Paper ID: 4476
student

SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Upper Stages, Space Transfer, Entry and Landing Systems (3)

Author: Mr. Piotr Perczynski
MT Aerospace AG, Germany

Mr. Barry Zandbergen
Delft University of Technology (TU Delft), The Netherlands
Mr. Juergen Starke
EADS Space, Germany

THERMAL PROTECTION SYSTEM FOR LONG-TERM IN-ORBIT CRYOGENIC PROPELLANT STORAGE

Abstract

Long-term storage of cryogenic propellants in space has been investigated for the Earth Departure Stage (EDS) proposed by EADS Astrium as a part of exploration space transportation architecture study initiated by the European Space Agency (ESA). In a typical mission, a 23-ton EDS including 16.7 tonnes of propellant is expected to remain in Low Earth Orbit for up to 30 days. It then performs an orbit injection burn with a Δv of 1900 m/s and a 24.5-ton payload. The past flights have shown that during orbital coasting, a typical cryogenic upper stage experiences propellant boil-off of 2% of the original propellant mass per day. For the EDS mission, such high boil-off would be prohibitive. According to system studies, the EDS average daily boil-off should be limited to 0.17% of original propellant mass.

The goal of research, as requested by EADS Astrium, was to investigate performance limits of passive thermal protection system (TPS) in reducing the EDS propellant boil-off. A coupled thermal model based on ThermXL software has been developed to solve steady state and transient cases. Additional models have been developed for structural sizing, and for heat transfer in liquid-hydrogen (LH2) and liquid-oxygen (LOX). The assembled models were used to analyze different passive TPS options. The TPS considered included different insulations, but also different structural interfaces, and tank designs. A 23-ton EDS and a 30-day mission have been used as a baseline for the research. For each TPS concept the propellant boil-off mass, and TPS dry mass were calculated. Based on mission performance required, a design space for boil-off and TPS masses was established. The concept performance was quantified by estimating an increase in payload mass for EDS orbit injection burn. Our analysis also addressed 50-ton and 24-ton variants of EDS, which were introduced by ESA in January 2009.

The analysis showed that improved passive TPS design, can reduce the average daily boil-off to 0.015%. A further trade-off between TPS and boil-off masses has increased the EDS mission payload by 2 tonnes. The investigation of different EDS variants has shown that the relative boil-off can be further reduced by increasing vehicle diameter and total propellant load.