From New Delhi by Susan B. Maitra

Hope for Indian rocketry program

Examination of the mission failure of the Polar Satellite Launch Vehicle shows how much went right, despite what went wrong.

On Sept. 20, India's long-awaited Polar Satellite Launch Vehicle (PSLV) took off from SHAR launching station only to falter at 650 km up and fail to complete its mission of putting an 850 kg satellite into low-Earth orbit at an altitude of 817 km.

Indian rocket scientists at the Indian Space Research Organization (ISRO) have identified the success of the 275-ton, 152-story PSLV with India's coming of age in rocketry. It was the first Indian launch vehicle to use liquid propulsion and has the potential to become a commercial launch vehicle.

Although the failure of the PSLV to deliver the satellite at the right altitude can be considered a setback, the PSLV technology is a qualitative improvement upon the previous series of Indian rockets, the SLV and the ASLV. PSLV is a four-stage rocket that uses liquid propellant, more efficient and more complex than solid propellants, for the second and fourth stages. The first and third stages use solid propellants. The next generation of rockets, the Geostationary Satellite Launch Vehicles (GSLV), will be using a cryogenic engine, and a liquid second stage with four liquid engine boosters. The first stage in the next generation of rockets will retain the solid propellants.

Besides the liquid engine, which is the Indian version of the French Viking engine that came about through a unique technology transfer almost a decade before the PSLV project was even approved, the first-stage solid propellant motor, the third largest in the world, functioned meticulously. The first stage and the two strap-ons ignited, lighting up the sky with brilliant yellow flame. The burnout and separation of the first stage occurred as scheduled, 111 seconds after launch.

The second stage also ignited as per expectation, followed by the heat shield separation. But at the second stage burn-out, the PSLV was at an altitude of 235 km, which was 10 km higher than it should have been.

The third stage also ignited perfectly, but at this stage some deviation in trajectory was noticed by the control center. Subsequent close review of the data indicates that there was a buildup of error in the vehicle's yaw angle during the second stage itself. The instantaneous position of a rocket is determined by three angles: the roll (the rotation about the axis along the length of the rocket); the yaw (side-to-side movement of the rocket with respect to its flight direction); and the pitch (up and down movement of the nose of the vehicle).

The first news of the mission failure that came out was based on statements made to newsmen present at the launch site. ISRO chief Dr. U.R. Rao said that the disturbances cropped up at the beginning of the third stage and went into the final stage. He pointed out that the errors built up in certain angles. "The errors of the pitch-down were such that the vehicle did not gain height and velocity. We have a control program, but it is something more than that," Rao was quoted as saying. He also made it clear at the time, that the case will be studied to figure out what exactly happened.

Later media reports, however, indicate that the failure was not a design mistake, but more likely the presence of a software bug in the vehicle's second-stage control system. The more detailed look to find the exact cause of the failure has revealed that, indeed, the rocket had begun to veer from the second stage. This means that the shot-gun analysis by the Indian press—which no doubt found its way into the international media—that the indigenously developed "flex nozzle system" of the third-stage motor had malfunctioned, was way off the mark. In fact, the system had functioned perfectly and had nothing to do with the overall behavior of the launch vehicle.

Real-time data on performance parameters indicate that all the solid and liquid motors functioned as per design and generated the requisite amount of thrust in their respective stages, stated *Economic Times* science and technology columnist R. Ramachandran. It also showed that despite efforts through the on-board control and guidance system of the PS-2, the second-stage engine, the rocket was put back on course, but not maximally. It appears that the software of the control system had failed to give the command for maximal control, even though the PS-2 hardware was fully capable of generating the requisite control forces.

At the same time, in the second stage, the thrust of the engine was controlled by gimballing the engine nozzle through an autopilot. While the maximum gimballing could be as great as 4 degrees from the vertical, the autopilot had been given a command for 1.5 degrees of gimballing. Scientists concur that if the autopilot had commanded the full gimballing, the rocket would have gotten back on course.