build a commercial single-stage-to-orbit reusable spaceship, called VentureStar.

NASA also is working with Orbital Sciences Corporation to design, build, and test fly an experimental two-stage reusable launcher called the X-34. Additional reusable space transporters are under development by a number of private firms, including Kelly Space & Technology, Inc., the Kistler Aerospace Corporation, Pioneer Rocketplane, and the Rotary Rocket Company. No list would be complete, though, without a mention of the pioneering DC-X, built by McDonnell Douglas Aerospace for the Strategic Defense Initiative Office, and flight tested between August 1993 and July 1995, before being reborn as a NASA vehicle, the DC-XA, which performed additional test flights between May and July of 1996.

All of these vehicles are or were intended for the commercial launch market. The commercial launch market consists of the launching of commercial and governmental payloads (usually communication satellites) for hire. It is a global market. The ever growing commercial demand for launchers, the entry into the market of new launcher suppliers (such as Russia, China, and Japan), and the relatively high cost of placing payloads in space, have driven the search for new, less expensive launchers utilizing the latest technologies in order to undercut the competition's prices. However, the use of untried launch systems, and the technical difficulties associated with reentry vehicles, pose high risks for those attempting to create a niche in the commercial launch market by utilizing new especially reusable technologies. A case in point is the COMET program and the Conestoga rocket.

COMET (COMmercial Experiment Transporter) was a NASA program intended to boost the fledgling microgravity industry. Part of the COMET

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spacecraft was a reusable reentry module. It was to be put into space by a completely new type of rocket, the Conestoga. Thus, like the current generation of reusable launchers, COMET combined reusability and a novel launch system in order to address the needs of industry. By examining the example of COMET, we will see the complexities and difficulties inherent in introducing new launchers, especially reusable vehicles, into the commercial market.

## A COMET is Born

In May 1990, the Center for Space Transportation and Applied Research (CSTAR) proposed COMET to the NASA Office of Commercial Programs. CSTAR, at the University of Tennessee in Tullahoma, was a university entity operating as a NASA Commercial Center for the Development of Space (CCDS). CSTAR proposed to procure three COMET missions for NASA for about $85 million over a period of five years. The focus of the COMET program was on jump-starting the incipient space-based materials processing industry. The COMET spacecraft would carry microgravity experiments into low earth orbit for a month, then parachute test samples back to Earth in a recoverable, reusable module. Another portion of the spacecraft, the service module, would be left in orbit for two to four years.[1]

The COMET concept offered many advantages over sounding rockets and the Space Shuttle, both of which have been used to conduct microgravity experiments. COMET would provide longer durations of microgravity, as well as longer exposure to space conditions than either the 7-8 minutes of sounding rockets, or the maximum of 16 days offered by the Space Shuttle. In addition, the COMET spacecraft, because it had no astronauts on board, experienced fewer vibrations than the Space Shuttle or, for that matter, the proposed Space Station (both Freedom and the current design). The absence of vibrations is a critical desideratum for certain microgravity experiments. For other experiments, the COMET offered a stable temperature in the payload area.[2]

CSTAR's role in the COMET program was to provide general oversight of the project, which would be undertaken by three prime contractors. The Space Division of Westinghouse Electric Corporation, Baltimore, would supply systems integration and the part of the COMET spacecraft that would remain in orbit, that is, the service module. Westinghouse also was hoping to sell COMET services to commercial and government customers through its Commercial and Civil Space Department under the trade name Westar

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[1] "COMET: COMmercial Experiment Transporter," NASA brochure, September 30, 1992; Center for Space Transportation & Applied Research, "COMET Customer's Operational Guide," March 23, 1992; NASA, Office of Advanced Concepts & Technology, Flight Programs Division, "Briefing on COMET Cost Growth to Paul Holloway," April 22, 1993, File 10783, NASA History Office Archive, Washington, DC (hereafter, NHO).

[2] Gregory Reck, interview with the author, NASA Headquarters, Washington, DC, February 17, 1998; Jim Hengle, interview with the author, Futron Corporation, Bethesda, MD, February 25, 1998.

(Westinghouse Space Transportation and Recovery). The Westar operation seemed to assure that COMET would have a commercial future [Colucci, 1991].

Space Industries International Inc. of League City, Texas, would provide payload integration, orbital operations, reentry module retrieval, and the reusable recovery module. The recovery module was the heart of the COMET concept. It carried microgravity experiments into space, then returned them to earth thanks to a calculated reentry of the module. Prompt recovery of the module insured that customers would have the rapid access to results required for microgravity experiments. Then, the reentry module could be turned around and flown again on a subsequent mission.

EER Systems Corp. of Vienna, Virginia, would furnish the Conestoga launch vehicle. The Conestoga was a new rocket concept, and the launching of COMET would mark its debut. Thus, the Conestoga "wagon" would be hitched to CSTAR's COMET. EER acquired the Conestoga concept, and stake in the microgravity business, when it bought Space Services Inc. (SSI) of Houston, Texas.

## Conestoga

SSI conducted a successful suborbital test of the first commercial rocket at their Matagorda Island, Texas, launch site in 1982. However, for a number of reasons having to do with the regulatory environment and government policy, it was not until 1989 that SSI entered the commercial launch market, which was then monopolized by Arianespace.

Created in March 1980 as a private stock company by European aerospace firms, banks, and the French space agency, Arianespace took over operation of the multinational European Space Agency's (ESA) Ariane rocket, including managing and financing of Ariane production, organizing worldwide marketing of launch services, and managing launch operations at Kourou, French Guyana. Ariane launches began in December 1979, and the initial series of missions was conducted under ESA responsibility. The first full commercial mission under Arianespace control was the launcher's ninth flight in May 1984, when an Ariane I successfully lifted the U.S. GTE Spacenet 1 satellite into orbit. By the spring of 1985, Arianespace held firm orders for orbiting thirty satellites and had options for launching twelve more – representing a combined order book value of about $750 million. Of those orders, half were from satellite customers outside the European home market. Arianespace marketing combined the best of both worlds: the marketing freedom of a private company, plus the direct support of government agencies [Arianespace, 1991].

Meanwhile, back in the United States, SSI's 1989 launch was historic for a number of reasons. It was the first U.S. commercial launch licensed by the Department of Transportation ["First," 1989], and it marked the inauguration of SSI's microgravity business, called Consort. Consort originated in 1988 in NASA's Office of Commercial Programs and the Consortium for Materials Development in Space (CMDS), of the University of Alabama at Huntsville, which managed the program. The CMDS was, like CSTAR, one of 17 NASA

Centers for the Commercial Development of Space. Launches took place on SSI's Starfire rocket from the Naval Ordnance Missile Test Station at the White Sands Missile Range, New Mexico ["Researchers," 1990; Ganoe, 1989].[3] The Starfire payload area provided about 22 cubic feet of experiment space. On each Consort flight, the payload reached an altitude of nearly 200 miles, and provided seven to eight minutes of microgravity. The payload parachuted to earth and was recovered about 50 miles down range. The entire mission, from launch to touch down, lasted about 15 minutes. Within 2 hours of landing, the payload was returned by helicopter to White Sands for post-flight tests.[4]

Despite the initial success of the Consort program, in 1990 SSI found itself in troubled financial waters, when its chief financial backer, Ventures, Inc., a venture capital subsidiary of Houston Industries, Inc., pulled out its $6 million financial support for the company ["SSI," 1990; "Private," 1990; "Space," 1987]. It was at this point that EER Systems Corporation purchased SSI, along with its Consort microgravity business, its launch technology and hardware, and the accumulated experience and knowledge of its managers. The acquisition of SSI allowed EER Systems to integrate launch capabilities into its established business of designing and building payloads.[5] EER was now in the commercial launch business.

Moreover, with the acquisition of SSI came the Conestoga launcher and its creator, Deke Slayton, then president of SSI, but now director of EER's Space Services Division. Donald K. "Deke" Slayton, one of the original seven Gemini astronauts, thought up the concept of a multiple-stage rocket consisting of a core motor with additional motors strapped around it. The number of additional motors depended on the size of the payload. This was the Conestoga rocket.[6]

**Trouble in Rocket City**

It did not take long before it became obvious to NASA, thanks to its system of project reviews, that the COMET program was in trouble. Moreover, as early as February 1992, COMET problems aired in the press following a major design review completed January 22, 1992. One serious, but short-term, problem was a launch delay arising from the late delivery of rocket engines by the Thiokol Corporation of Ogden, Utah ["COMET," 1993].

NASA, however, felt that COMET problems went deeper. CSTAR was not performing competently as project manager, was incapable of handling such a complex engineering effort, and was causing repeated schedule delays. NASA further was troubled by the project's mushrooming costs, which had

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[3] NASA, Press Release 90-58, April 23, 1990, File 10,784, NHO.

[4] "Consort Suborbital Launch Program," brochure, August 19, 1992, File 10,784, NHO.

[5] Hengle interview.

[6] "Rocket Away!" *EER Systems Newsletter*, vol. 5, no. 1, Winter 1991-92, pp. 1-2, and "Commercial Launch Only Partial Success for Research Team," *Sun-News* [Las Cruces, NM], September 11, 1992, p. 13, File 10,784, NHO.

ballooned from $85 million to an estimated $158 million for three missions. In order to cut its losses, NASA reduced COMET to a single-mission program with a budget of $65.8 million [Seitz, April 30, 1995; Seitz, July 25, 1995].[7]

Still, CSTAR management of the COMET program continued to worsen. None of the three COMET contractors complained, as long as NASA continued to pay their invoices. CSTAR saw its own financial advantages to keeping the project alive. If the COMET program were to be reformed, NASA would have to take the first step, or at least that was how the situation was perceived by Jack Levine, director of flight programs in NASA's Office of Advanced Concepts and Technology, who recently had been made responsible for the COMET program.[8]

Although first launch had been scheduled for September 1, 1993 ["COMET," 1993], by December 1993, the launch date had slipped to early March. Nonetheless, fabrication and assembly of the COMET vehicle was making progress in December, 1993, when the COMET spacecraft completed a series of tests at Goddard Space Flight Center in Greenbelt, Maryland, in preparation for its first flight. The COMET spacecraft next underwent integration checks with the payload of experiments prior to shipment to the Wallops Flight Facility in Wallops Island, Va., and EER began assembling the Conestoga rocket at the launch site [Seitz, January 3, 1994].

By January 1994, the relationship between NASA and CSTAR had reached bottom. NASA announced plans to phase out CSTAR and five other Commercial Centers for the Development of Space. The termination of CSTAR raised several major questions about COMET's future, especially who would run the COMET program. At the same time, NASA ordered an extensive independent review of the COMET program. The review examined financial, technical, and schedule problems and was to be completed in early February, 1994.

But, as the independent review was taking place, Congress intervened. On January 14, 1994, the heads of the House and Senate appropriations committees, Sen. Barbara Mikulski (D-Md.) and Rep. Louis Stokes (D-Ohio), directed NASA to release $7.2 million in the COMET budget, but only if the program successfully completed the independent review ["NASA," July 4, 1994; Seitz, July 25, 1994; "Space," February 27, 1987].[9] Senator Mikulski, deeply interested in the U.S. space program, counted among her constituents the Baltimore-based Space Division of Westinghouse Electric Corporation, as well as portions of EER Systems.

NASA's review of the COMET program continued into April 1994. Then, on May 5, 1994, with the results of the independent review in hand, Daniel Goldin, NASA Administrator, announced that the space agency would refuse to continue funding COMET. The independent review team had

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[7] Jack Levine, interview with the author, private residence, Washington, DC, March 13, 1998.

[8] Levine interview.

[9] Levine interview.

concluded that the COMET recovery vehicle would have had a greater probability of success if it had been built using regular NASA procurement and management practices, instead of through a grant to CSTAR. Moreover, the program created a serious liability problem for CSTAR and its contractors, as well as for NASA, in the event that the recovery module landed outside the safe area of the Utah Test and Training Range in the sparsely populated Great Salt Lake desert.[10] As one anonymous congressional staffer commented to a *Space News* reporter, "It sounds like it [COMET] has a massive cost overrun, there is no commercial market [for it] and NASA doesn't need it. I don't think anyone is going to try and save it" [Seitz, May 9, 1994].

**Frankenstein**

Nonetheless, despite Goldin's announcement, COMET was not dead. Congress brought it back to life. CSTAR COMET program managers convinced Sen. Mikulski and Rep. Stokes that NASA should release COMET funding on condition that the contractors agree to waive NASA's legal liability. In a letter dated June 10, 1994, Mikulski and Stokes requested that NASA release all COMET funding. NASA agreed, but attached certain strings laid out in a letter to COMET contractors dated July 18, 1994. NASA wanted CSTAR out of the COMET program, and asked the three contractors to enter into a fixed-price contract with NASA for the first launch in exchange for the release of the remaining $14 million in funding. In addition, NASA asked the contractors to accept legal liability for the reentry vehicle ["NASA," July 4, 1994; Seitz, August 8, 1994].[11]

The immediate reaction of COMET contractors was that such major changes so late in the program could kill the enterprise. EER Systems viewed NASA's proposal to change its relationship with the contractors as an unnecessary complicating factor that could drag the process out for months. Neither a consortium nor a joint venture arrangement, as proposed by NASA's acting associate administrator for Advanced Concepts and Technology, Gregory Reck, were satisfactory to the contractors, who no longer wanted to be part of what appeared to be a doomed (i.e., unfunded) program ["COMET," July 26, 1994; Seitz, July 25, 1994].[12]

NASA officials met with representatives of the three COMET contractors on August 5, 1994, to attempt a resolution of outstanding questions and to resurrect the program. NASA now removed the biggest roadblock to an understanding by agreeing to drop the agency's demand for a new contract with the three-company team. Neither Westinghouse nor Space Industries was interested in pursuing the project. After long discussions during the final months of 1994, on March 28, 1995, NASA signed a sole-source, firm fixed-

[10] Hengle interview; Levine interview.

[11] Hengle interview; Levine interview.

[12] Reck interview; Hengle interview.

price contract with a single party, EER Systems [Seitz, July 25, 1994; Seitz, August 8, 1994; Seitz, January 9, 1995; Seitz, April 3, 1995].[13]

Unlike the other COMET contractors, EER Systems saw COMET as a great opportunity, an opportunity to make lemonade out of lemons. Since its acquisition of SSI and the Conestoga rocket design, EER had been looking for payloads to launch. The firm landed a five-launch contract with the Strategic Defense Initiative Office (now the Ballistic Missile Defense Organization) to place segments of the so-called Star Wars system in orbit at low cost [Lenorovitz, 1993]. However, when the President and Congress killed the Star Wars program and changed that agency's agenda, the Conestoga lost that customer. The COMET program, then, appeared as a way to provide Conestoga with its first payload. And, once the Conestoga rocket was proven, customers would be easier to find.[14]

As part of its deal with NASA, EER would find commercial payloads for the first COMET launch, which was now scheduled for May 29, 1995. Westar, Westinghouse's effort to garner paying customers for COMET, along with Westinghouse itself, was no longer part of the COMET program, leaving EER free to seek out clients. Indeed, as early as January, 1995, EER announced that they had secured five firm commercial payloads for the first COMET flight, and that they were negotiating with customers for space on a second COMET mission, COMET 2, scheduled for launch in 1996 [Seitz, January 9, 1995].

Also key to EER's management of the COMET program was the decision, made at NASA's suggestion, to change the COMET landing site from Utah to the Atlantic Ocean.[15] This change reduced the reentry liability risk immensely, and facilitated the process of obtaining a launch license from the Department of Transportation. Ultimately, however, the Department of Transportation did not issue its launch approval until 72 hours before scheduled launch on August 4, 1995.[16]

**A License to Return**

The granting of that license was a unique event for the Department of Transportation's Office of Commercial Space Transportation (OCST). Empowered by both the Commercial Space Launch Act of 1984 (as amended) and Presidential Executive Order 12465 to license all U.S. commercial launches, the OCST had no authority to license vehicle reentries, descents, or landings. Yet, that was exactly what COMET's reentry module would do. The cause for this regulatory gap was the changing nature of space transport technology.

The Space Shuttle, a partially reusable vehicle that lands under its own power, was a known, though new, space transport technology, when the Space

[13] Hengle interview; Levine interview.

[14] Hengle interview.

[15] Hengle interview; Levine interview.

[16] Hengle interview.

Commerce Act of 1984 was formulated. Although the Shuttle carried commercial payloads into orbit, it was exempt from launch licensing by Section 21(c) of the Space Commerce Act of 1984, which explicitly excluded NASA and the Department of Defense launches from Department of Transportation licensing requirements. It was only in the wake of the 1986 *Challenger* disaster that the Shuttle's grip on the U.S. commercial space launch market ended, and the OCST issued its first license for a commercial launch in 1989.

Aside from the Shuttle, commercial space transport systems capable of controlled reentry, descent, or landing were only imagined when the Space Commerce Act was formulated in 1984. Therefore, in licensing the COMET reentry vehicle, the Department of Transportation's OCST had to interpret imaginatively existing regulations and treat the reentry vehicle as a payload. The OCST had broad authority to determine whether the launch of a payload should be prevented because its launch might jeopardize public health and safety, the safety of property, or any national security or foreign policy interest of the United States.

The OCST, then, required EER Systems Corporation to apply for and obtain a favorable payload determination, before launch could occur. This determination required EER to demonstrate that the integrated system (launcher plus payloads) was capable of being operated safely. A key aspect of operational safety was EER's ability to land the reentry vehicle without causing harm to people or property, and that meant being able to calculate rather precisely the vehicle's landing area. The ability to land within the designated area was affected by several factors determined immediately before initiation of reentry. Those factors included pointing accuracy, timing of the retroburn, and duration of the retroburn. Upon descent, a parachute was released to assure a soft landing. In considering the safety of reentry, the OCST considered three criteria: 1) the probability of the reentry vehicle landing outside the designated landing site; 2) the risks to the public in the immediate vicinity of the landing site (defined as the area within 100 miles of the designated landing site); and 3) the risks to the general public beyond that 100-mile zone. The three criteria were intended to address the risks to public safety that resulted from a "human-induced reentry," which the OCST defined in a way to distinguish it from a free-fall reentry resulting from orbital decay.[17]

Ultimately, the OCST licensed the COMET reentry vehicle as a payload on a licensed expendable launch vehicle. In this way, the OCST licensed the first landing of a reusable space vehicle before passage of legislation (still pending) that would empower the OCST to license vehicle landings.

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[17] Department of Transportation, "Financial Responsibility for Reentry Vehicle Operation," May 1995; idem, "Report on the Effects of Parachutes on Risk Mitigation to Third Party Property Individuals," March 1993; idem, "Risk Sensitive Assessment of Flight Termination System on Reentry Vehicles," August 1994; idem, "Survey of Reentry Vehicles," April 1991, X-33 Archive, NASA Headquarters, Washington, DC.

## Conclusion

Launching the Conestoga on schedule was another problem. Launch was to take place at NASA's Wallops Flight Facility. Before its acquisition by EER, SSI had signed a Memorandum of Agreement on September 2, 1986, with NASA for the use of launch facilities and services at Wallops to support SSI's commercial expendable launch operations.[18]

The inability to establish a firm launch date hindered EER's efforts to line up customers. In their quest for commercial payloads, EER discovered that customers' chief requirement was the ability to launch on demand. The Conestoga was not fated to launch according to schedule. Like so many other COMET launch dates, the August 4, 1995, date was postponed to August 12th, when high winds over the Wallops Island site again delayed the launch until the following day. Then, just one minute and 38 seconds before launch, two of the CASTOR Thiokol engines malfunctioned [Leonard, August 28, 1995; "Winds," 1995; Schefter, 1984; "Design," 1984].

Although NASA announced a new launch date, October 20, 1995, the first Conestoga launch, with the COMET spacecraft onboard, did not take place until three days later, on October 23, 1995, because of additional delays. The faultless lift-off seemed to assure the success of the Conestoga rocket and the COMET spacecraft. However, just 46 seconds after launch, the Conestoga broke into pieces 23 kilometers off the Virginia coast at an altitude of 10 kilometers [Ferster, 1995].[19] That one launch failure marked the end of both COMET and the Conestoga. EER was out of the launch business, and abandoned selling space on future COMET missions.

We will never know how successful, technologically or financially, the COMET reentry module would have been. That is in the nature of failures. What is clear, though, is the exceedingly difficult and risky nature of using new technologies to serve the commercial market, whether those new technologies are reusable reentry vehicles, like the COMET spacecraft, or new launch systems, like the Conestoga. But the lessons of COMET and Conestoga reach beyond the commercial launch market to the policy world.

The failure of CSTAR to adequately manage the COMET program raises serious questions about the role of universities in the commercialization of space, or at least as managers of programs involving complex engineering processes. Engineering projects need a single individual, not an academic committee, to take responsibility for project progress and budget. Moreover, they cannot be financed through grants, in the way that NASA underwrote CSTAR's COMET program. Contracts, not grants, in which payments are made as specified performance goals are achieved, provide not only a check against waste, but also a carrot-and-stick framework within which a project can be brought to fruition, or halted if performance is unacceptably below contract standards. Indeed, the way one manages an engineering project becomes all the

[18] Action Document Summary, August 29, 1986, File 10,782, NHO.

[19] NASA, Press Release N95-64, October 12, 1995, File 10,783, NHO.

more critical when the project involves a new, untested technology or technological system. CSTAR's lack of reentry systems and general engineering experience were serious program hindrances.

The conduct of the COMET program also raises questions about the relations between government (specifically NASA) and industry. NASA played the vital role of creating and funding the program in order to foster the nation's nascent microgravity industry. Here would appear to be an argument in favor of government support and even guidance of industry. However, NASA did not carry the program to fruition, that is, turn COMET into a real commercial venture. That task ultimately fell to industry itself, in the form of EER. In the end, it would appear that NASA's (government's) crucial role was to supply the venture capital for the project. Industry did what it does best, that is, finding paying customers in the hope of turning a profit. Being handed lemons can be a powerful motivating force.

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