COMPOSITE MATERIAL STRUCTURES FOR THE FUTURE EUROPEAN LAUNCH VEHICLES

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Introduction - Every journey begins with a first step. However, trapped in a deep "gravity well", whether you're going into Earth orbit, exploring distant worlds, or coming back home, the first and last few hundred kilometers of the journey are always the toughest part. The Core Technology project of the Future Launchers Preparatory Programme (FLPP) of the European Space Agency (ESA), is helping to prepare future access to space, and make it cheaper, safer and more flexible than today.

Large numbers of spacecraft manufacturers worldwide rely on the healthy and competitive European expendable launcher vehicle fleet – namely Ariane-5 and soon Soyuz and Vega – to successfully transport their various payloads into space.

However, in general, these commercial launch vehicles are based mainly on 'conventional' rocket technology. Today's expendable launchers have reached a 'plateau' in terms of technical implementation and cost per flight.

Novel technological solutions, which cope with the ever-changing environmental loading conditions from launch until to payload delivery in orbit, are required to improve performance and reduce the cost of access to space, while still keeping high reliability

Representing a sizeable European investment, the general objective of the FLP Programme is to prepare these technical elements as well programmatic ones to make an informed decision in the future on the best operational launch vehicle system to respond to the future institutional needs, while maintaining competitiveness on the commercial market at that time.

How well ESA does this will be a major determining factor in Europe's effectiveness in providing for this assured access to space in the future.

The FLPP accomplishments regarding advanced composite material structure concepts for Next Generation Launch Vehicles - Due to the unique requirements of launch vehicles, the overall structural architecture – including tanks, structures and thermal protection – must achieve, as a design goal, the lowest mass possible compatible with the combined mechanical, thermal and fatigue loads and cost objectives. Major challenges include reducing overall structural mass, manage structural margins for robustness, containment of cryogenic hydrogen and oxygen propellants, reusable thermal protection system for RLV, etc. Future launch vehicle requirements, for instance in upper-stage structures, will require higher structural efficiency which in turn will need investigations into new materials processing technologies. Emerging technologies that can significantly reduce the dry mass are studied in the programme. The leap in technology is the development of low specific mass materials and stiff structures that can withstand high stresses. The development of these advanced materials and processes must be carried out well ahead of the design phase.

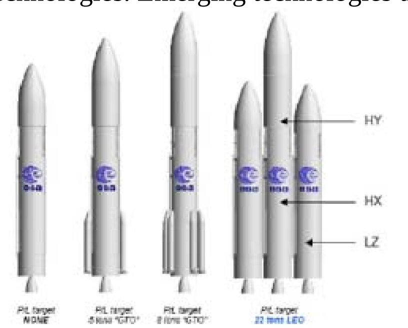

Figure 1- NGL HH SC modular family of European LV (ASTRIUM-ST)

Carbon-fibre reinforced polymer (CFRP) structures

The latest conceptual designs for ELV and reusable space transportation systems require unprecedented and very large lightweight metal and composite structures. Several CFRP structures are currently under investigation in FLPP: cryo-tank / cryo line / inter-stage and ring / thrust frame.

CFPR Cryogenic Tanks for Upper Stage - The inert mass of an upper stage has a direct impact on launch vehicle performance. To maximise the payload mass, the upper stage must use lightweight structural concepts to improve the mass fraction of the stage. CFRPs, as the CF/PEEK, offer advantageous specific strength and stiffness compared to metals and has therefore been identified as candidate for cryogenic tanks for the upper stage. The thermal conductivity of composite as well as under fairing stage concept allows reduction in mass of thermal protection required to limit the thermal entries. The technology development and maturation encompasses material assessment, processes improvement and structure concept studies.

In addition to the lightweight wall concepts investigated (simple skin, sandwich, multiwall), numerous issues have to be mastered before the development of composite cryogenic tanks:

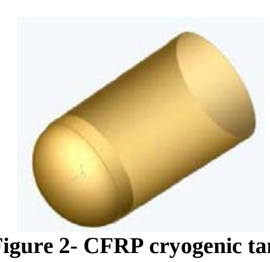
Figure 2- CFRP cryogenic tank demonstrator (Eire Composites)

- Hydrogen permeability and tightness of local areas. Permeability of LH_2 through the tank walls. An alternative design consists on introducing a thin and tight barrier or liner concept. However that liner technology has to be developed for cryogenic conditions.
- Singular points and interfaces, in particular interfaces with primary structures.
- Tight assembling of different tank parts.
- Cold and hot thermal protection integration.
- Behaviour with damage and health monitoring
- Reusability and operability

Applicability to LOX containment is also foreseen, along with all its specific problems such as LOX compatibility, reactivity and flammability with CFRP.

***CFRP structures* –** Several typical other CFRP structures for ELV as well as RLV have been investigated and demonstrators fabricated and verified by testing.

Figure 3- Intertank with a payload bay (EADS-CASA)

Intertanks- The main characteristics of such a full-scale structure are as follows: (i) large structure, with typical dimensions in the range of 5 to 8 m, sometimes non-symmetrical, (ii) large thermally and mechanically loaded composite structure, as the structure must bear all the inertial efforts from the front cryotank and the dynamic loads encountered during all the phases of the mission, (iii) local loads introduction, (iv) temperature gradient conditions due to cryogenic tanks and TPS. Generally manufactured with AFP machines.

Figure 3- Intertank demonstrator (EADS-CASA)

Thrust Frames- The main characteristics of such a full-scale structure are as follows: (i) very heavily loaded structure, with different design load cases to take into account, for instance, un-symmetrical cut-off or idle of one engine, (ii) very harsh environment due to its location close to the engines: thermal, vibration, acoustic and chemical, (iii) very large number of interfaces leading to a complex design. This structure combines different technologies: CFRP structure based on BMI resin, metal matrix composite struts, metallic parts (aluminium, titanium alloys,…)

Figure 4- Thrust frame for two gimbaled engines (2 x 87.2 kN) (SABCA-SONACA)

These various requirements lead to CFRP-based structure made of intermediate modulus carbon fibre and BMI resin type matrix selected because of its good fracture toughness and mechanical properties up to 175°C.

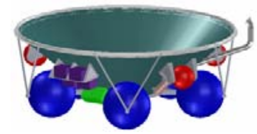

Figure 5- Monocoque thrust frame for cryogenic Upper Stage (EADS-Dutch Space)

Wing box segment- High temperature, high strength composite material selection and joint design are the challenge of the wing article. Therefore, a material consisting of intermediate modulus carbon fibre embedded in a bismaelimide (BMI) type resin matrix is favoured for the fabrication of this subsystem.

Figure 6- Fiber Optic, Health Monitored, Heat Resistant CFRP Airframe Structure (RUAG)

Reusable Thermal Protection Systems (TPS) composite structures for the high temperature range applications- Various materials and technologies are potential candidates, such as Cf/SiC CMC, metals, SPFI, rigid insulation. A CMC TPS demonstrator featuring a typical area of the windward surface, with both relevant heat flux and representative interfaces between TPS elements, has been developed with shingles and seals and verified for ca. 2 re-entries at peak re-entry flux in Scirocco CIRA PWT. Relevant architecture concepts and fastening principles have been assessed. No damage on shingles has been found.

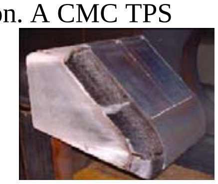

Figure 7- CMC demonstrator (SPS)

Figure 7- CMC demonstrator under plasma testing (SPS, CIRA, VKI)

The refurbishment and repair methods for CMC shingle have been verified at the stagnation area. The I/F accessibility has been validated as well.

Conclusion The technological know-how in all launch vehicle fields cannot be considered as something 'once gained and never lost', especially because Europe must respond to the future institutional launch vehicle requirements and be able to compete in the strong commercial market. On the other hand, it is not wise to depend on as-yet-unavailable technology to reach a fixed schedule and cost in a future launch vehicle development programme. The FLPP Core Technology project, with its various subsystem composite material demonstrators, will mature the technologies, demonstrate feasibility and answer the question for each concept: "Does the technology for a Next Generation Launcher exist or it within reach ?".