Risks in Satellite Launching

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SPACE ACTIVITIES involve two broad categories of industry. One is the use of space as a place to do business, and the other is that of providing transportation between Earth and space. Satellite launch vehicles serve as transports for satellites to be put into space. Invariably, launch vehicle technology has been the key for any country to be self-reliant in space industry. The important issues that affect faster long-term growth in the space industry are related again to the launch vehicle technology. Firstly, it is the minimal improvement in launch failure rates over the last decade. And secondly, it is the high launch cost. This article discusses the issues involved and projects the reusability as the solution in sight.

Launch Failures

A study led by the accounting firm, KPMG Peat Marwick, lists the frequent launch failures as the most important issue to be addressed under the space infrastructure sector. If we look at the launch failures in the U.S., the world-leader in the space industry, the situation is no better than that in a recent entrant-country to the group of space faring nations. Between August 1985 and March 1987, the U.S. faced series of five failures. Titan rockets of the U.S. Air Force suffered two consecutive failures, destroying a pair of multi-million dollar photo-reconnaissance satellites. The most terrible was the explosion of the NASA's Space Shuttle Challenger in 1986, that killed seven astronauts and destroyed a $2-billion spaceship. A Delta rocket carrying a $58-million national weather satellite failed. And, an Atlas rocket was struck by lightning in flight, destroying a $125-million Navy communications satellite. This worst spate of disasters during 1985 to '87 led to the temporary grounding of the entire fleet of the U.S. satellite launch vehicles for some time.

Even after about twelve years, this reliability issue in the U.S. appears to have not got improved. Between August 1998 and May 1999, there has been again a string of failures, perhaps the most awful in the history of U.S. satellite launch vehicle industry. The Titan 4A mission on August 12, 1998 failed when the vehicle costing $344 million exploded 40 seconds after liftoff from Cape Canaveral, Florida. A classified national security communications intelligence satellite ("eavesdropping satellite") worth about $800 million was destroyed in this mission. On August 26, Boeing's maiden launch of Delta 3 carrying a 3,876-kg Galaxy broadcasting satellite blew up 71 seconds after liftoff. The total cost of launch vehicle and satellite was $225 million. Lockheed Martin's Titan 4B on April 9, 1999 injected a $250-million missile warning satellite in a non-retrievable wrong orbit. On April 27, Lockheed Martin's Athena 2 could not place an Earth-imaging satellite in the required orbit and the satellite was lost. On April 30, U.S. Air Force Titan 4B costing $433 million placed an $800-million military communications satellite in a non-retrievable wrong orbit. On May 4, Boeing's $85-million Delta 3 rocket placed a 4.5 ton Orion-3 $145-million communications satellite in a useless lower-than-intended orbit. The total loss to the U.S. due to these six failures is estimated to be in excess of $3.5 billion (Rs. 15,050 crores)! A House Intelligence Subcommittee, under direction from President Clinton, has recently called the U.S. Air Force to explain the series of failures of the governmental launches. These failures demonstrate rather clearly the complexity of the task of making a launch vehicle work correctly.

General H. M. Estes, retired from the U.S. Air Force and the former head of the U.S. Space Command, said, "Getting good, reliable launches and also getting costs down are huge issues for the U.S. Government. We can't even get the first one right! We have to fix this launch problem — get the reliability up and the cost down — or the whole space business is going to slow way down. This is the critical national issue that's not really recognized." The U.S. Aerospace Corporation reviewed the worldwide satellite launch situation and found that there had been about 60 significant launch failures since 1990. Basically, the company rediscovered that "launch is a risky business." The company's Vice President John F. Willacker said, "Performance and safety margins are much less for the present day satellite launch vehicles than for aircraft."

Launch Cost

A typical passenger aircraft flying long distances costs about the same as a typical launch vehicle. It has a similar number of parts and is built to similar tolerances. The amount of propellant a launch vehicle burns to reach a low Earth-orbit (LEO) is about the same as an aircraft burns to go from North America to Australia. And, the cost of single airline-ticket for this travel is about $1,500. Looked at this way, it would seem that the cost of getting into orbit should be much less than $20 per kg. But the present American rate for a LEO is about three orders of magnitude higher, about $18,000 per kg.

Rates charged for satellite launches by different launch industries are always kept as trade secrets. However, the current rates of launch cost are estimated to be widely varying from $5,000 to 18,000 per kg for a LEO and $18,000 to 33,000 for a geo-synchronous transfer orbit (GTO) that is higher than a LEO — lower rates may pertain to Chinese, Russian, and European launches (in that order) while the highest ones are believed to be for the U.S. Recently, India, thanks to an earlier contractual obligation by Arianespace, is reported to have paid relatively a cheaper rate of about $26,700 per kg for its INSAT-2E launched into a GTO on April 5, 1999.

Missile Based Technology

All along, the launch vehicle technology has had the technologies of intermediate-range ballistic missile (IRBM) and inter-continental ballistic missile (ICBM) as its base. Every space faring nation has developed its launch vehicle technology from the IRBM and ICBM technologies. Traditionally, these missile technologies adopt low margins on performance and safety. The erstwhile USSR launched the world's first satellite Sputnik modifying its ICBM R-7. Also it modified its T-3 ICBMs for use as launch vehicles for Sputniks II and III and its T-3As to launch its "luniks." The Juno I, which launched the first American-satellite Explorer I on January 1, 1958, had as its booster the first stage of the already developed medium-range ballistic missile Redstone. The two developed American-IRBMs Jupiter and Thor were converted for use as launch vehicles, the former serving as the first stage of the Juno II, and the latter being the first stage of such combinations as Thor-Able, Thor-Agena, Thor-Delta, and Thor-Epsilon.

Noting the complexity of launch vehicle technology development, the Chinese, in 1959, abruptly stopped their Earth-satellite program "Project 581" and started their rocket program "Project 1059" to develop their rocket vehicles. Then came their Dong Feng series of IRBMs and ICBMs. The ICBM Dong Feng-5, flown successfully in 1971, matches the American Atlas and Soviet's R-7. The Dong Feng series paved the way for Long March satellite launch vehicles of China — Dong Feng-5 for Long March-1 and Dong Feng-5 for Long March-2. Continuing with this series, China now has the vehicle Long March-3 to launch a 4,800 kg payload to GTO.

Propulsion System

The propulsion system is the most expensive and critical part of any launch vehicle. This system operates under high pressures and extreme temperatures. It is always made to operate at its maximum power all the time resulting in very low margins on performance and safety. Imagine the condition of your car engine after you drive the car continuously for thirty minutes against a very steep gradient with the accelerator fully pressed!

Cryogenic propellant rocket motors, required to construct launch vehicles for large satellites, are the most complicated machines. In addition to the high pressures (70 to 100 times the atmospheric value in the combustion chamber) and extreme temperatures (3,000 to 3,300^{o}C in the combustion chamber and -200 to -256^{o}C in the propellant tanks), these motors have turbines rotating at a few tens of thousands of revolutions per minute. The turbines are run by expanding high pressure and high temperature combustion gases. The propellant pumps, run by the turbines, pressurize the cryogenic propellants to values much higher than the combustion pressures.

Reusable Launch Vehicle

All over the world efforts are in progress to bring down significantly the launch failure rate and the launch cost. The common route accepted by all to achieve both the objectives lies in the construction of reusable launch vehicles (RLVs). They are to be "designed to cost" with sufficient margins on performance and safety.

The underlying challenges are the development of extremely lightweight but high strength composites, liquid oxygen (LOX) and liquid hydrogen (LH2) compatible composites for propellant tanks, high temperature resistant materials, and construction of rocket engines of innovative designs, using LOX-kerosene, or LOX-LH2 propellant combinations. At the highly evolved stage the construction of rocket based combined cycle air-breathing engines that use air-LOX-LH2 is also involved.

These RLVs will be capable of returning safely to Earth after launching their satellites in the intended orbits. They will be reused for hundreds of such missions as it is done for airliner operations. The global goal is to reduce through reusability the launch cost by one order of magnitude in the first phase and then by another one order in the second phase. Two stage to orbit partially or fully RLV as well as single stage to orbit RLV are being developed. The plan on RLV propulsion system is to adopt suitable semi-cryogenic or cryogenic rocket propulsion for the first phase (first ten years) and then go for a rocket based combined cycle air-breathing engine for the second phase (next ten years). Although the various companies engaged in this effort project to achieve the first-phase developmental objective before 2003, a conservative regular operational date for this could be around 2010.

The efforts of "cheap access to space" through RLV technology are particularly more vigorous in the U.S., because the U.S. launch industry with its present highest launch-costs loses every year large number of commercial-satellite launches to non-American launchers. This has created a severe criticism from the U.S. public of their launch industries.

Given that U.S. manufactured satellites, and though to a lesser degree US launch services, are used throughout the world, the U.S. is still a major player in the space business. With their vigorous efforts to win the race for reducing the launch cost, as the first step, the U.S. launch industries expect to recover the launch business they lost to China, Russia, and Europe. As the next parallel step, more importantly, the total U.S. space industries hope to retain their preeminent prowess in the space business that is expected to give growths in multiples of GDP once the launch cost is significantly reduced.

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