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Dynamical and thermal qualification of the C–SiC nose for the IXV

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ABSTRACT

The Intermediate experimental Vehicle (IXV) atmospheric re-entry demonstrator, developed within the FLPP (Future Launcher Preparatory Program) and funded by ESA, was aimed at developing a demonstration vehicle that gave Europe a unique opportunity to increase its knowledge in the field of advanced atmospheric re-entry technologies. Within this program, HERAKLES, Safran Group, was in charge of the TPS of the windward and nose assemblies of the vehicle, and has developed and manufactured SepcarbInox® Ceramic Matrix Composite (CMC) protection systems that provided a high temperature resistant nonablative outer mold line (OML) for enhanced aerodynamic control. A key component of this TPS is the nose assembly, which is one the most loaded part during re-entry.

The paper describes the analysis activities that led to the qualification of the nose assembly, through two activities:

- Dynamical behavior of the nose.
- Thermal behavior of the nose

For both cases, the paper shows how FE models, compared with tests results, led to the understanding and simulation of the nose assembly behavior, allowing HERAKLES to confirm the design margins before flight.

1. Introduction

IXV is an ESA program for the acquisition of in-situ data for a lifting body vehicle during re-entry and for in-flight validation of critical technologies, such as Thermal Protection Systems (TPS). The prime contractor is Thales-Alenia Space, and the vehicle has the following main dimensions and characteristics:

- Length: 4.40 m + 0.66 m (flaps)
- Width: 2.24 m
- Height: 1.54 m
- Mass: about 1.9 t.

HERAKLES has been in charge of the design and manufacturing of the windward assembly and nose TPS (see Fig. 1).

The IXV mission is representative of a Low Earth Orbit return, with a Mach number of about 28 at 90–100 km altitude, and max heat flux specified at 650 kW/m². This led to an estimated max temperature on TPS outer skin of 1650 °C. The duration of the re-entry is 20 min, during which the acoustic load is 70 dB, and deceleration is 3g.

General description of the TPS designed by HERAKLES is to be found in [1].

2. IXV nose description

The nose assembly is the largest Carbon–Silicium Carbide (C–SiC) TPS of the vehicle (see Fig. 2). Its outer skin is

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made of a single piece CMC nose cap made of C–SiC material (> 1.3 m wide). This nose cap has an integrated stiffener and 16 attachment legs. It also has 7 pressure ports made of C-SiC material.

The nose cap is attached to an aluminum ring using 16 Inconel stand-offs, designed to accommodate thermal expansion of the nose while withstanding mechanical loads. The ring is equipped with brackets, which are used to attach the nose to the cold structure, and fastened to an aluminum dome that provides support to the insulating layers. Insulation is made of layers of alumina blankets and silica aerogels. Metallic parts are designed by RUAG Aerospace for HERAKLES.

3. Dynamic justification of the nose

The qualification levels for the nose are based on the technical specification, which encompass the vibratory environments of vibration and acoustics of the launcher, separation shocks, fairing jettison and mortar shocks due to parachute opening (Figs. 3 and 4). Those vibratory environments are simulated by Sinusoidal excitation, shock levels and random loads.

Material's laws used for dynamic analysis are orthotropic material's laws for CMC parts, and isotropic for insulation layers and metallic parts. Metallic joints on bulkhead are considered clamped, and Nastran solver 103 real modal analysis has been used.

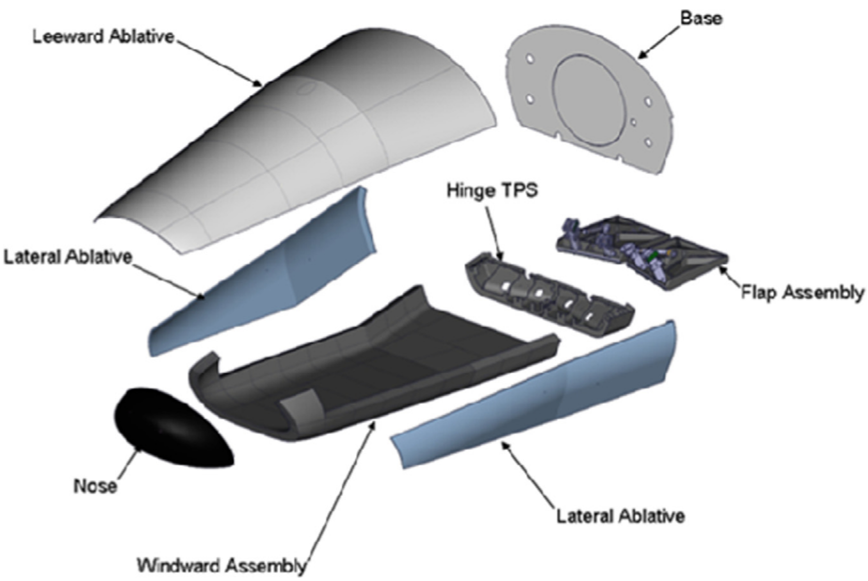

Fig. 1. IXV TPS assemblies.

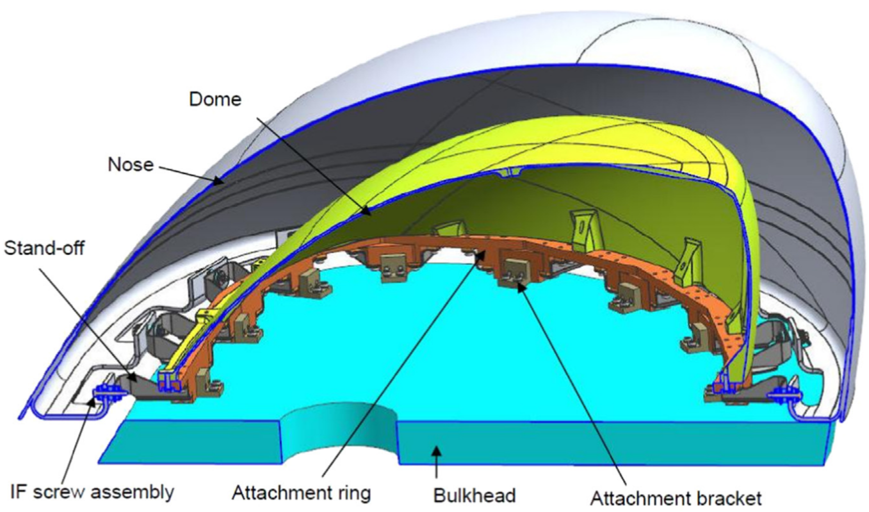

Fig. 2. Nose assembly.