CRYOGENIC TRANSFER MODULE: ISRAELI GTO UPPER STAGE PROJECT FROM THE LATE 1980'S

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Abstract

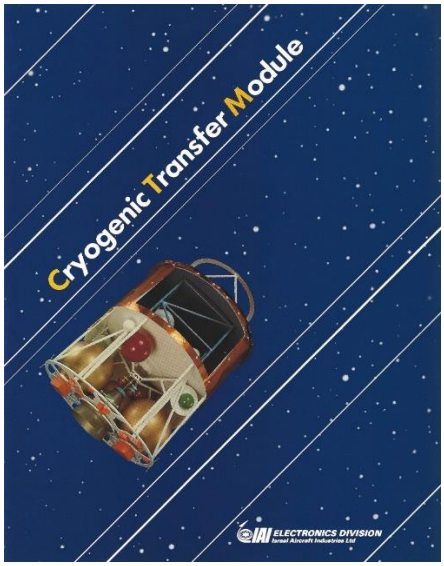
During the late 1980'and early 1990's, when Israel's indigenous launch capability was in its early stages, the Israel Aircraft Industries (IAI) via MLM plant, suggested a cryogenic upper stage as an export product. MLM was (and still is) the prime contractor and integrator of Israeli satellite launch vehicles (The" Shavit") and is one of the most potent aerospace and missile provider in Israel to this day. The paper will describe the technical aspects of the upper stage that was intended to carry a large and massive communications satellites through a transfer orbit, to the designated slot in the geostationary orbit. This project was financed by IAI RD funds, without support of Israel Space Agency and without a direct request of Israel's Ministry of Defense. Nevertheless, it is a reminder of IAI/MLM ambitious approach towards space, at the formative years of Israel space missions.

Background

In the eighties of the twentieth century, the Israel Aerospace Industries developed both the Israeli satellites and the launchers that carried them into space. The Israeli space program was primarily intended for security needs, but the industry also thought about commercial development directions. One of the interesting directions was the development of an upper stage with a liquid propulsion system, designed to transfer satellites from low orbit to geostationary orbit.

It is understood that such an upper stage is not intended for the Israeli satellite launcher (which is small, limited in volume and capacity to carry cargo into space) but for various satellite launchers in the world.

The system's developers thought of using this engine as an export product that would fit a variety of satellite launchers in the world, and it was developed at the expense of MLM[1]'s R&D funds and not at the expense of the Ministry of Defense - the "father" of the Israeli space program at the time.



The front page of IAI brochure on the cryogenic transfer module, prepared for the Paris Airshow. [2]

This is the main reason why the full development was to be relied on foreign customers. With lack of buyers, the project was terminated before a single, fully developed transfer vehicle was built (and launched).

Technical characteristics

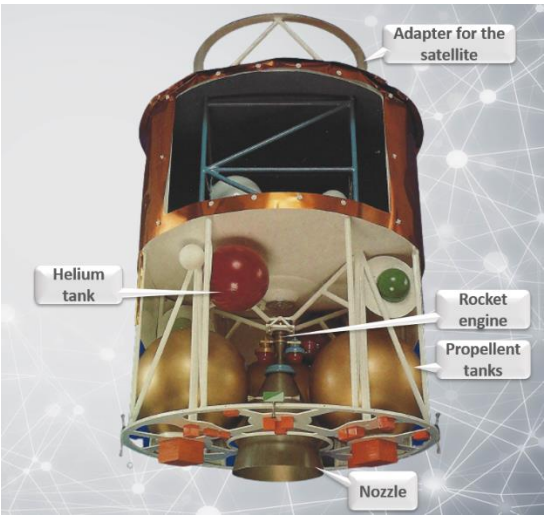
The modular transfer stage, as it was known, was designed to use cryogenic fuel – Hydrogen, and Liquid Oxygen (LOX). It should be emphasized that in Israel of that time, the knowledge of using cryogenic materials for space propulsion did not exist at all, since all three stages of the launcher developed by Israel Aerospace Industries had a solid propellant. Therefore, the engineers saw an opportunity to enter the world of new knowledge, which could bear fruit in other subjects as well, for the future. The performance of the unit was to be:

- Thrust: 10,000 Newtons
- Propellants: Liquid Hydrogen and LOX
- Toal propellant mass: 4800 kg
- Total burn time: 2100 seconds, divided up to 5 segments. The engine is re-ignitable
- The CTM was designed to elevate a payload of 2.1 tons from a height of 200 km to a Geostationary orbit.

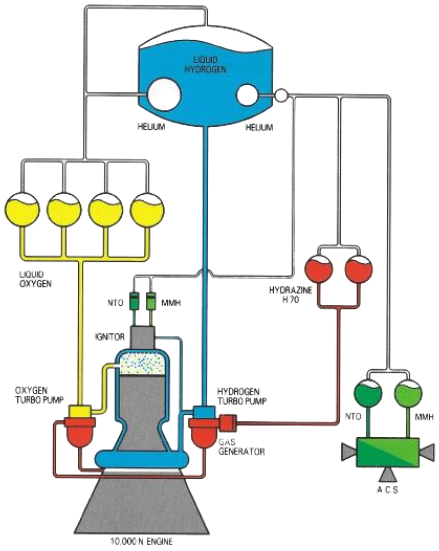
[1] MLM was (and still is) responsible for the design and production of Israel satellite launch vehicles

[2] From the author's archive

- The propulsion system is a pump-fed design, with turbines driven by an independent gas generator.
- The tanks for the LOX and liquid hydrogen are pressurized with cold helium, and a multilayer blanket can provide insulation for a 10-day mission.
- A three-axis attitude control system operates with ten 20 N bipropellant thrusters arranged in 4 clusters.
- The thrusters use MMH[3] and NTO[4] fed from two helium pressurized tanks.



Model of the cryogenic transfer module[5]



Schematic layout of the system

Special attention was made to the propellent tanks, to be used in the microgravity conditions in space:

The propellent management device developed by IAI endures propellent flow during all phases of the mission. Including maneuvers, in zero gravity environment.

In space, the tank enables gas-free liquid flow, irrespective of the relative position of the liquid in the tank.

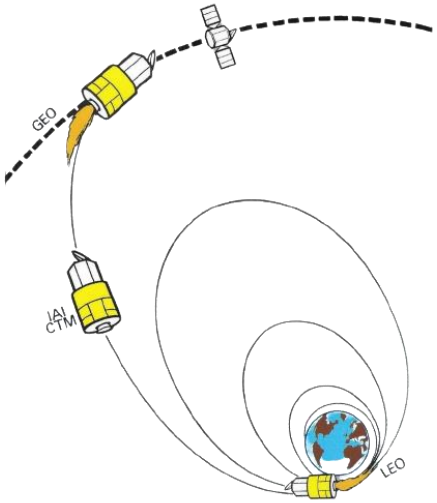
- Tank capacity: 13/3 liters.
- Materials:

  Tank shell – Titanium;

  Acquisition system: stainless steel.

[3] Monomethyl hydrazine
[4] nitrogen-tetra-oxide

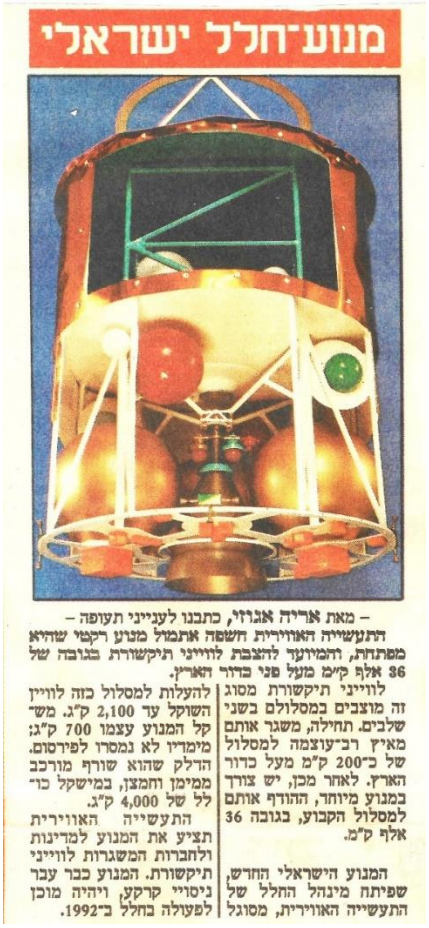
[5] More pictures of the subsystems can be found in the presentation accompanying this paper



Planned trajectory – a lift from LEO to GEO

The available information (to date) is not clear, on WHICH launch vehicle the system was about to be incorporated. However, the system was able to transform medium launch vehicles designed to carry satellites to LEO, to offer a new orbital regime, without "paying the price" of developing a totally new, heavy and costly SLV.

Israeli media coverage of the project



מנוע־חלל ישראלי

– מאת אריה אגוזי, כתבנו לענייני תעופה –

התעשייה האווירית השמה אתמול מנוע רקטי שהיא מפתחת, והמיועד להצבת לווייני תיקשורת בגובה של 36 אלף ק"מ מעל פני כדור הארץ.

לווייני תיקשורת מסוג זה מוצבים במסלולם בשני שלבים. תחילה, משגר אותם מאיץ רב־עוצמה למסלול של כ־200 ק"מ מעל כדור הארץ. לאחר מכן, יש צורך במנוע מיוחד, ההודף אותם למסלול הקבוע, בגובה 36 אלף ק"מ.

המנוע הישראלי החדש, שפיתח מינהל החלל של התעשייה האווירית, מסוגל להעלות למסלול כזה לוויין השוקל עד 2,100 ק"ג. משקל המנוע עצמו 700 ק"ג; מימדיו לא נמסרו לפירסום. הדלק שהוא שורף מורכב ממימן וחמצן, במישקל כולל של 4,000 ק"ג.

התעשייה האווירית תציע את המנוע למדינות ולחברות המשגרות לווייני תיקשורת. המנוע כבר עבר ניסויי קרקע, ויהיה מוכן לפעולה בחלל ב־1992.

First data on the system from "Yediot Aharonot", Israel's lead daily newspaper

- Very little data was reported on Israeli media.
- One exception was this account giving some technical data as well as target date for space operation: 1992 (it had never materialized…)

Also of interest, the newspaper stated that the stage has passed ground tests – a fact that can not be backed up by the IAI records or interviews with veteran IAI engineers, by the author.[6]

Aftermath

No cryogenic propulsion was ever developed in Israel to date. However, some elements of the MLM experience with the cryogenic transfer module might helped in developing the non-cryogenic engines, used for steering the Israeli SLV; Also of interest, IAI's MLM was chosen as the developer of the Israeli Lunar lander, Beresheet.

[6] On January 2024