TESTING ON SOLID ROCKET MOTOR PROPELLANT MATERIALS TO BE UTILISED FOR THE END_OF_LIFE MANOEUVRE OF GEO/LEO SATELLITES

ESTEC, 26-05-2016

Authors: M. Balduccini (2); M. Ciranna (1); A. Cretella (1); G. Fundarò (1); E. Gizzi (1);
(1) AVIO S.p.A.
(2) MaBa Consulting SRL

SUMMARY

- Introduction
- Needs and characteristics of EOL propulsive maneuvers
- Solid propulsion seems to be attractive and it needs to perform an extensive, accurate and reliable qualification effort
- Main environmental conditions to be considered for propellant qualification
- Combined effects of individual mission environments
- A proposed test campaign

INTRODUCTION

This presentation shows the main contents of a solid propellant characterization plan considered as appropriate to support the required EOL reliability need. In fact:

- **Solid Propulsion can be considered one of the most convenient options for carrying out the End Of Life Satellite operations.**
- **EOL maneuvers are characterized by very long "On-Orbit Storage" time under environmental conditions that are very different from the ones applicable to the SRM utilized for the military market.**
- **Exhaustive SRM propellants characterization data seem not available to date, and this constitutes a critical element for the utilization of Solid Propulsion since a very high reliability is formally requested to the EOL satellite maneuvers.**
- High reliability **is motivated by the consideration that a failure could generate catastrophic damage.**

NEEDS AND CHARACTERISTICS

The International regulations (*) introduce the need of a propulsive operation to be activated (on most satellites) at the end of the operative life (removal from space protected regions).

(*): Our reference is the ECSS-U-AS-10C 10/02/2012: Space sustainability: Adoption note of ISO 24113 Space Debris mitigation requirement

Where needed, the propulsion operations mentioned above have the following characteristics:

- **They are activated after a long "on-orbit storage" time (i.e. the operational life of a GEO satellite is of the order of 15y)**

- **They are critical for cost and safety impacts since a failure during the EOL firing of a GEO satellite could cause impact/ damaging of third party properties (another satellite), while a failure during the deorbiting firing of a LEO satellite could cause damage on population (wrong re-entry trajectory)**

SOLID PROPULSION QUALIFICATION

Several propulsion technologies can be utilized for implementing the propulsion operations needed at the EOL; among them the utilization of the Solid Propulsion appears as attractive due to its low recurring cost and relatively high reliability.

But in order to meet the minimum reliability requested by the "rules" for the EOL propulsive operations, the solid propulsion system shall be qualified basing on the specific environment foreseen for its mission. This is particularly mandatory since, for the solid propulsion, no significant health check is feasible during the very long "on orbit storage" phase of the satellite mission.

The characterization background of Solid Propellant is extensive due to its utilization in the military market; nevertheless, some specific characteristics of the GEO and LEO end of life propulsive missions deviate from the "traditional" military requirement and consequently generate the need for a dedicated characterization / qualification effort.

MAIN ENVIRONMENTAL CONDITIONS (1/3)

Main environmental conditions to be considered for propellant qualification are:

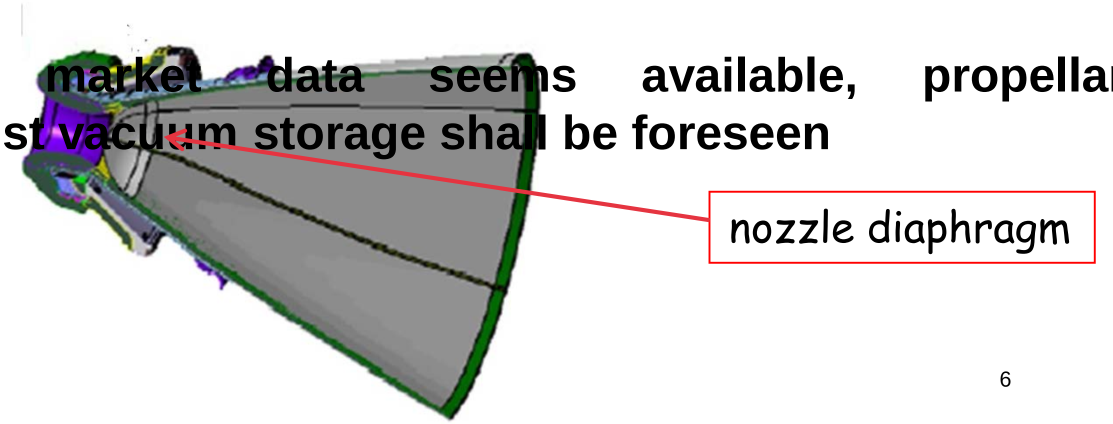
<u>Total lifetime</u>

A total lifetime of more than 15 years is a "state of the art" requirement for military solid propulsion, nevertheless <u>the storage conditions that are foreseen on ground are different from the ones typical of the EOL LEO/GEO missions</u>.

<u>Storage condition/ Vacuum</u>

The present approach of installing a nozzle diaphragm sealing is not considered as applicable considering also the (high) probability of having a set of SRM where some of them have lost their diaphragm sealing could introduce thrust unbalances severely affecting the control of the vehicle.

Since no military market data seems available, propellant characterization against vacuum storage shall be foreseen



MAIN ENVIRONMENTAL CONDITIONS (2/3)

Storage condition/ Max temperature

Propellant characterization at max temperature in vacuum condition shall be developed

Storage condition/ Min temperature

Propellant characterization of min temperature in vacuum condition **shall be developed**

The layout of the Deorbiting SRMs within the hosting Vehicle is expected to consent a reduction. But the testing basing on the (military standard) extreme temperatures is recommended since it is possible to consider the test an "accelerated degradation test"

Storage condition/ Temperature cycling

Propellant characterization against thermal cycling in vacuum should be introduced

Storage condition/ Radiation

Propellants sensitivity to worst case mission radiation doses, as well as to proton and X-ray induced radiation, should be quantified

Storage condition/ Atomic Oxygen (for LEO only)

For LEO missions, and in cases where SRM materials are exposed to ATOX environment/ flux, the relevant characterization of propellant and ignition materials should be carried out

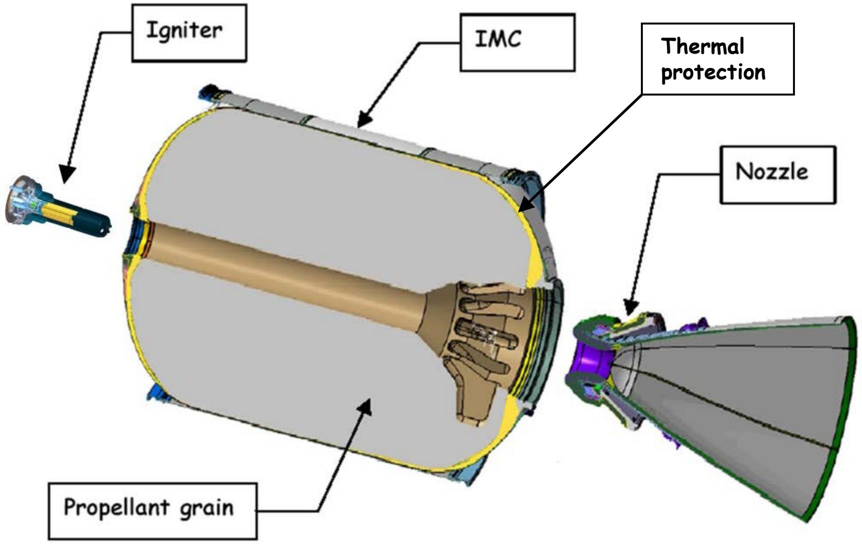
MAIN ENVIRONMENTAL CONDITIONS (3/3)

Elements to be characterized cannot be limited to the propellant itself. In fact a significant degradation of the capabilities/ performance of:

- **The propellant ignition materials**
- **The propellant direct interface to its thermal protection**

could lead to the SRM failure or anomalous firing.

All 3 elements: propellant, ignition material (up to SRM interface) and propellant / thermal protection interface shall be characterized against the above environme



COMBINED EFFECTS OF MISSION ENVIRONMENTS

Effect of simultaneous presence of different environments/ loads:

- **An assumption (1) on the potential coupling of the different environments in generating degradation effects, is presented in the following table:**

	T	V	R	Tx	Tc
T:Mission Time		coupled	No interaction	coupled	No interaction
V:Vacuum			No interaction	coupled	coupled
R:Radiation				No interaction	No interaction
Tx:Tmax; Tmin					(2)
Tc: Temp cycling					

(1) Compromise between individual environment effect evaluation and test cost and duration

(2) Temperature cycling includes Max-Min temperature

PROPOSED TEST CAMPAIGNS

Campaign 1: TVTx

It includes the testing of coupling of mission time (T), Vacuum (V) and Maximum or Minimum temperature (Tx): Campaign 1max is including T max and Campaign 1min is including Tmin.

Campaign 2: VTc

It includes the testing of coupling of Vacuum (V) and Temperature cycling (Tc)

Campaign 3: R, radiation

It is carried out in order to evaluate the potential degradation effects due to the radiation environment; it is subdivided in a subtest based on proton/ heavy ions radiation (3p) and one based on electrons and X-ray (bremsstrahlung) radiation (3x)

Campaign 4: AO, Atomic Oxygen

It shall identify the degradation associated to the worst case integrated flux/ environmental density of Atomic Oxygen

Campaign 5: SCP, Solid Combustion Products contamination test

A testing could be necessary to characterize the propellant in terms of generation of solid combustion products (see max dimension of 1mm required by ECSS adoption note of ISO 24113)

Note: Avio has developed dedicated test specification and procedures to be tailored according with specific needs

RESUMÉ

- **The need to demonstrate full compliance with the minimum level of reliability requested by international rules applicable to the End Of Life maneuvers, imposes the execution of a specific characterization program on Solid Propulsion materials.**
- **Such characterization program shall be based on the worst case environment that could be experienced but shall be reviewed for each specific mission in terms of applicability.**
- **The characterization plan will lead to know the potential sensitivity of the Solid Propulsion Materials to the expected EOL environment, namely max and min on orbit storage temperatures, temperature cycles, radiation, Atomic Oxygen (LEO only), all in the frame of a very long "on-orbit storage" time.**

THANKS

Emanuela Gizzi

Mauro Balduccini

emanuela.gizzi@avio.com

mbalduccini@mabaconsulting.it