SPACE PROPULSION SYMPOSIUM (C4)
Propulsion System (1) (1)

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CHALLENGES IN RESTART OF PRESSURE FED LIQUID UPPER STAGE

Abstract

The advantage of liquid rocket engine is its multi start capability for optimising the required injection velocity of the payload. Restarting of liquid stages in space flight enables injecting satellites in different orbits / inclination, payload improvement for mission specific elliptical orbit with greater argument of perigee. Restarting will also help in deorbiting of spent stages and consuming the left out propellants in stages. This will help in reducing the risks of stage explosions and minimizing space debris. Liquid rocket thrusters have undergone restarts earlier in spacecrafts for orbit raising and 3 axis control as well as station keeping. For the first time in Indian launch vehicle program, restart of upper stage pressure fed engines was experimented in one of the recent flights.

The restart of engine calls for challenges viz firing the engine in heated condition, purging the engine after hot burn and fixing the idle time between hot starts etc. Mission planning and controllability of the stage were addressed in order to have a smooth restart operation in space. This includes collision free restart, adequate battery power and tracking visibility of the stage. Technical solutions were adopted in propellant management for different fill fractions to settle them at the outlet of the tanks for smooth restart. Ensuring gas free propellants at the outlet of the tank in zero gravity, adequate gas availability for commanding valves and regulators benign thermal condition for the free flow of the propellants are some of the complex propulsion aspects considered in restart mission.

Before attempting the restart in flight, ground hot test in simulated vacuum was successfully carried out with 2 restarts to demonstrate the restart capability of the upper stage engine. As part of sequence finalisation for ground tests, engine skin temperature measured in earlier missions were used. The temperature at the time of restart was predicted using mathematical models. Performance of engines during restart in flight was normal and both the engines showed identical behaviour during transients and steady state. The demonstration trials carried out in flight has given sufficient confidence in taking up future restart mission requirements. The details of the restart during flight on upper stage engines and the challenges in stage propulsion system for restart and how it was overcome are elaborated in this paper.