SPACE DEBRIS MITIGATION MEASURES APPLIED TO EUROPEAN SPACE TRANSPORTATION SYSTEMS

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ABSTRACT

Since the early days of the Ariane program, European organizations in charge of the development of Space Transportation Systems have shown great attention to the question of sustainability of space operations, developing and applying a comprehensive set of mitigation requirements to all their systems.

The first study in that frame was ESA led at the end of the 80's, identifying exhaustively what should be done to limit the generation of orbital debris and giving the first requirements which were applied to the Ariane 1-4 family. These requirements were progressively consolidated through an ESA PSS standard (former name of ECSS) and a CNES standard, closely derived from the IADC guidelines adopted in 1992. These standards were later used as the basis for a European Code of Conduct signed by ASI-BNSC-CNES-DLR-ESA in 2005, which itself served as the basis of the ISO 24113 and ISO 20893 widely approved at international level. The French Space Operations Act (FSOA), in force since 2010, is now the reference for any operation taking place from the European Spaceport in French Guiana.

Following the mishap of the upper stage of flight V16 in November 1986, 9 months after the launch, modifications were implemented in 1989 on the propulsion system of the stage, enabling a complete passivation at the end of the mission; no explosion occurred ever since; the orbital lifetime in GTO of the stage and its dual payload adaptation structure was statistically well within the 25 years prescribed by IADC (23 years after the Ariane maiden flight!), but for LEO missions, there was no possibility to deorbit the system, due to non-reignitability of the HM7 engine.

Such concerns were taken into account since the very beginning of the development of Ariane 5. In its earlier version with the storable upper stage EPS, all stages were properly passivated and the upper stage was deorbited in a controlled way for LEO missions. The current "high energy" version A5ECA uses the same upper stage engine than the one of Ariane 4, non reignitable, leading to orbital durations longer than 25 years; however, a recent modification has been implemented enabling to use the energy released by the passivation of the stage in a way reducing both the apogee and the perigee, hence the orbital lifetime.

The other European launcher currently operated from the Guiana Space Center, Vega, complies perfectly with both the FSOA and the ISO 24113. Vega is equipped with a very versatile upper stage AVUM which is deorbited in a controlled way for every mission requiring such end of life maneuver, and fully passivated otherwise.

The development of the new European launchers Ariane 6 and Vega C is currently under finalization; their operation in the near future will be, by design, fully compliant with all the requirements from FSOA and ISO 24113. It is exactly the same for the Space Rider, small operational shuttle currently developed by ESA.

1 HISTORICAL INTRODUCTION

1.1 Early orbital launches in Europe

The launcher-related space debris concern started in Europe with the launch of the French Diamant A rocket from Hammaguir, in Sahara, on 26 November 1965. It carried a small satellite called Astérix into a 527 x 1,697 km inclined at 32°. [1].

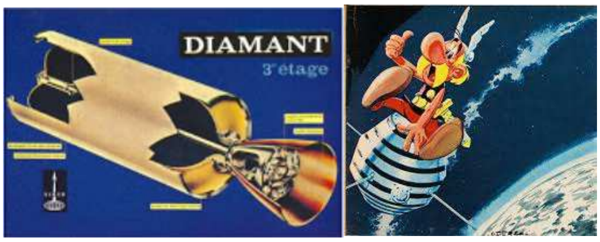

Figure 1. Diamant A and Astérix

The upper stage is solid-propulsion based, with a filament would casing, weighing 68 kg; there was no Attitude Control System, as the stage was spin-stabilized with a timer to ignite the engine. Astérix is a nearly spherical satellite, 50 cm in diameter, weighing 43 kg, presenting therefore a low Area to Mass ratio. Fig.1.

Proc. 8th European Conference on Space Debris (virtual), Darmstadt, Germany, 20–23 April 2021, published by the ESA Space Debris Office
Ed. T. Flohrer, S. Lemmens & F. Schmitz, (http://conference.sdo.esoc.esa.int, May 2021)

Both objects are still in orbit; with an apogee significantly higher than 1,500 km, their orbital lifetime may be over 1,000 years.

The same launch also released two debris in orbit, but they both re-entered the atmosphere, one in 1967, the other in 2004. Four additional Diamant upper stages are still in orbit, with 9 long-lived satellites and some debris which have not yet re-entered atmosphere.

One can also mention in this recall of early days the launch of the Prospero X-3 satellite by United Kingdom, using a Black-Arrow launcher, on 28 October 1971. Both the upper-stage and the satellite are in very stable orbits and will remain there for quite some time.

Of course, there was no mention yet of any concern related to space debris at that time, and the European contribution to the global orbital population was then still very minor…

1.2 Ariane 1 flight V16

The first serious event linked to a European launcher was the violent fragmentation of the upper stage of the Ariane 1 flight V16. The launch placed the satellite Spot 1 flawlessly into its Sun Synchronous Orbit at 800 km altitude on 22 February 1986, but the third stage H8, (10.3 m long, 2.6 m diameter, 1,400 kg), exploded on 13 November 1986, 9 months after the launch. Fig. 2 presents the corresponding Gabbard diagram, extracted from [2]; the strong variation in apogee (and period) denotes the intensity of the fragmentation.

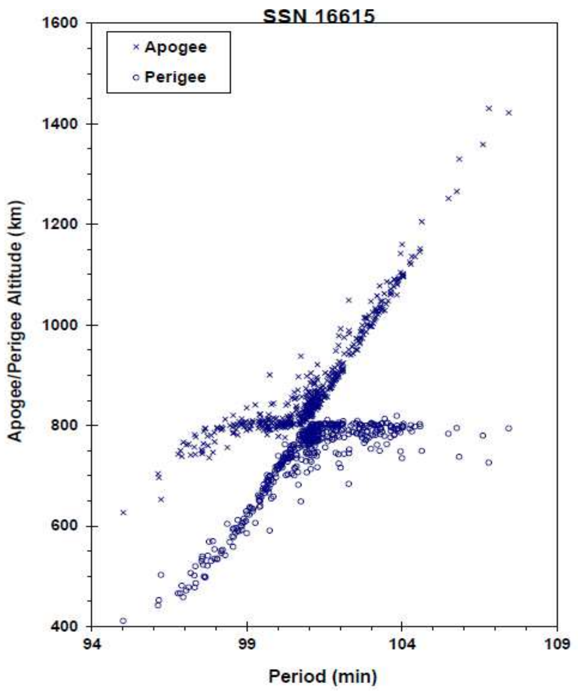

Figure 2. Gabbard diagram – Ariane V16 upper stage fragmentation - NASA [2]

Some 463 debris were cataloged initially, of which 30 are still in orbit. The analyses identified that the fragmentation was probably due to the loss of the external cryotechnic thermal protection, leading to the boiling of the residual propellants trapped in the tanks and the tank common bulkhead rupture; a collision with a debris could however not be ruled out.

The decision was then taken to implement a passivation system on the upper stages H8 and H10 of all the Ariane versions, 1 to 4. The first application took place on flight V35 on 22 January 1990, and then systematically following V59 on 26 September 1993; no similar fragmentation ever occurred since this modification.

2 EARLY STANDARDIZATION EFFORTS

2.1 ESA "Safe Disposal" study

In the opinion of the authors, the very first initiative dealing with identification of recommendations aiming at mitigation debris generation for launcher operations is probably the "Safe Disposal of Orbiting Systems" initiated by Pr. Walter Flury from 1987 to 1990. This study involved most of the European industry involved in space activities, covering every domain of operations such as Observation satellites, Telecommunication, Space Station modules, Hermes… A systematic "fault-tree" approach enabled the identification of all potential sources of debris, and of course associated recommendations to prevent them.

The part specifically devoted to Ariane 4 and Ariane 5 dealt with all stages, including dual payload structures. The now "classical" mitigation measures were identified, such recommendations on long term integrity leading to passivation measures (following the V16 anomaly), End of Life (EOL) operations and attention not to release operational debris such as fairings, pyro bolts, clamp bands.

This document was used as one of the basis for the Ariane 5 design, although this development was already initiated since 1987 (and 1984 for the Vulcain engine).

The "Safe" study had some influence on the Issue 2 of the ESA-PSS-01-40, released in September 1988. The corresponding requirements were sound and constructive, but probably too theoretical at that time. [3].

2.2 CNES Normative Reference

By the same time, CNES prepared its first standard devoted to Space Debris, the CNES-MPM-51-0012 "Exigences de Sécurité – Débris Spatiaux" prepared in 1998 and rendered applicable by decision of the CNES Director General on 18 June 1999.

It was a very complete set of requirements, dealing with all the topics.

- Limitation in number of debris released per mission; no Mission Related Objects released; no voluntary fragmentation; prevention of small debris from Solid Propulsion or Pyrotechnics; selection of materials minimizing debris generation upon impact; selection of materials withstanding degradation in orbit leading to debris generation
- Limitation of accidental fragmentations with a probability of explosion during operational phase limited to 10^{-4}; passivation
- Protected zones in LEO and GEO, associated to the 25-year rule; probability of successful End of Life maneuvers > 99%
- Casualty risk associated to controlled atmospheric re-entry to remain within the threshold dictated by the "Sauvegarde" CNES
- But there was not yet a requirement on un-controlled re-entries…

Since the development of Ariane 5 was already well engaged by that date, there was no retroactive effect of these rules but only a "best effort" observed.

2.3 International Standardization effort

2.3.1. IADC

At international level, the first high level Guidelines influencing directly the design of launchers in Europe are the ones from the Inter-Agency Space Debris Coordination Committee (IADC).

Its first meetings started in 1987 as a coordination group between NASA and ESA, and the first "official" meeting took place in Moscow in 1993.

The IADC Guidelines, adopted unanimously by the then 11 members (now 13) are considered as the "Bible" of space debris mitigation.

The first version was published in 2002; it was revised in 2007 [4] and is now again under revision.

2.3.2. EDMS

In parallel to the IADC efforts which lasted 5 years to reach unanimous approval, five European Agencies joined by the end of 1999 in an effort to write a set of European Debris Mitigation Standards (EDMS); the structure of the document was directly derived from the CNES Normative Reference mentioned previously.

The exercise converged in April 2003 with the Issue of the Final Draft 1-a.

Unfortunately, it was then clearly explained that this group of engineers were not entitled to write standards, so the document was never officially approved.

2.3.3. European Code of Conduct

Immediately after the failure to conclude with the EDMS, the same working group modified the text, mostly replacing all the "shall" by "should", renaming it European Code of Conduct (ECoC).

The first draft version of ECoC was produced in September 2003. The finalized official version was approved and signed by ASI – BNSC – CNES – DLR and ESA on 28 June 2004.

Several evolutions of this document were issued, until the arrival of the ISO standards.

Associated to this ECoC, a Volume 2 "Guideline Support to Implementation" was produced in January 2004.

2.3.4. ISO 24113

The ECoC was used as the basis for the standardization effort at the level of International Standardization Organization (ISO). It led to the issue of the highest level standard on the topic of Space Debris Mitigation, the ISO 24113 [5].

Its first version was issued on 1st July 2010. It has been revised in 2019.

In 2020 a dedicated "second tier" standard solely dedicated to Launchers was produced, the ISO 20893; it gives some additional details compared to the ISO 24113.

2.4 Current Reference at European level

2.4.1. French Space Operations Act

France issued a Law devoted to all Space Operations called French Space Operations Act (FSOA), approved on 3 June 2008 and rendered applicable in 2010.

The FSOA is associated to two Applicable Documents, the Decree Regulating the Operation of the Guiana Space Center (REI) and the Technical Regulation (RT), and by a set of non-normative "good practices implementation" called "Guide des Bonnes Pratiques (GBP)".

The RT deals with all the flight phases, for both launchers and satellites. It has requirements very similar to the ones in ISO (hence in ECoC, EDMS, IADC and CNES MPM-51-0012 ☺) but with much more numerical details, such as probabilistic approaches to requirements, casualty on ground or End of Life Maneuver for instance.

The RT covers all the safety aspects on ground and in flight, at launch and re-entry (controlled or random), nominal or following failure.

It has been revised in 2017 [6] and is currently under a new revision.

2.4.2. ESA reference

The highest level policy of ESA is to apply ISO 24113; this guarantees a very good coherence with international partners.

The ESA Policy is expressed through the ESA/ADMIN/IPOL(2014)2 issued on 28 March 2014 and approved by ESA Director General. [7].

It specifies the application of the ECSS-U-AS-10C Rev.1 dated 3 December 2019, which is itself the Adoption Notice of ISO 24113:2017. [8].

The IPOL adds the threshold for on-ground casualty risk which is not (yet) in the ISO 24113.

Last, a dedicated ESSB-ST-U-004(1/0) dated 4 December 2017 deals with the ESA Re-entry Safety Requirements, capturing the casualty risk threshold of 10^{-4} per re-entry. [9].

2.4.3. Applicability

It is important to note that despite different reference documents between France and ESA, both sets of requirements are hopefully very coherent, with only minor differences; this is due to the permanent and excellent relationship between both teams, for instance through the ECSS Space Debris Working Group which has been set in place 20 years ago.

During a new launcher related development, both ESA Standards and French FSOA are applicable.

During the production phase under Arianespace responsibility, the French FSOA is applicable.

3 ARIANE

3.1 Ariane 1 to 4

Following the V16 flight mishap, a passivation system was implemented on the upper stages H8 and H10 of all the Ariane 1 to 4 launchers. Fig. 3 presents the functional propulsive scheme of H8 and H10.

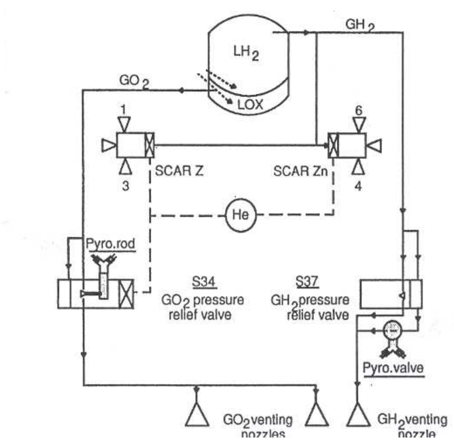

Figure 3. H8-H10 passivation scheme

On the Oxygen side, the GO2 pressurization line has been modified with the inclusion of a pyro-rod in the S34 GO2 Pressure relief valve, to cut the G02 venting line; the tank can then be depressurized through the two equilibrated GO2 venting nozzles.

On the Hydrogen side, the principle is somehow similar with the inclusion of a pyro valve on a small line mounted in parallel to the S37 GH2 pressure relief valve.

Fig. 4 gives the pressure evolutions on both sides without (top) and with (bottom) the passivation system; its efficiency is obvious! More details are given in [10].

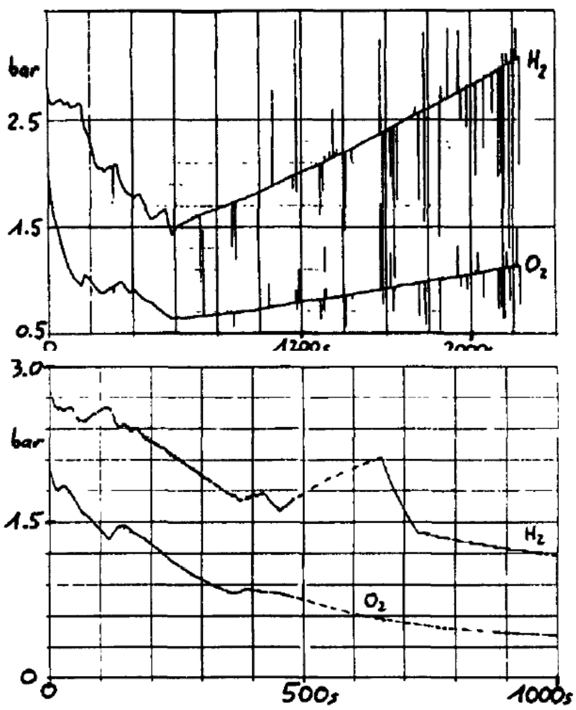

Figure 4. H8-H10 pressure evolution without (top) and with (bottom) passivation

The last flight of an Ariane 4 launcher, the 116th, occurred on 15 February 2003. There are still 61 upper stages in orbit to date, 8 in LEO-SSO (some with very significant orbital lifetime), and 53 in GTO.

There are 22 non-passivated stages left in orbit, but as they are more than 28 years old it is most probable that they are "naturally passivated" by now.

There are also 7 Dual Payload Structures (Sylda and Spelda) but as they have a very high Area-to-Mass Ratio, their orbital lifetime should be limited.

3.2 Ariane 5 EPS

The Ariane 5 "Etage à Propulsion Stockable" EPS (Storable Propellant Upper-Stage) was the first upper-stage developed for Ariane 5, with a maiden flight on 4 June 1996 (not to successful though…). It is the "Lower Energy" upper stage consisting of 10 tons' storable propellants used in a pressure fed propulsion system.

It has been used for all the initial operations of Ariane 5 up to 2005, then for the ATV and Galileo launches.

The passivation system consists in the inclusion of a dedicated line added on the pressurization lines of both pairs of tanks, as seen on the detail of the top of the stage presented in Fig.5.

These lines consist in a burst disk set at 6 bars, used as a safety barrier for the ground operations. Then a pyro valve is used on both sides with redounded trigger order in order to cope with the End of Life Maneuver probability of success specified at 90%. Last, a T shaped exhaust thrusters enables a passivation with minimized residual torque (although non-zero due to parietal pressure integration on the stage conical structure).

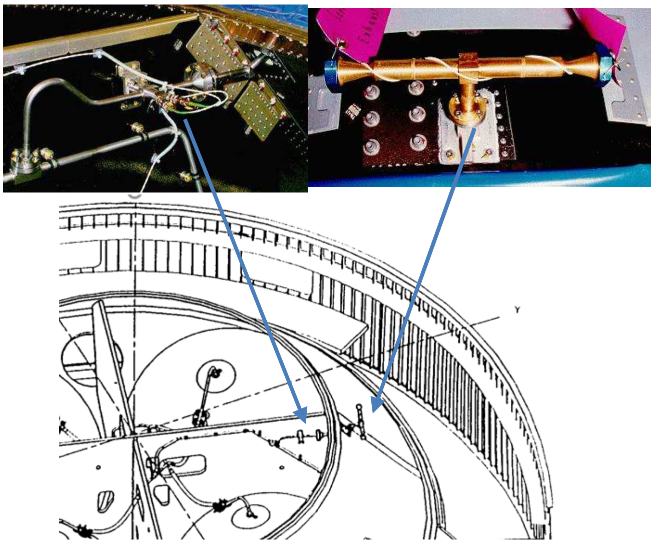

Figure 5. Ariane 5 EPS passivation scheme

Fig. 6 shows the typical pressure evolution over several flights, on the N2O4 side (similar on MMH side), showing the high efficiency of such system.

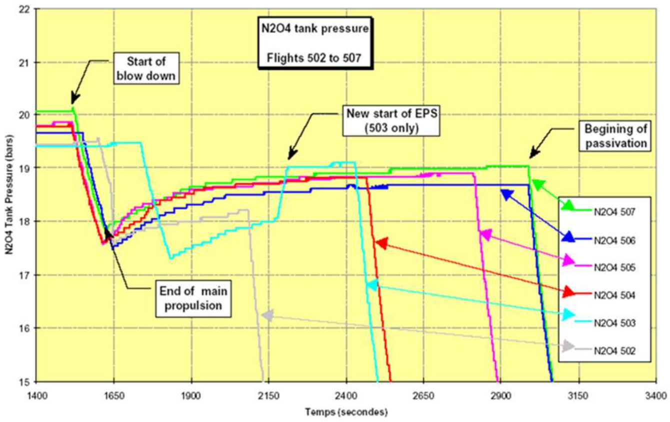

Figure 6. Ariane 5 EPS pressure evolution with passivation (N2O4 side)

This efficiency can also be visualized on the nice picture fig. 7 taken by the CNES Telescope TAROT located in La Réunion Island, showing the passivation phase of an EPS shortly after the separation of its 4 Galileo satellites. The two white shadows on each side of the stage are the plumes generated by passivation, giving evidence of propellant droplets ejection.

During the development of the passivation system, it was demonstrated by tests that the passivation thrusters could not be clogged by ice, and that solid particles ejected were of few microns in size at the most. Additional details can be found in [11] and [12].

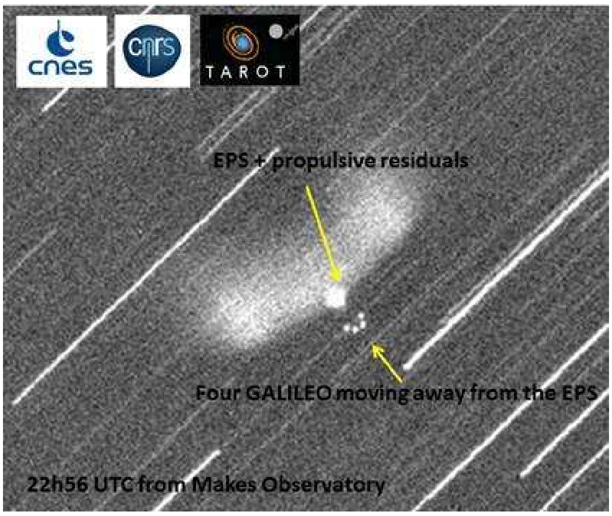

Figure 7. Ariane 5 EPS passivation at the end of Galileo mission – P. Richard - CNES

3.3 Ariane 5 EPC

The Ariane 5 main stage “Etage Principal Cryotechnique” EPC is not orbited; it was so in the initial designs as explained in [11] but as its attitude control in orbit prior to a deorbitation boost was too complex to master, with the strong tendency of EPC to move into a flat-spin mode, it was decided to modify the staging of the launcher, increasing the propellant mass of EPS in order to force a natural re-entry of the EPC.

It nevertheless largely enters in the exo-atmospheric zone, so it is submitted to all the space debris regulations (“in Earth orbit or re-entering atmosphere…”); furthermore, if it exploded during its ballistic phase, it would generate a very large number of debris potentially long-lived despite a low perigee.

We decided to passivate the EPC just after the separation with the upper-stage in order to avoid such explosion. The EPC, during the separation phase, is submitted to two antagonist effects: The Liquid Oxygen crossing a gaseous volume of cold Helium induces a significant loss in pressure; in the same time, the Liquid Hydrogen raising on the “hot” sides of the tank heats up and the associated pressure increases rapidly. As the common tank bulkhead is not properly oriented to withstand such negative delta pressure, the stage could explode within 10 seconds (worst case) after separation if not passivated.

Passivation of EPC is done first on the LH2 side, pyrotechnically opening a 26 cm hole in the side of the side of the tank 5 seconds after separation, inducing a very fast pressure drop, guaranteeing integrity of the common bulkhead; then, 25 seconds after separation, thanks to a pyrotechnical delay, the LO2 tank is passivated through a T shaped thruster located on top of the tank.

The following pictures in fig. 8 show a general view of the side of the EPC, with the LH2 passivation hole pointed out by an arrow, and respectively the LH2 passivation hole and the LO2 passivation thruster, not visible inside the front skirt of the stage.

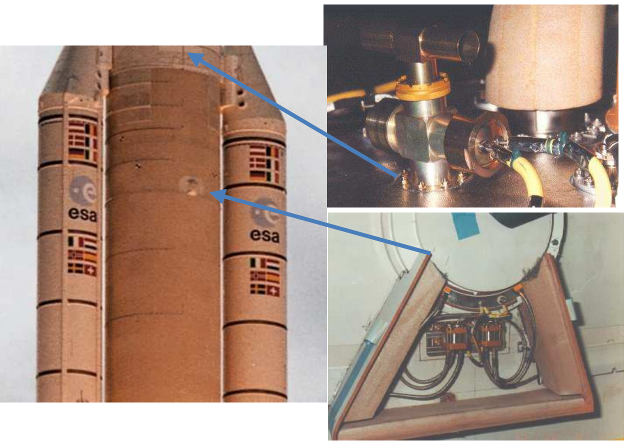

Figure 8. Ariane 5 EPC passivation system

The LH2 passivation hole has a "convergent-divergent" shape which enables the generation of a thrust, inducing a transverse torque and a lateral spin of the stage, larger than 90°/s; this rotation enables the averaging of the drag and the cancellation of the lift during the atmospheric re-entry phase, thus reducing drastically the dispersion of the impact point of the stage.

3.4 Ariane 5 ESC

The Ariane 5 "Etage Supérieur Cryotechnique" ESCA is the "high-energy" upper stage of Ariane 5. It is cryotechnic, with nearly 15 tons LO2-LH2 and it is propelled by the HM7B engine, which is the same as was used on Ariane 4.

Fig. 9 shows the propulsion main stage synoptic, derived from that of Ariane 4 H10 upper stage.

As for the upper stage of Ariane 4, the HM7B engine is non-reignitable, meaning that there can be no actively controlled deorbitation at the end of mission. The statistical orbital duration of the ESCA is long, typically some 45 years; fig. 10 gives a typical distribution of some of the 61 ESCA left in GTO; note that the computation is truncated at 100 years, which explains the "strange" distribution on the right of the figure.

The Dual Payload Structure Sylda has a much lower lifetime due to a high Area-to-Mass Ratio.

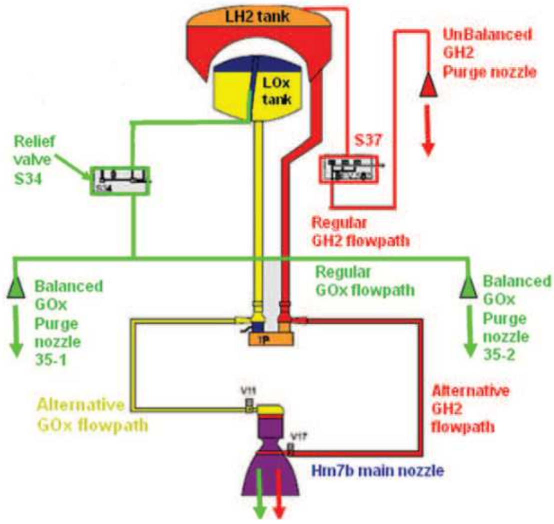

Figure 9. Ariane 5 ESCA propulsive scheme

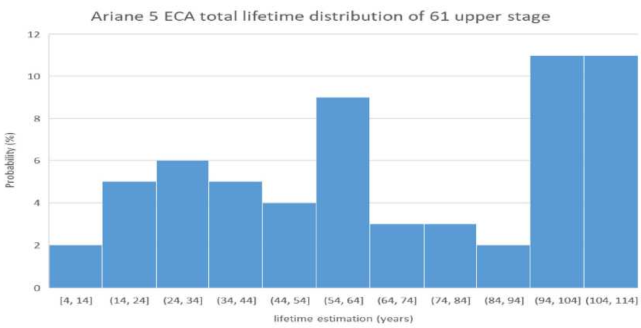

Figure 10. Statistical distribution of ESCA in GTO

This orbital lifetime is very scattered due to perturbations, Sun-Moon gravitational, Solar Radiation Pressure, and Earth shape effects; computation has to be done using statistical tools such as STELA [13].

It is worth mentioning here that despite an orbital lifetime larger than 25 years, the ESCA remains coherent with the French FSOA-RT text Art. 55.1.a which recalls that no retroactive measures shall be considered; since the first flight of ESCA took place in 2003, 5 years before the Law, the 25-year rule is not applicable. It was nevertheless decided to do a best effort in order to improve the situation as much as possible.

An End Of Life Maneuver (EOLM) has been developed for the Ariane 5 ESCA, making optimal use of the ΔV generated by the passivation; indeed, the tanks at engine cut-off present a high volume with significant pressure, i.e. a high potential energy which can be used to lower the final perigee. This idea was first exposed at IADC 2006, then described in [14], refined in [15].

At End Of Mission, the passivation ΔV orientation (angle Θ with respect to Velocity vector) leads to simultaneous modification of both perigee (top) and apogee (bottom), as shown in fig. 11.

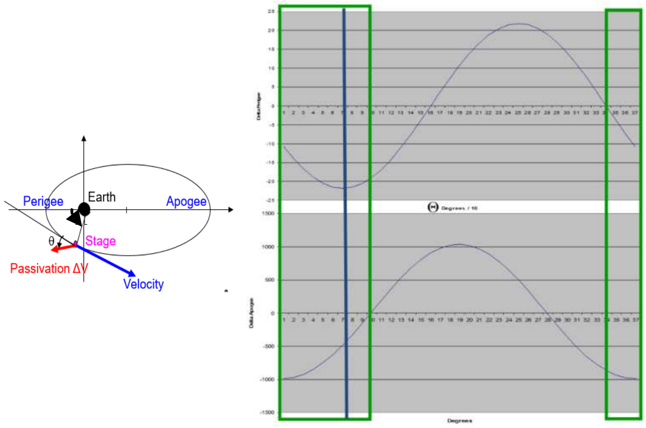

Figure 11. A5 ESCA EOLM principle. Perigee (top) and Apogee (bottom) modification

The variation of final Perigee has a strong influence on residual lifetime, as can be seen on the fig. 12 from [16] which gives graphically the residual lifetimes as a function of final perigee: Black or Red correspond to durations in the order of 100 years or more, where Green of Blue are less than 25 years.

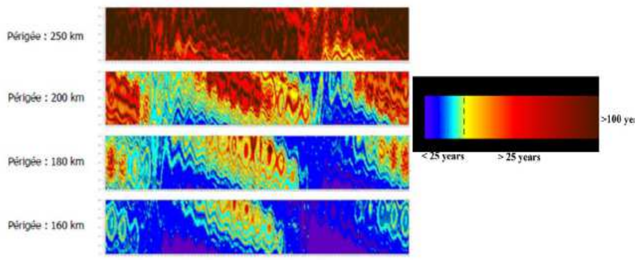

Figure 12. Orbital lifetime of A5 ESCA vs. Perigee

The EOLM is based on a modification of the passivation scheme of the ESCA. As shown on fig.13, the LH2 and GH2 are led to flow directly through the engine combustion chamber, while the LO2 and GO2 go through the equilibrate Oxygen purge. There is no combustion of course, but the efficiency of the H2 passing in the chamber is much better than through purge orifices, and both O2 and H2 thrusts are aligned.

The thrust produced by the passivation of the H2 side through the combustion chamber is very efficient, with an initial thrust in the range of 100 N for an initial pressure at 1.8 bar; see fig. 14.

As described in [16], the tricky part of the maneuver is to optimize the sequence of the valves between H2 and 02 side in order to maximize the global ΔV; after an initial pressure drop, the liquid remaining in the tanks can regenerate and rebuild some pressure.

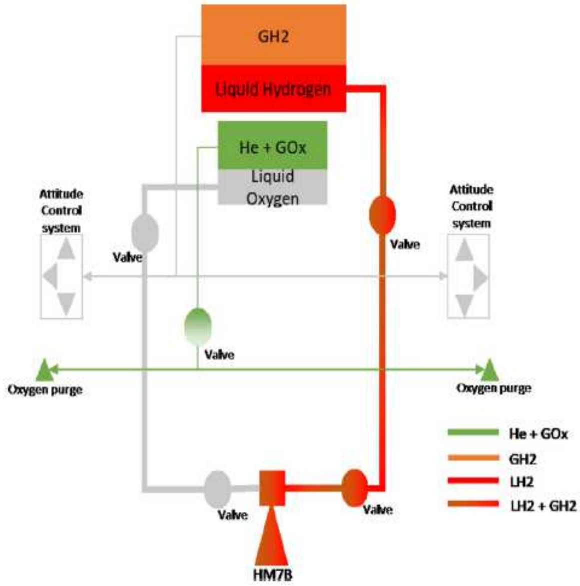

Figure 13. EOLM process for A5 ESCA

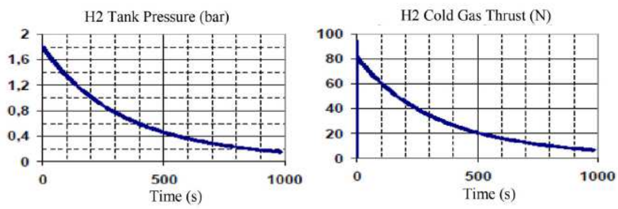

Figure 14. Pressure and thrust evolution on H2 side

A typical multi-boost strategy is shown in fig.15. The corresponding ΔV is in the range of 12 m/s for a nominal mission (standard statistical performance reserve).

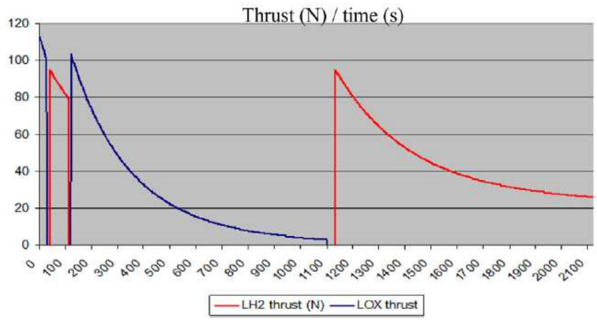

Figure 15. Example of a multi-boost EOLM strategy

This procedure appears to be very efficient; it has been applied so far 8 times, all successful, and will be applied on the 8 remaining Ariane 5 ECA missions planned today.

Fig. 16 displays the typical statistical result without (left) and with (right) this maneuver for the mission VA249; it is the result of a Monte-Carlo analysis with a number of draws (in X bar) large enough to guarantee the results with a 90% probability; lifetime (in Y bar) is given for each of the draws. It can be seen on this specific example that the residual lifetime for that mission was reduced from 32.65 to 14.2 years, as confirmed by the TLE analysis after flight.

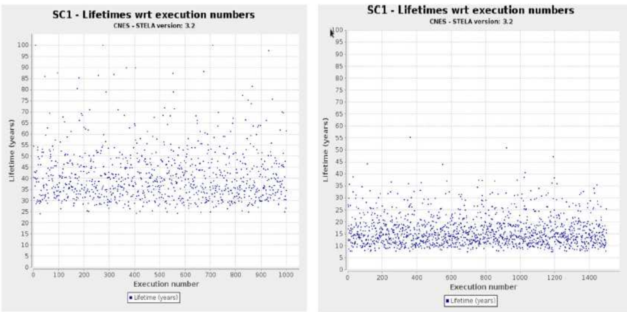

Figure 16. Typical change in ESCA residual lifetime without and with EOLM [16]

4 VEGA

The Vega launcher, deployed from the Guiana Space Center, utilizes a storable propellant upper stage called AVUM. Its mass is relatively small, in the range of 550 kg, and the casualty risk associated to its random reentry is very close to the casualty risk threshold, depending on mission inclination. It was nevertheless baselined to systematically perform a controlled deorbitation at the end of each mission within the LEO Protected Region. One AVUM is nevertheless still in orbit, but will comply with the 25-year rule and the 10^{-4} casualty risk, and two others did reenter in an un-controlled way.

Vega can also be equipped with a Dual Payload Structure called VESPA. Its upper part VUP is left in orbit, which is compliant with the principle identified in both ISO 24113 (ESA rules) and FSOA; the residual lifetime is usually low, as the Area-to-Mass Ratio is very high, and the associated casualty risk is largely below the threshold, so this operation is fully compliant with all the rules.

Fig.17 display general views of AVUM without its cover cone (left picture) and VESPA (two lower black structures on the right picture).

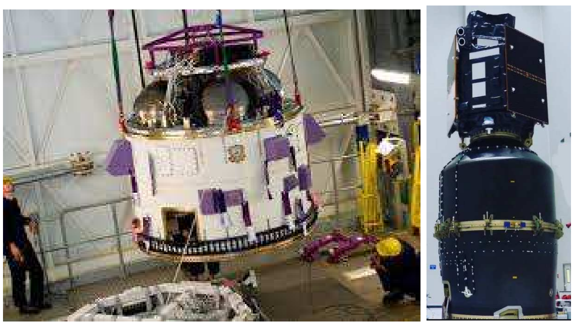

Figure 17. Vega. AVUM (left) and VESPA (right) - AVIO

Last, Vega has performed the maiden flight of its multiple payload dispenser SSMS during flight V16 on 2 September 2020. It enabled the launch of some 64 satellites, but did not generate any additional debris in orbit; the structure remained attached to the AVUM which was deorbited in a controlled way at the end of the mission.

5 NEAR FUTURE

5.1 Ariane 6

The new European heavy launcher Ariane 6 is currently under qualification and aims at soon replace Ariane 5 as Europe’s workhorse.

The Upper Liquid Propulsion Module ULPM is a large cryotechnic stage based on the new Vinci engine; this engine is reignitable 5 times in orbit, so it will allow a systematic controlled deorbiting of the upper stage for every mission passing through the LEO Protected Zone, as required.

There is no dedicated Attitude Control System, replaced by an Auxiliary Power Unit. As on every other European launcher, the batteries are passivated at the end of mission. The Double Payload Structure remains in orbit less than 25 years.

Ariane 6 therefore is fully compliant to all the applicable debris mitigation requirements.

5.2 Vega C

The qualification process of the evolution of Vega is currently ongoing, and the space debris related questions do not pose any problem. The new upper stage AVUM+ is slightly larger than the initial one, but has been conceived considering D4D (Design For Demise) constraints: the main propellant tanks are now in Aluminum instead of Titanium, which improves greatly the casualty risk on ground. Fig. 18 shows the Ariane 6 ULPM on the left (Vinci without its long nozzle) and the AVUM+ on the right.

Vega C is therefore also fully compliant to all the applicable space debris mitigation requirements.

Figure 18. Ariane 6 ULPM (left, ArianeGroup), Vega C AVUM+ (right, AVIO)

5.3 Space Rider

The last Space Transportation System currently under full development is the Space Rider. This reusable system, closely derived from the IXV which was launched successfully aboard Vega VV05 on 11 February 2004, is composed of two parts (see fig. 19): the reusable Orbital Module lands under parafoil at the end of its mission and before being readied for its following one; the Propulsion and Resource Module, derived from the AVUM+ with some additional functions (Power generation, telecommunications…) performs the deorbitation of the complete system, before being separated and re-entering in a controlled way in the Ocean, thus generating no casualty risk; no additional debris is released in orbit during the mission.

The design and operations of the Space Rider are fully compliant with our requirements.

Figure 19. Space Rider (AVIO)

6 CONCLUSION

European Agencies, Industries and Operators have taken the question of Space Debris Mitigation seriously, ever since the V16 H8 mishap in 1986, 9 months after the launch.

Coherent sets of Guidelines, Codes of Conduct, Standards and even Law on the French side have been developed. These rules are fully compliant with those established by our partners at international level, as the convergence process is permanently ongoing, through IADC, ECSS and ISO frameworks.

New launchers are announced in near future, as several “small” launchers are considered to cope with the foreseen drastic increase in space operations; there should also be new orbital stages, under the names of Kick-Stage, Motorized Dispenser, Orbital Transfer Vehicle… performing In-Orbit Servicing, assembly, repair, maybe even Active Debris Removal. One could even imagine Human Missions performed from the Guiana Space Center!

To face this domain extension of the use of our Space Transportation Systems, it is important to continue to work on evolutions of our Standards and Laws; the current activities dealing with their revisions testifies that this challenge has really been fully understood.

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