HyImpulse – Hybrid Propulsion based Launch Vehicles for Small Satellites

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Overview: HyImpulse Technologies GmbH is a NewSpace Start-up in South Germany, a spin-off out of the historical chemical rocket propulsion research center of the German Aerospace Center (DLR) at Lampoldshausen. Our mission is to unlock the full potential of the rapidly growing multi-billion-dollar small satellite market by eliminating the current bottleneck of frequent, reliable, low-cost and dedicated access to space. We are developing an orbital Small Launcher (SL1), powered by our Paraffin-LOX 75kN hybrid motor (HyPLOX75). The HyPLOX75 motor would be used to power the first, second stage engines of SL1 and the technology demonstrator, sounding rocket (SR75) as shown in Fig. 1.

SL1 Architecture: SL1 is composed of 3 stages. The design parameters of the engines have been optimized according to the flight envelope for a payload of 400 kg to a 500 km orbit. A summary is given below.

	1st Stage	2nd Stage	3rd Stage
Rocket motor	HyPLOX75	HyPLOX75	HyPLOX25
Number of motors	8	4	4
Burn time [s]	72	144 (2x72s)	144 (2x72s)
Sea level thrust [kN]	81	65	-
Vacuum Thrust [kN]	94	100	27.5
Sea level specific impulse [s]	262	207	-
Vacuum specific impulse [s]	298	321	313

Engine Cycle Selection: A trade-off study between a pressure fed system, a turbopump fed system for each the 3 stages has been conducted. The options considered are as below with parameters of comparison being mass of the system, number of components, cost and thrust to weight ratio. For turbopump cycles, only a Gas Generator (GG) cycle has been considered for it's ease of applicability to hybrid engines.

P- N2	Pressurization feed system with Nitrogen as the pressurizing gas
P – He (Selected for 3rd stage)	Pressurization feed system with Helium as the pressurizing gas
TP-TP	Turbopump feed system with GG open cycle - both oxidizer and GG fuel are compressed by a dedicated pump
TP-P (Selected for 1st, 2nd stage)	Turbopump feed system with GG open cycle - only the oxidizer is compressed by a dedicated pump, while the GG fuel is fed through a pressurization system

Based on the trade-off studies, a GG cycle with a central turbopump has been chosen which will supply 2 engines with LOX. Helium is used to pressurize the GG fuel (ethanol) and to initially pressurize the LOX-tank. During the operation of the engine, the ethanol is pressurized with helium the whole time, while the LOX-tank pressurization is replaced with gaseous oxygen. The hot exhaust gases from the turbine are used to vaporize a small amount of the high-pressure LOX-flow in a heat exchanger, reducing the amount of inert pressurization gas needed. The fuel rich reaction with oxygen results in a very clean combustion products with minimal amounts of soot.

SL1 Turbopump Design: 6 design options were considered, and a decision matrix created to evaluate the best option as shown below:

		Option 1 double impeller	Option 2 oil lubrication	Option 3 standard layout	Option 4 LOX+EtOH pump	Option 5 centered impeller	Option 6 electric pump
criteria	Factor	rating					
overall design complexity	3	3	5	8	2	8	8
manufacturing cost	2	4	7	6	2	5	5
turbopump weight	1	3	6	8	1	8	5
rotordynamics	3	8	3	5	2	9	7
rocket performance	1	6	5	7	9	7	4
operation complexity	2	6	5	6	4	6	9
	sum	62	59	78	34	88	82

Based on the matrix, a centered LOX impeller system has been chosen. The layout is as shown in Fig. 2 and has the following characteristics:

- LOX-cooled ball bearings;
- Inducer to increase the suction performance of the pump;
- Radial pump impeller, that is centered between two bearings;
- Dump sealing to prevent a mixing of LOX with fuel-rich hot gases;
- Partially admitted supersonic turbine, driven by fuel-rich hot gases

The pump sizing has been done in a trade-off between 1 TP for 1 engine and 1 TP for 2 engines with the latter option being chosen due to advantages that reduce production cost and production time significantly, even though a constraint is placed on an even number of engines per stage. The TP's development is ongoing whether the GG's development is reaching completion at HyImpulse. Shown in Fig. 3 is a GG firing test. All the technical development are on track towards the maiden launch of SL1 in Q4 2022. This project is partly funded by the EU Horizon 2020 SME Phase II grant.

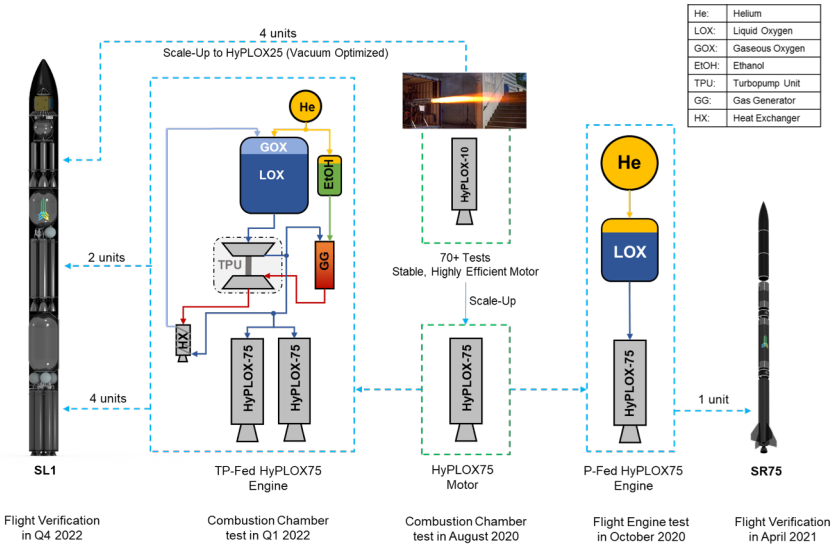

Fig. 1. Propulsion system relationship

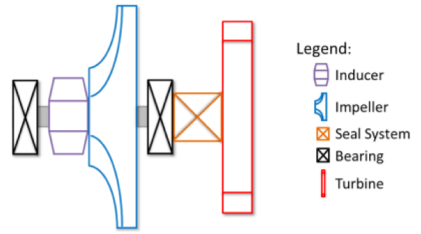

Fig. 2. HyImpulse turbopump rotor layout

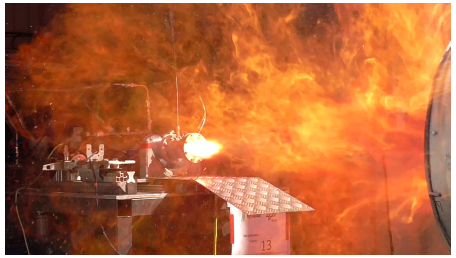

Fig. 3. HyImpulse GG firing test

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