COMS BIPROPELLANT PROPULSION SYSTEM (COMS 특별세션)

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Korea Aerospace Research Institute (KARI) has jointly developed a bipropellant propulsion system for Communication, Ocean and Meteorological Satellite (COMS) with EADS Astrium in UK. The technology relevant to a bipropellant propulsion system is quite new one in Korea, which is transferred for the first time, with development of COMS propulsion system. It hasn't ever attempted before, and hasn't got any general idea itself as well, in Korea. The COMS Chemical Propulsion System (CPS) is designed to perform both the orbital injection function, to take the spacecraft from transfer orbit to Geostationary Earth Orbit (GEO), and all on-station propulsive functions throughout the lifetime of the satellite. All station keeping manoeuvres are performed using the CPS. The design, manufacture and testing of COMS CPS are addressed in this paper. Feasibility of COMS CPS applicable to the other advanced mission is investigated as well.

KEY WORDS: Chemical Propulsion System, Bipropellant, Geostationary Earth Orbit, Transfer Orbit

1. INTRODUCTION

The COMS (Communication, Ocean and Meteorological Satellite) illustrated in Fig. 1, is a geostationary satellite for multiple missions such as meteorological monitoring, ocean monitoring, and telecommunication. KARI has undertaken the task of implementing the COMS under the financial support from four Ministries in Korean government: MOST (Ministry Of Science and Technology), KMA (Korea Meteorological Administration), MOMAF (Ministry Of Maritime Affairs and Fisheries), and MIC (Ministry of Information and Communication).

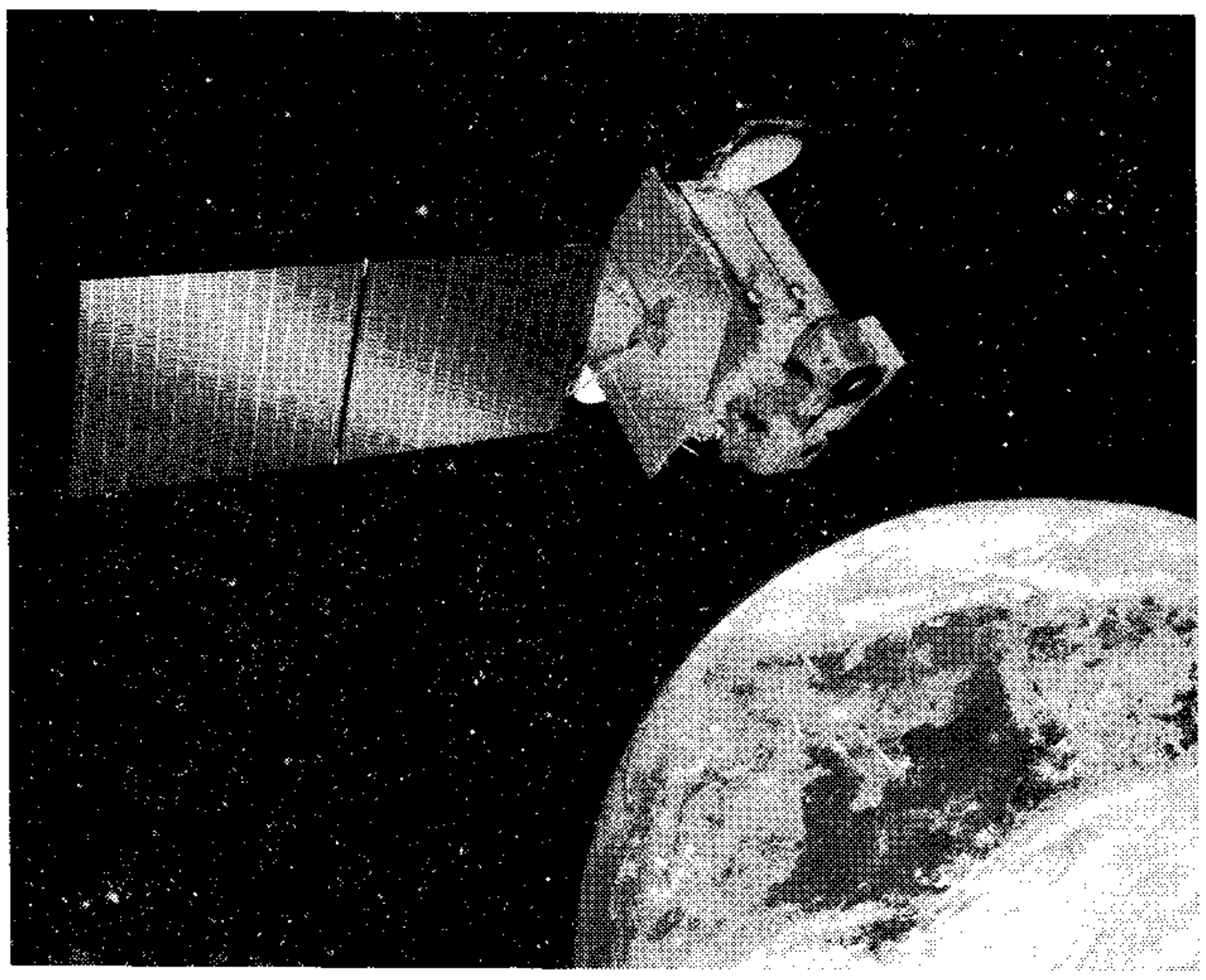

Figure 1 COMS in flight

KARI is developing the COMS satellite in cooperative efforts with a French company as a main contractor. This company is also developing the ocean payload, which is named as GOCI (Geostationary Ocean Color Imager). The Meteorological Imager (MI) is being developed by an American company, and the communication payload and ground station is being developed in Korea.

The meteorological data obtained by the COMS will be distributed within the global coverage area for public use, and it will contribute to the weather forecast accuracy improvement in this area. The ocean monitoring mission of the COMS has a special meaning, since it is the first ocean monitoring mission in geostationary orbit in the world.

In terms of a propulsion system, COMS incorporates a chemical propulsion system which utilises bipropellant; the combination comprises MMH as a fuel and MON-3 as an oxidiser. In the framework of COMS implementation, COMS CPS has been separately developed in collaboration with UK company. The technology relevant to a bipropellant propulsion system is quite new one in Korea, which is transferred for the first time, with development of COMS propulsion system. It hasn't ever attempted before, and hasn't got any general idea itself as well, in Korea.

In this paper, therefore, the design, manufacture and testing of COMS CPS will be addressed. Feasibility of COMS CPS applicable to the other advanced mission shall be investigated as well.

2. COMS CHEMICAL PROPULSION SYSTEM

2.1 Propulsion System Overview

The Chemical Propulsion System for COMS is derived from and identical in operation to the generic Eurostar E3000 CPS as used on Eutelsat W3A. The CPS layout on the platform has the two propellant tanks embedded into the core structure with the pressurant tank located within the equipment cavity. This concept is already familiar with flight proven heritage.

The Chemical Propulsion System is designed to perform both the orbital injection function, to take the satellite from transfer orbit into geostationary earth orbit, and also the ability to perform all on-station propulsive functions throughout the lifetime of the satellite. Combining these two separate capabilities into the one propulsion system, results in a high performance CPS with maximum flexibility for the various types of mission.

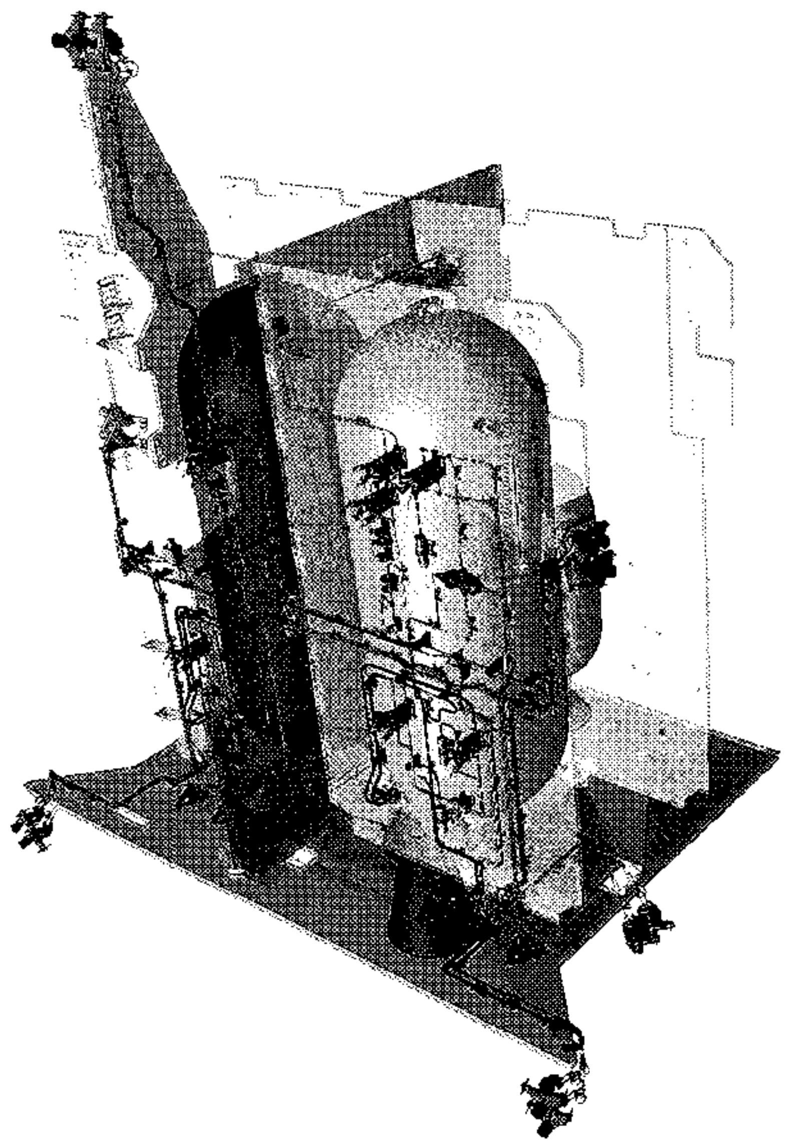

Figure 2 COMS CPS layout

2.2 CPS Description

The chemical propulsion system (schematic shown in Figure 3) is a helium pressurised bipropellant system using MMH and MON-3. A common propellant storage and feed system supplies the liquid apogee engine (LAE) and the reaction control thrusters (RCT's).

The system is designed to operate in a constant pressure mode during the LAE firings using a regulated helium supply. Following completion of the orbital injection manoeuvres, the regulated helium supply and the LAE are isolated. The remaining propellant is supplied to the reaction control thrusters in blow down mode. This is to maximise reliability by providing a major system simplification.

The helium pressurant storage system consists of a single cylindrico-spherical pressurant tank and lines to the normally closed pyrotechnic valves (PV02 and PV03). The manifold also incorporates a pressure transducer (PT3) and a fill and vent valve (FVV01). PV02 and PV03 isolate this supply from the regulator avoiding any possibility of premature pressurisation during the launch phase. Further normally closed pyrotechnic valves (PV04, PV05, PV06, PV07) and non-return valves (NRV1 to NRV4) separate the propellant tanks during the launch preventing any possibility of mixing of propellant vapours.

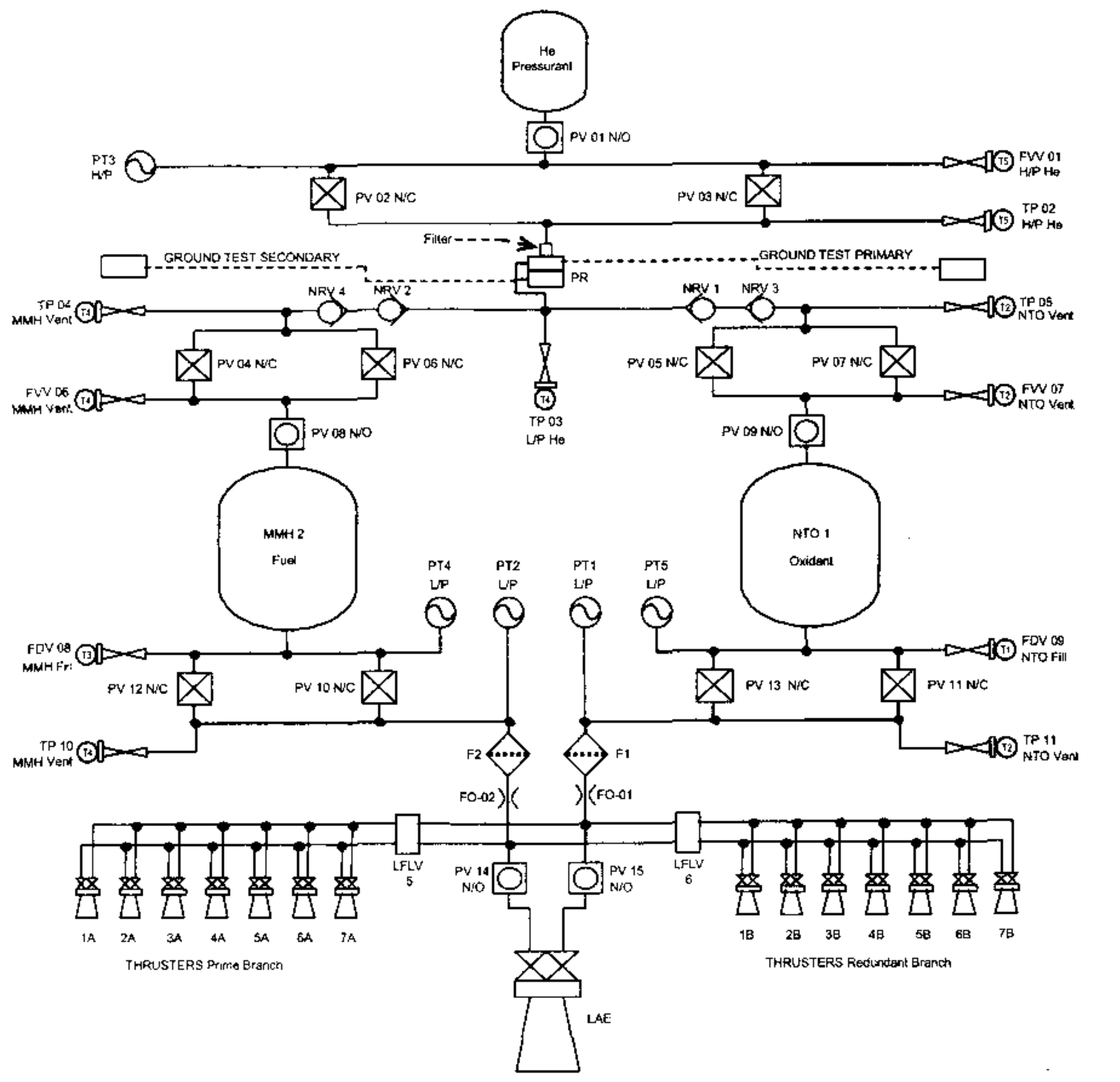

Figure 3 COMS CPS schematic

Downstream of each propellant feed line is a set of pyrotechnic valves (PV08, PV09, PV10 to PV13). These are normally closed pyrovalves, and are actuated during priming of the propellant feed lines during LEOP. They also enable the S/C level testing of all components within the liquid feed line section to be performed safely without necessitating the propellant tanks to be pressurised. They are also required in order to enable the proof testing of RCT's which are integrated during satellite AIT as the case may arise.

Each branch of thrusters is controlled by a low flow latch valve (LFLV5 & LFLV6). These units, which can be opened or closed, are capable of reverse polarity operation providing redundant capability and also have redundant driver circuitry. They provide a means of controlling propellant input to the RCT flow control valve. Both sets of valves (LFLV's and PV's) also provide safety inhibits between the propellant tanks and the thrusters during launch. The LFLV's have a back relieving capability allowing any build up of downstream pressure to be released into the upstream line. This situation is possible in cases when the temperature of the liquid in the downstream lines increases as a consequence of satellite thermal control.

Four low pressure transducers (PT1, PT2, PT4 and PT5) monitor the pressure of the both propellants within the feed line system. Propellant filters are included in both the fuel and the oxidant lines, downstream of the last test port providing the required filtration.

In order to load the propellants, vent propellant vapour and pressurise the ullage, one fill valve and one vent valve per propellant tank is required. These valves are located such that they are accessible whilst the satellite is on the launch pad so that the propellant and pressurant tanks could be off-loaded in the event of an emergency during launch operations.

A further seven test ports are required to access other lines for cleaning, priming and venting operations in cases where the lines are isolated from the remainder of the system manifold because of pyrotechnic valves, non-return valves, etc. They also enable the flight function of the pressure regulator and non-return valves to be checked during ground tests.

3. CPS DESIGN, MANUFACTURE AND TESTING

CPS design has been accomplished to meet the specified requirements, and to outline the design and qualification status of the equipment used within the CPS design. A summary of COMS CPS performance analyses is being described hereafter.

The finalised COMS CPS design has been analysed to confirm its suitability for flight. The layout of the system and the performance of each component were converted into a mathematical model which could then be analysed to make performance predictions using system level inputs. Actual flow performance data from delivered components were used, and propellant pipes were modelled from CATIA model data. The analysis was performed using only validated software which was developed and has been validated against flight hardware.

The analyses as to CPS performance are as follows:

- Prediction of pressurant tank size and load
- Propellant tank capacity
- Prediction of orifice sizes
- Determine propellant loading conditions
- Simulate propellant flow through system and LAE performance
- Simulation of system performance from Launch to EOL with residuals

Prior to performing the performance analyses for the propulsion system, the ability of the CPS to contain the necessary propellant and pressurant in accordance with the mission requirements must be determined. Hence pressurant and propellant loading analyses were performed first. Through this analysis, the COMS helium tank is demonstrated as capable of containing the necessary pressurant mass for all mission cases.

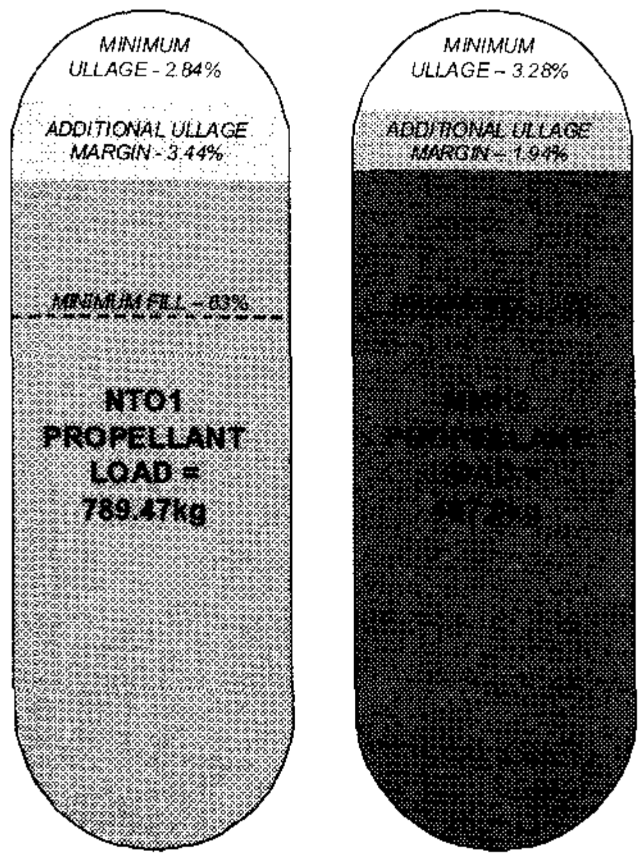

Figure 4 Predicted propellant tank capacity

Next the appropriate analysis was done to confirm that the tanks are capable of containing the propellant mass necessary for the mission. The maximum tank capacity is limited by the predicted temperature changes between loading and initialisation in orbit. For an Ariane launch, the results show that the tank capacity is limited by the temperature constraints as the minimum ullage is greater than 2%. It has been verified by this analysis that the tanks are capable of containing the propellant load necessary for COMS.

In addition, additional margin is demonstrated over the propellant requirement. The analysis deems the COMS CPS to be capable of meeting the propellant loading requirements of the mission referring to Fig. 4. The optimum loading pressures of the tanks are calculated to be 7.0 bar of MMH and 7.5 bar of NTO when the loading temperature is 275K.

The specialised analysis program is used to predict the performance of the CPS throughout the transfer phase of the mission. Two missions have been analysed to give "best" and "worst" case predictions. A mathematical model was made of the system using software. The mathematical model was analysed to provide predictions of operational performance, using inputs from:

- Mission inputs
- Thermal analysis predictions
- Calculated and measured propellant flow rate coefficients
- LAE performance coefficients from hot fire data

During the each AEF, the CPS functions as a regulated pressure fed system. The mechanical pressure regulator is responsible for converting the stored high pressure gas into a regulated feed pressure to the tanks of between 17 and 18 bar. For the selected LAE, the performance is predicted to be within the requirements for the mission as depicted in Fig. 5. A good performance is predicted for the LAE which reflects the higher than average performance obtained from the LAE hot fire test. It can be concluded that the COMS CPS is capable of fulfilling the transfer phase of the mission.

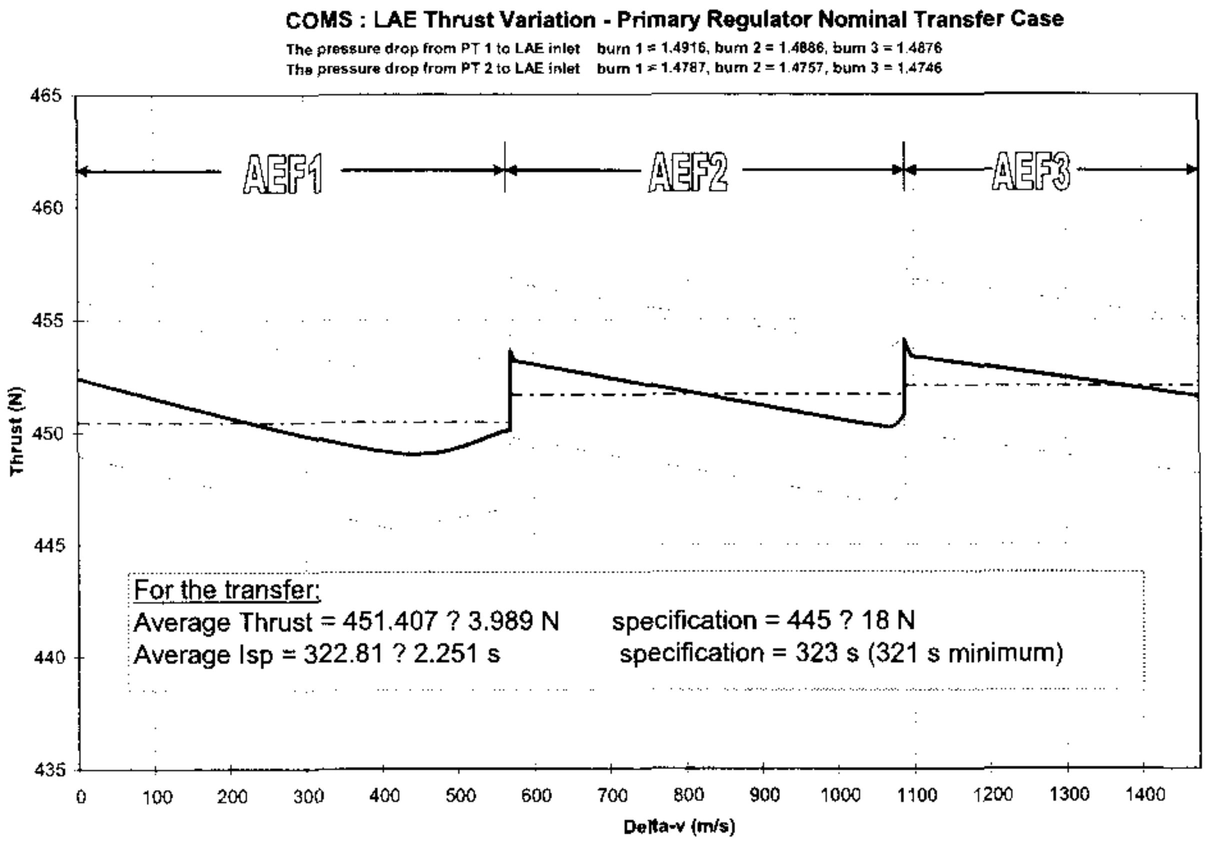

Figure 5 LAE thrust variation in the course of transfer orbit

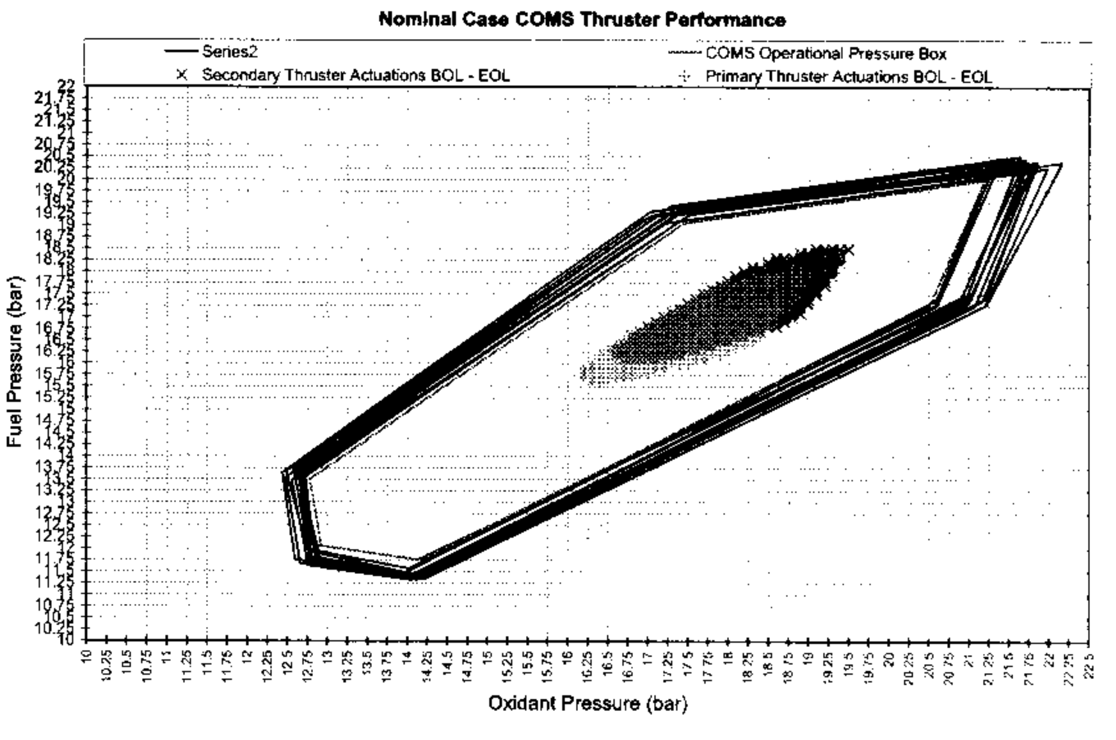

Figure 6 On-station performance anticipated

On-station performance analysis was conducted to make a prediction of the propellant consumption throughout the on-station duration of the COMS mission. 10,000 times simulated missions were analysed using a Mote-Carlo technique. The key inputs which determine the performance of the CPS throughout the on-station phase of the mission are:

- Results of Transfer Orbit predictions for remaining propellant
- Thermal analysis predictions for orbital and seasonal temperature variations
- Calendar of predicted manoeuvres to graveyard
- Input coefficients obtained from the thruster hot fire tests

The thruster input coefficients will vary between thrusters. Each thruster has been assigned a location upon the COMS structure based upon its performance characteristics, and this is also factored into the simulation also.

The results of the On-station analysis show that for the inputs and margins considered, the accumulated thruster firings shall stay within the operation box defined, throughout the duration of the on-station mission as presented in Fig. 6. The mission can be completed using the primary or secondary regulator, for the Nominal or Backup Strategy. The minimum mission duration of 7.7 years is confirmed.

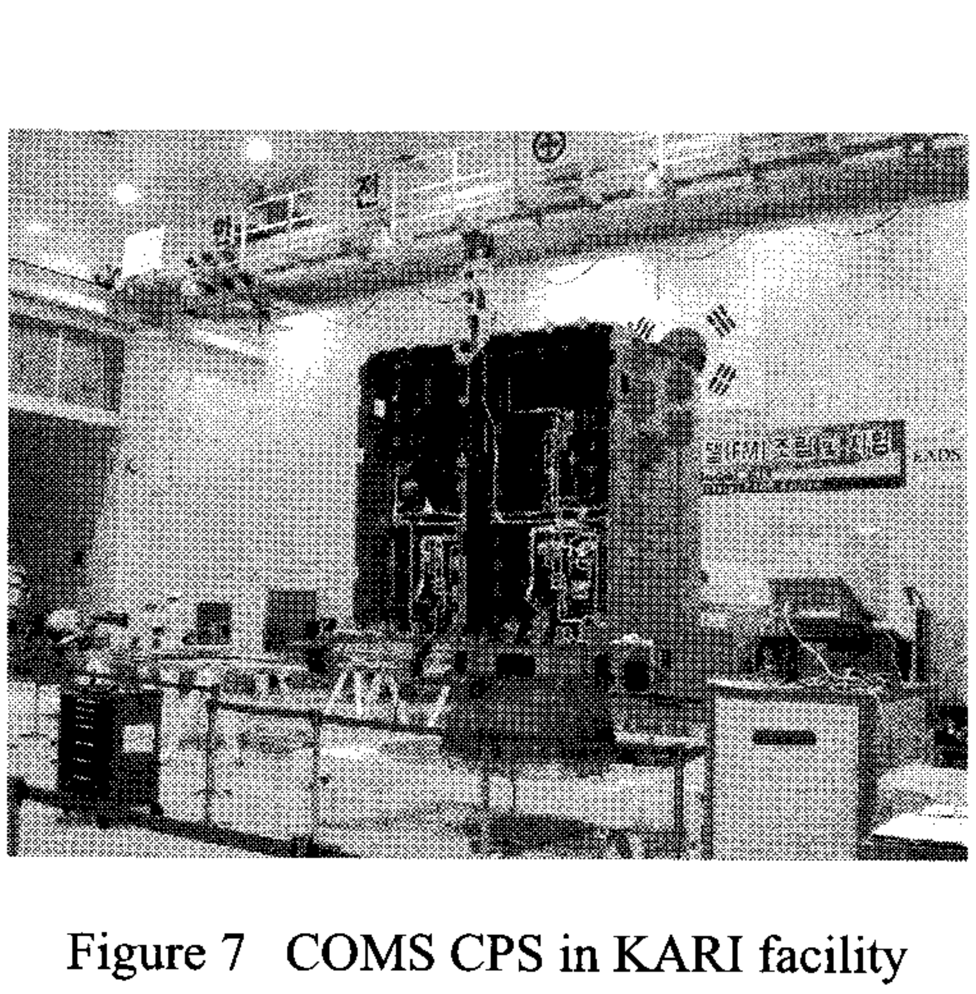

Figure 7 COMS CPS in KARI facility

The results of the analyses conducted, allow us to conclude that the CPS is capable of fulfilling the mission requirements. The results show that the COMS has a performance which is very similar to what we would expect of an equivalent Eurostar 3000 mission.

Manufacture and testing of the CPS were successfully accomplished. The FM (flight model) CPS assembly, as shown in Fig. 7, has been delivered to KARI at the end of August this year.

4. CONCLUSIONS

The Analyses performed to show that the CPS is fully capable of fulfilling the needs of the COMS mission. The Transfer orbit performance analysis shows that the CPS is capable of fulfilling the LEOP requirement. The on-station analysis has shown that the CPS is capable of fulfilling the mission requirement. The propellant /pressurant loading and tank capacities analysis shows that the CPS is capable of storing the propellant and pressurant required for COMS. All CPS components are suitably sized to cope with the propellant throughput required. As a result, the CPS has been verified for COMS. Manufacture and testing of the CPS were successfully accomplished, and COMS CPS assembly was transported to KARI to perform S/C level integration in Korea.

The bipropellant propulsion is a popular means to make spacecraft fly toward deep space. Therefore the development of COMS CPS must be the cornerstone of a propulsion system in Korea, for a future spacecraft being assigned more advanced mission.

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