By Merryl Azriel

The Pedestrian Cause of a Spectacular Crash

At 2:38 AM GMT on July 2nd 2013, a routine launch of three navigation satellites out of Baikonour Cosmodrome turned decidedly atypical when the rocket took a nosedive into the launch site seconds after takeoff.

The crash has been repeatedly described as "spectacular," and it's hard to stay away from the adjective. A television crew expecting to capture live footage of the launch instead found themselves rapidly adjusting their viewing angle as the rocket hewed left, right, and then over, shedding fairing and nose cone in its fiery, rocket-accelerated return to the ground.

The immediate aftermath entailed evacuation of the Cosmodrome, where the Proton's 600 tons of toxic fuel was feeding orange flames at the site of the crash. Announcements went out to residents of the three nearest towns to stay inside with windows closed and air conditioners off to prevent inhalation of highly hazardous fuel vapors. By a combination of adherence to safety procedures and sheer good luck, no one was injured in the initial crash or its aftermath and a combination of rain and the fire quickly dissipated the gaseous clouds of fuel.

Looking for a Culprit

In time-honored fashion, the next stages of the incident involved rampant speculation and the formation of an investigation commission. Given the epidemic of quality-related failures coming out of Russian space in the past three years, statements from government officials were characteristically harsh, promising criminal prosecution and polygraph tests for the engineers involved in Proton's manufacture. Initial speculation focused on the 0.4 second premature separation of the rocket from ground system cabling and an apparent 1,200°C temperature spike in one engine – indicative of a fire – at the time of liftoff. Neither of these factors have yet been accounted for and as of the time this article goes to press, the investigation commission is still looking into possible causes and ramifications.

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These factors were quickly overtaken as candidates for the primary cause of the failure by one finding: all three yaw angular velocity sensors in the rocket had been installed upside down. Aleksandr Lopatin, chair of the investigation committee, confirmed this root cause in a press conference on July 18. Lopatin reported that the faulty installation had taken place on November 16, 2011 before some of the most recent quality controls had been put in place. As is common throughout the Russian rocket assembly process, no photographic or video documentation was taken of the installation. Two supervisors signed off on the installation, apparently without checking too closely, since an arrow on each sensor that was supposed to point upward, instead pointed downward in the rotated installation position. However, Lopatin noted that there was some room for interpretation in the instruction manual and there was no corresponding arrow in the mounting plate with which to match the one on the sensor. There are pins on one end of the sensor intended to ensure correct installation, but experimenting investigators found that these could be forced into the wrong position with a little effort.

The commission plans to recommend photographic documentation throughout the rocket assembly process, a step that has recently been implemented for Breeze-M manufacture in response ▶▶

Confused by upside down sensors, a Proton-M launched on July 2 was airborne for only seconds before it crashed back to the ground. – Credits: Vesti.ru, Roscosmos to the multiple failures of that upper stage in recent years. Proton-Ms in storage have been inspected for a similar deficiency, but all appear to have their angular velocity sensors properly installed. There is currently no method other than visual check to determine whether these sensors have been correctly installed: color-coded cables work in either direction and angular velocity of a rocket at rest is zero, whether upside down or right side up.

It was initially thought that environmental cleanup of the toxic propellants would require shutting down the Cosmodrome for up to three months, but soil, water, and air sample testing seemed to allay fears of rampant contamination. Some personnel were back onsite within days, and although over 13,000m^2 were treated with a hydrogen peroxide and iron complexonate solution to neutralize the contaminants, officials reported that none of their samples tested above safe levels of nitrogen tetroxide or unsymmetrical dimethylhydrazine (UMDH). Within a couple weeks, all non-Proton launches were put back on schedule. The first post-crash launch took place on July 27 with the takeoff of the Progress M-20M cargo ship headed for the International Space Station. Proton is scheduled for a return to flight in September.

From Reliability to Uncertainty

The Proton rocket is one of the longest operating and most reliable heavy launch vehicles, rivalled only by the Soyuz family. The first Proton, developed from intercontinental ballistic missiles, was launched in 1965. It has seen several upgrades since that time that improved fuel consumption, reduced mass, increased payload capacity, and consolidated production under Khrunichev. The latest variant, Proton-M Enhanced, has been operational since 2007.

There have been several mission failures of Proton-lofted spacecraft in recent years, feeding into the general manufacturing quality crisis of the Russian Federation's space program. These failures, however, have generally been attributable to the booster attached to Proton-M, most commonly the Breeze-M. A September 2007 launch was an exception, when a pyrotechnic firing cable failed to disconnect the Proton's first stage before the second stage commenced firing. In that instance, the rocket crashed over 600km away from the Cosmodrome. One must look back to the early days of Proton's development to find an analogous first stage failure of this persistent launcher.

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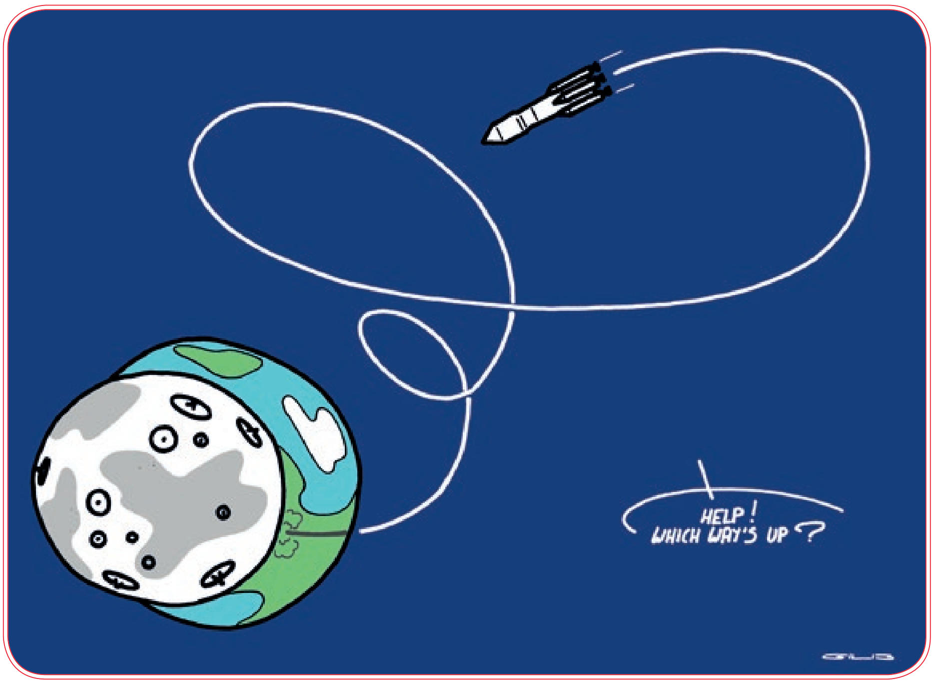
In 1969, in the Proton's 17th flight, a missing hydraulic lock plug allowed oxidizer to leak into a pump shaft. The result was ignition of the shaft and failure of one engine that brought down the entire craft 30 seconds after launch. By 1977, however, the Proton's reliability rating was considered to be 90%. To-date 388 flights have been undertaken by this launcher, of which 23 have failed. Of those failures, five occurred within the past three years.

The July 2nd flight did not use the near-ubiquitous Breeze-M, but a new upgrade to the Block DM. This was the second attempt to test out the Block DM-03, the first having exploded due to over-fueling in 2010.

While commercial operators scramble to find alternative launchers for their satellites, Russia itself may be feeling the impact of this crash for some months to come. If unable to loft their Express-AT1 and Express-AT2 satellites in the next few months, broadcasting during the Sochi-hosted winter Olympics could be compromised. Already, cable channels have gone dark throughout much of the country due to an orientation issue with the operational Express-MD1's antennae.

"This particular issue with Proton can be probably resolved quickly," RussianSpaceWeb's Anatoly Zak recently told Space Safety Magazine. "It is crazy that in the age of digital cameras and iPhones, they still do not have photographic and video documentation of all assembly procedures." Whether the lessons from this crash will be applied to the broader Russian space industry is a question only time can answer.

Gil's Corner



Navigational confusion. Credits: Gilles Labruyere
Gilles is Principal Mechanical Engineer of the Aeolus satellite at ESA, and previously of Envisat. He has been drawing space related cartoons since 1994.