GSLV-D1 ROCKET LAUNCH ABORT ON THE PAD – AN EXPERIENCE

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ABSTRACT

GSLV-D1 rocket is the first Geo-stationary launch vehicle of ISRO weighing around 400 tonnes capable of launching about 2 tonnes of payload into Geo Transfer Orbit (GTO). The launch vehicle is configured with a solid propellant first stage, earth storable propellant second stage, cryogenic propellant third stage and four numbers of earth storable propellant strapped on boosters. As per launch chronology, the four liquid propellant strapped on boosters will ignite at T-4.8 seconds. Once all the liquid propellant boosters attain the required level of thrust, the core solid rocket will be ignited at the count down of zero. In the case of GSLV D1 launch, at one second before the core rocket ignition, the launch checkout computer sensed that one of the liquid strapped on boosters did not develop the required level of thrust and aborted the launch. The rocket anomaly was investigated and the rocket was launched successfully into GTO in about 3 week’s time.

This paper describes the safety actions taken on the pad, which includes the fire fighting operations and actions taken before dismantling the liquid propellant booster stage for refurbishment. This paper also highlights the improvements made in the launch vehicle and on the pad, like changing the launch vehicle propellant tank insulating materials and use of fire retardant paints.

1. INTRODUCTION

ISRO launched a two tonne class satellite into GTO by the indigenously developed first Geo Stationary Launch Vehicle (GSLV) on 18th of April 2001 from Satish Dhawan Space Centre SHAR. Prior to this event, using the same launch vehicle, the launch was attempted on 28th of March 2001. Due to a snag in one of the liquid strapped on boosters, the launch was aborted one second prior to the lift off.

GSLV Configuration: (4L40+S139) + (L37.5) + (C12)

GSLV is a three-stage vehicle with over all length of 49m and lift off mass of about 415 tonnes.

The first stage comprises of a solid propellant motor (S139) and four liquid propellant strapped on boosters (L40). S139 stage is 20m long and 2.8 m in diameter and it carries 139 tonnes of Hydroxyl Terminated Poly Butadiene (HTPB) based solid propellant. The stage develops about 4736 kN thrust and burns for 149 seconds.

The second stage is 11.6 m long and 2.8 m diameter. It is filled with 39.3 tonnes of hypergolic propellants (UH25 and N2O4). It produces a thrust of 804 kN and burns for a period of about 135 seconds.

The third stage of GSLV is a Cryogenic propellant Stage (CS). The stage is 11.6 m long and 2.8 m diameter. It is filled with 39.3 tonnes of hypergolic propellants (UH25 and N2O4). It produces a thrust of 804 kN and burns for a period of about 135 seconds.

The Payload Fairing (Heat Shield), which is 7.8 m long and 3.4 m in diameter, protects the vehicle electronics and the spacecraft during its ascent through the atmosphere. It is jettisoned once the vehicle has reached an altitude of...
about 115 km. The spacecraft, which is mounted over the equipment bay through a payload adapter, is separated by a Merman clamp-band joint and spring mechanism that provides the required separation velocity.

Inter-stage structures, which connect different stages of GSLV, house the avionics and control systems. The vehicle equipment bay housing electronic systems like processors, navigation system, control system, guidance system, telemetry system, telecommand system, etc, are mounted above the cryogenic stage.

2. NECESSITY OF LAUNCH ABORT SYSTEM

All the four liquid strapped on boosters are given the ignition command at 4.8 seconds before the nominal lift off time. After confirming that they have developed 95% of the thrust within the stipulated time, the ignition command will be given to the core solid motor. This is to ensure all four liquid engine boosters are functioning normally and develop equal thrust before igniting solid motor. Launch Hold Release System (LHRS) is incorporated between launch pedestal and vehicle. This system holds the launch vehicle during strapped on boosters thrusting phase. After confirming the strapped on boosters have developed 95% of rated thrust, the system actuates the hydraulic mechanism to release the vehicle before the ignition of core solid motor. Total sequence of operations is controlled by launch computers through Automated Launch Sequence (ALS) software, thus avoiding any catastrophe at launch pad.

3. CONDITIONS FOR INITIATION OF ABORT SYSTEM

3.1 Normal sequence of operations

Automated launch sequence (ALS) software manages and controls all the activities (reversible or irreversible) of the launch vehicle from 12 minutes (T-12 min) before lift off. It commands at T- 4.8 seconds all L40 strapped on boosters to ignite. ALS checks the critical parameters continuously. Once all L-40 chamber pressures are confirmed to be within the specified limit at T-1.3 second, the command for LHRS is issued at T- 1 second. It further commands at T - 0.5 second to actuate wire rope locking mechanism of cryogenic stage umbilical connectors and get the status of LHRS before giving the next command. This releases the launch vehicle from launch pedestal. At T - 0 second, ALS issues command to ignite first stage solid rocket motor.

3.2 Conditions for aborting the launch

Condition One
At T-4.8 seconds
- ALS commands ignition of all L-40 and confirms chamber pressure

T-1.3 to T- 1.0 second
- ALS compares chamber pressures of L-40s and
- Checks 95% of thrust value

If found less than 95% of thrust value in any one of the L-40 boosters, ALS aborts all L-40 engines at the same time

Condition two
T-1.0 second
- ALS actuates Launch Hold and Release System (LHRS) and monitors its execution for release
- If not released by T - 0.3 seconds, ALS aborts all L-40 engines at the same time

Condition three
T-0.3 seconds
- ALS commands valve for wire rope locking of cryogenic stage umbilical unit at T-0.5 sec
- LHRS confirms release status
- If not released, ALS aborts all L-40 engines at the same time

4. IMPACT OF LAUNCH ABORT ON ROCKET STAGES

In case of launch abort after ignition of the strapped on liquid booster rockets, following are the consequences.

First stage is a solid propellant rocket motor. Exhaust coming out from all four liquid boosters impinges on jet deflectors. There is a possibility that heat radiation may be transmitted through solid motor nozzle and may cause auto ignition of solid core stage. Similarly liquid boosters are provided with external thermal insulation pads for maintaining the temperature of liquid propellant. Hence there is a possibility that these insulations may get ignited due to radiation from the strapped on boosters exhaust gases.
Second stage is a liquid propellant rocket motor. In order to keep liquid propellant at 18-21°C inside stage tanks, they are covered with thermal insulating material (Poly Urethane pads). Due to launch abort, there is possibility of these insulating material catching fire.

Third stage carries 12 ton of liquid oxygen and liquid hydrogen in its stage tank. Hydrogen being a highly flammable gas, protecting the stage from naked flame and heat radiations poses a challenge.

5. BUILT-IN WATER BASED FIRE SUPPRESSION SYSTEM

Three numbers of pumps of capacity 270 m$^3$/hr each and 100m discharge head delivers water at a steady pressure of 10 bars to the following fire fighting system.

5.1 Water Monitors around Umbilical Tower

Four numbers of remotely controlled water monitors discharge water from each head from a distance of 15 m to the rocket. These water monitors can be maneuvered in azimuth as well as in elevation to throw water precisely at fire spot up to second stage of vehicle.

5.2 Water spray nozzle at UT

In addition to the above, water can be sprayed on rocket from fixed water spray nozzle located at 42m and 29m elevation. This system is for fire suppression at upper stages of launch vehicles.

5.3 Criteria for initiating fire suppression system

Criteria for initiating fire suppression system by the safety officer are well defined in terms of hierarchy of command. After getting authorization from the Chief of Range operations, safety officer activates the fire suppression systems.

6. LESSON LEARNT FROM ABORT

6.1 What has actually happened?

After the ignition of four L40s, ALS noticed in one of the strapped on booster, the chamber pressure has not developed to the specified level. ALS at pre specified time (one second prior to the ignition of core solid booster) commanded to shut off all four L40 liquid booster rockets and withdrawn all commands which would have been issued to release rocket from LHRS and ignition of first stage, thus aborting / scrubbing the launch.

6.2 Scenario

At T- 4.8 second, ALS commanded all liquid propellant engines to start for ignition. The following events took place.

- Combustion process started for all L-40s
- One of the L-40 failed to attain full combustion
- Shutoff command issued and automatic system safety actions took place.
  - Engine purging with nitrogen
  - Purging pushed the left-out fuel and oxidiser from engine into atmosphere thus making rocket safe from explosion
- Un burnt fuel outside atmosphere burnt and ignited the insulation pads of one L-40 due to wind draft – (Un anticipated event)

Actions taken

- Safety Officer monitored closely the events with closed circuit television
- Water monitors were initiated remotely from the Launch Control Centre located at about 5km from the launch complex
- Large quantity of water was sprayed on rocket from Umbilical tower
- Fire was brought under control thus saving the Launch Vehicle and the launch pad

7. REFURBISHMENT FOR NEXT LAUNCH

After shut off command and quenching of fire on thermal protection PUF pads, following safety actions were initiated:

- De-pressurisation of propellant tanks to just above atmospheric pressure.
- De-pressurisation of gas bottles to 5 bars.
- Draining of the cryogenic propellants from the third stage
- Draining of liquid propellants (200t) from all L40s and second stage.
- Thorough purging of L40s with nitrogen (nearly 40 cycles of pressurization to 5 bar and depressurization) and brought the stage to safe condition.
- After monitoring the safe values of tank pollution level, the L40 was de-stacked from rocket.
- Transportation of stage to Vehicle Integration Building for investigation and corrective actions.
After assessing the root cause of the problem, the engine was replaced with a new one.
Assembly of engine, testing and certification for flight worthiness.
Transported back to launch pad for assembly with GSLV.
Launched successfully without any flaw in 21 days.

8. IMPROVEMENTS MADE

Fire was noticed over one of the liquid boosters. Fire and large quantity of smoke was seen over the pad. Though multiple closed circuit TV views were available for the safety officer, there was some difficulty in identifying the booster, which was on fire due to symmetry. This was required mainly to point the remote water monitors to the correct location. Hence proper identification of the views relating to the camera location was made and colour coding was introduced for the boosters, so that from the CCTV views, it is possible to identify the booster.

The thermal insulation poly-urethane foam (PUF) pads were coated with fire resistant paint, so that the chance of catching fire is minimized.

The launch emergency scenarios were thought of and the actions to be taken by all concerned were discussed and documented. The fire fighting operations involve throwing of large quantity of water on the launch vehicle. Apprehensions were expressed on the salvaging of the launch vehicle. The hierarchy of commands for the safety actions following launch abort was reviewed and the safety officer was given full authority to take appropriate actions based on the real time scenario.

9. GREAT LESSON

The launch vehicle was on fire and large quantity of water was dumped on the launch vehicle, which created tense and anxious moments. The hope, confidence and the dedication of different teams made the aborted launch vehicle to fly as a successful mission in 21 days.
Fig. 5 Water sprayers were operated from Umbilical tower and from the ground

Fig. 6 GSLV ready for takeoff

Fig. 7 GSLV takes off