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# OPERATIONS OF THE ARIANE 4 THIRD STAGE FOR SPACE DEBRIS PREVENTION

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## ABSTRACT

Operations are performed by the ARIANE 4 third stage during the payload separation and avoidance phase to preserve the structural integrity of the tank common bulkhead. Modification of the ARIANE 4 launcher third stage have been developped in order to avoid tank fragmentation afterwards due to the pressure effects resulting from vapourization of LOX and LH2 residuals. The paper describes the investigations which led to this modification and the operating mode of the on-board devices.

## 1. EVENTS IN ORBIT

ARIANE 4 is a three stage vehicle with optional strap-on boosters ( solid and/or liquid ), designed for GTO, SSO and LEO missions.

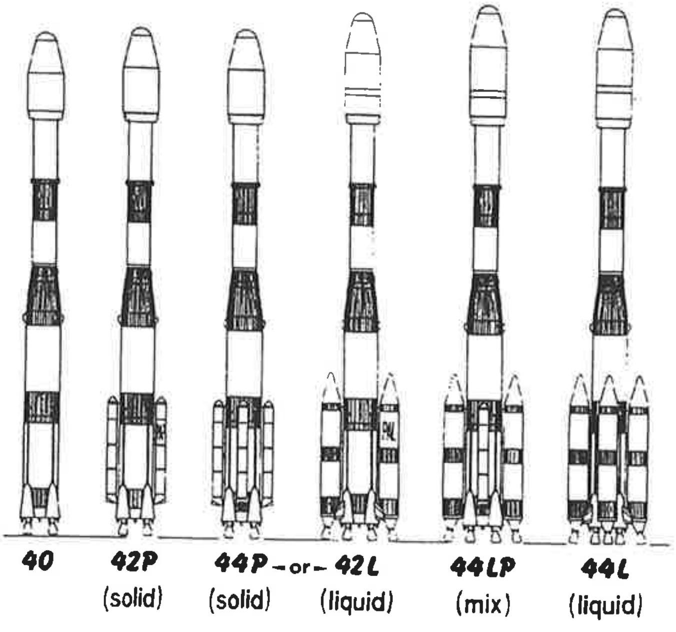



FIG. 1 : ARIANE 4 VERSIONS

While the spent lower stages fall naturally into the ocean, the upper composite is injected in orbit. ( See viewgraph 2 ).
In a general case ( dual launch, GTO ), there are four new objects in orbit : the two satellites, the SPELDA upper part with the upper adaptor and the largest part composed of the cryogenic third stage ( H10 ), the Vehicle Equipment Bay, the lower adaptor and the SPELDA lower part.

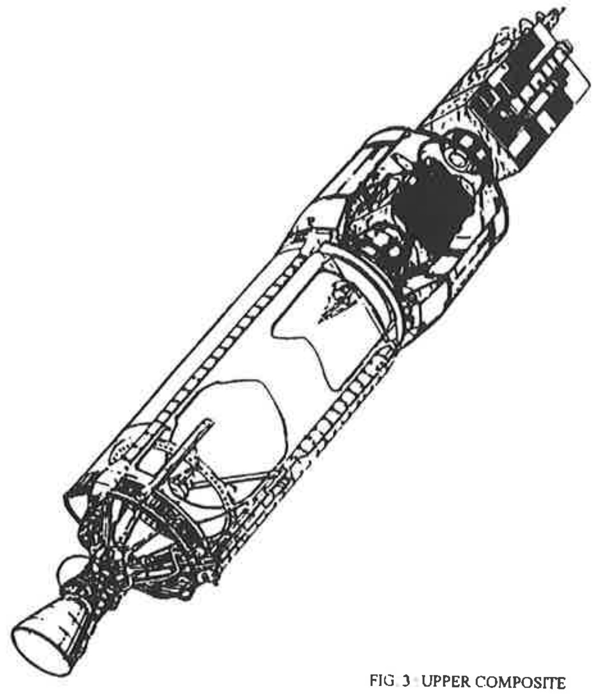


FIG. 3 : UPPER COMPOSITE

After burn-out, the H10 is still a hazardous space object because of the significant amount of LOX and LH2 residuals ( typically 280 kg ) which can generate fast pressure build-up in both parts of the tank. The common bulkhead configuration imposes that the difference of pressure between both sides stays within the specified limits.

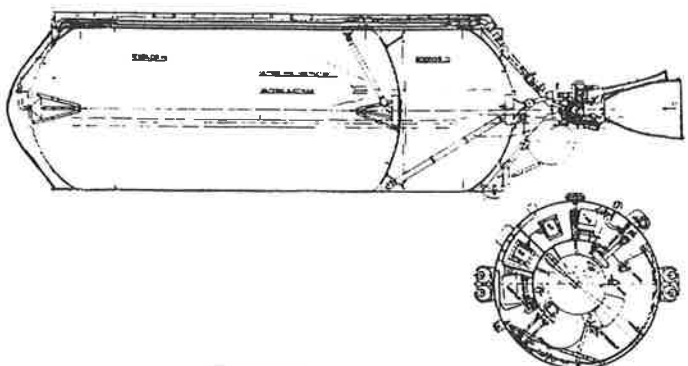
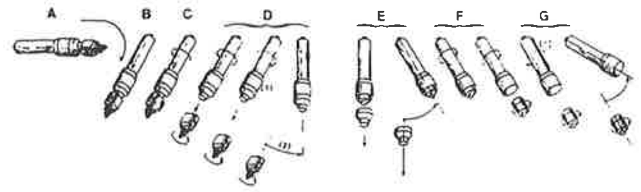


FIG. 4 : H10 TANK CONFIGURATION

The pressure evolutions have therefore to be well predicted to safely perform, by means of the roll attitude control system ( SCAR ), all the programmed manoeuvres leading to the payload separation and ending with the H10 avoidance phase.




A and B : Orientation of composite (3rd stage + payload) by 3rd stage roll and attitude control system (SCAR)
C : Spin up by action of SCAR (2)
D : Separation of upper spacecraft. Then spin down (1) and reorientation by action of SCAR
E : Upper SPELDA jettisoning. Reorientation as requested by inner spacecraft.
F : Spin up and separation of inner spacecraft.
G : 3rd stage avoidance maneuver (spin down, reorientation of 3rd stage, spin up at 5 rpm and Lox valves opening).
Note : Spacecraft separations can also be accommodated under a 3 axis stabilized configuration.

FIG. 5 : SCAR PHASE

When the H10, with the VEB, is definitively abandoned on its final orbit, pressure relief valves are expected to control the pressure build-up still generated by the residual propellants.

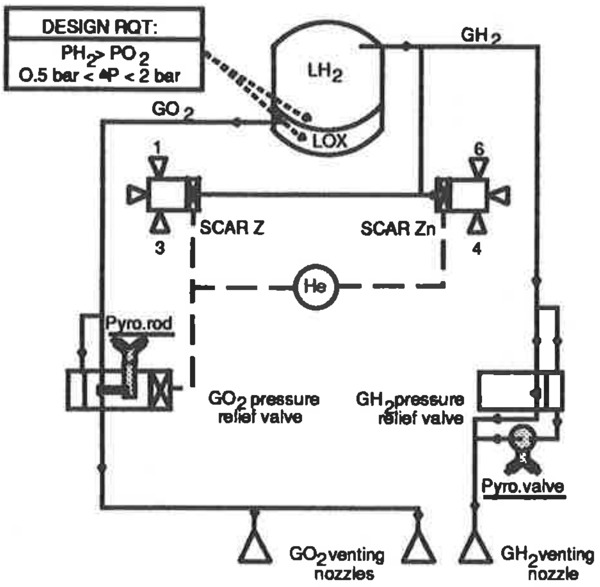



FIG. 6 : ARIANE 4 3rd STAGE PRESSURANT GAS VENTING SYSTEM

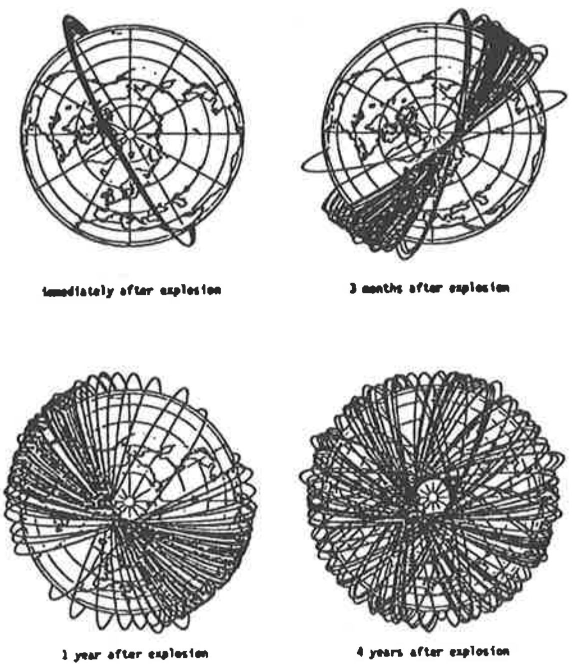
As time passes, the third stage and SPELDA are slowly deorbited because of the aerodynamic drag. All the objects in orbit are tracked by NORAD. The status of ARIANE third stages is the folllowing :

| DECAYED | LOST | EXPLODED (DESINTEGRATED) | CURRENTLY TRACKED |
|---|---|---|---|
| L01 - L03 - L04 - L07 - V9 - V19 - V20 - V21 - V29 | L08 - V14 | V16<br>(61 DEBRIS STILL TRACKED OUT OF 499 INITIALLY CATALOGUED) | ALL OTHERS<br>(EXCEPT: L02 - L5 - V15 - V18 - V36 = NO ORBITATION) |
| 9 | 2 | 1 | 38 |

Reference: ESA bulletin of space objects - issue 13 - Jan 93

FIG. 7 : STATUS OF ARIANE 3rd STAGE TRACKING BY NORAD (ARIANE LAUNCH STATUS: V55 - DEC 92)

The tank break-up of V16 in SSO, several months after the launch, has been identified during this tracking.




Reference: Report of the ESA Space Debris Working Group (ESA SP-1109 - NOV 88)

FIG. 8 : COMPUTER SIMULATION OF THE EVOLUTION OF FRAGMENT ORBITS FROM THE ARIANE V16 UPPER STAGE EXPLOSION

The important space pollution which resulted from the above explosion led to the decision of determining its origin in view of designing preventive measures.
The investigations, which were conducted by CNES and ARIANESPACE, in relation with NASA / NORAD permitted to determine the cause of the break-up.
They allowed to exclude the batteries and the pyrotechnic tank destruction system as possible causes of the explosion.
The more probable cause identified is either a tank wall rupture resulting from a thermal random cycling or a bulkhead rupture resulting from an overpressure on one side because of a possible leak in a propellant circuit.

It was therefore concluded that the more appropriate measure consists in rendering the tank fully inert by means of a complete draining just after the end of the mission.

## 2. ON-BOARD MODIFICATION

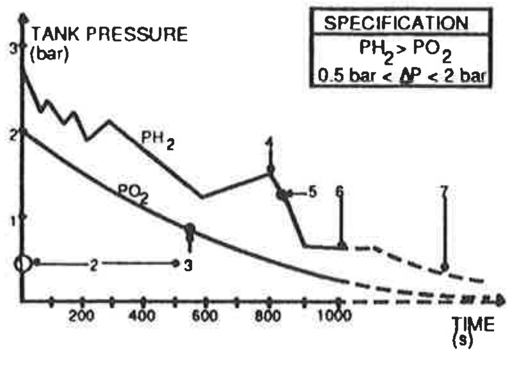
The selected modification called the " passivation " was developed in the frame of an ESA ARIANE 4 complementary development programme.
The calendar of the whole activity is the following :

- V16 launch : Febuary 86
- H10 Break-up : November 86
- CNES / AE working group : November 86 to July 87
- Modification design definition phase : Sept. 87 to Nov. 88
- Critical Design Review of the pyro rod : July 89
- Qualification steering committee : December 89
- First flight application ( V35 ) : January 90

The energy contained in the H10 comes from the vapourization of the residual propellants. The mean values of the main parameters at engine cut-off are :

| | HYDROGEN | OXYGEN |
|---|---|---|
| liquid mass | 120 kg | 160 kg |
| gas pressure | 2.7 bar | 2 bar |
| gas temperature | 150 K | 170 K |
| valve threshold | 3.3 bar | 2.35 bar |

The hydrogen is used for the SCAR manoeuvres.
The oxygen is vented by means of the controled pressure relief valve and gives longitudinal thrust during the SCAR phase.
The basic idea of the modification is to achieve the full depletion of the H10 tank.




Note: pressure/time scales not necessarily respected

EVENTS

① End of H10/Payload separation

② H10/Payload distancing phase (S34 commanded open)
Associated H10 attitude control (SCAR's)

③ S34 pyro rod firing (S34 blocked open)

④ Opening of SCAR 1+3+4+6

⑤ Closure of SCAR 1+3+4+6
S37 pyro valve firing (opened position)

⑥ New max H2 tank regulated pressure (approx. 0.6 bar)

⑦ Permanent GH2 leak through opened pyro valve (S37 closed)

FIG. 9 : ARIANE 4 3rd STAGE PASSIVATION SEQUENCE

To meet this requirement, valves are maintained open irrespective of the electrical and pneumatic energy available on - board.
The pressure relief valves have been fitted with pyrotechnic devices which allow definite depletion and depressuration of the tank.
The operating sequence is added to the standard one with an appropriate timing such that the difference of pressure between both tank parts still meets the bulkhead design requirements.
The LH2 pressure relief valve is linked to a venting pipe composed of two tubes which are normally sealed. The pyro-rod cuts the end of the two tubes. After that, the tank pressure decrease through the venting pipe.
The LOX controled pressure relief valve is opened upon an electrical command. After that, the pyro-rod extends and blocks the valve in open position.

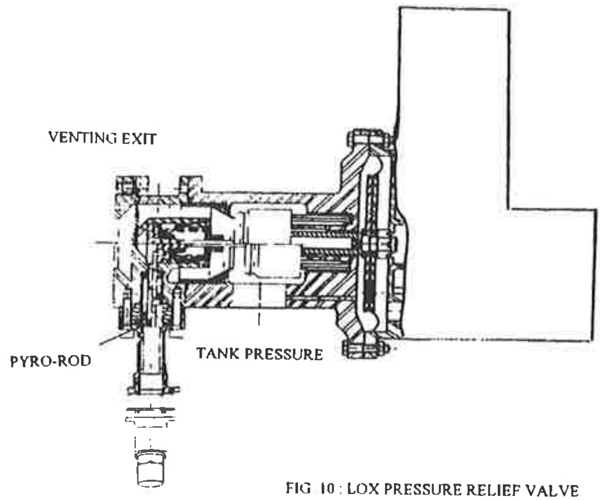



FIG 10 : LOX PRESSURE RELIEF VALVE

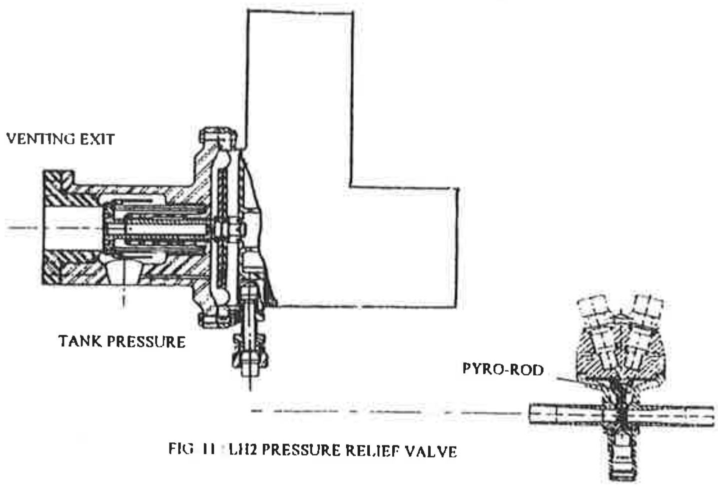



FIG 11 : LH2 PRESSURE RELIEF VALVE

For the time being, the application of this passivation measure is limited to SSO and LEO missions of the ARIANE 40 version, because at first of the availability of the four additional pyro circuits which are needed ( use of circuits normally allocated to boosters ), then because of the critical aspect of the space pollution in low orbits. So far, this passivation measure has been successfully implemented on V35, V44 and V52.

The flight data of V52 are here under.

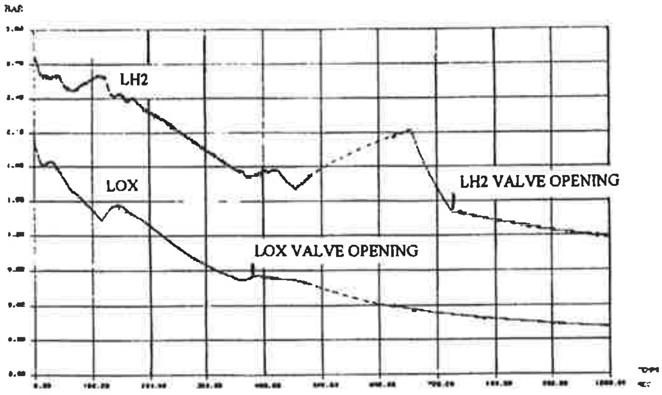



FIG. 12 : H10 TANK PRESSURE EVOLUTION

REFERENCE TIME H3 ( H10 ENGINE CUT-OFF )

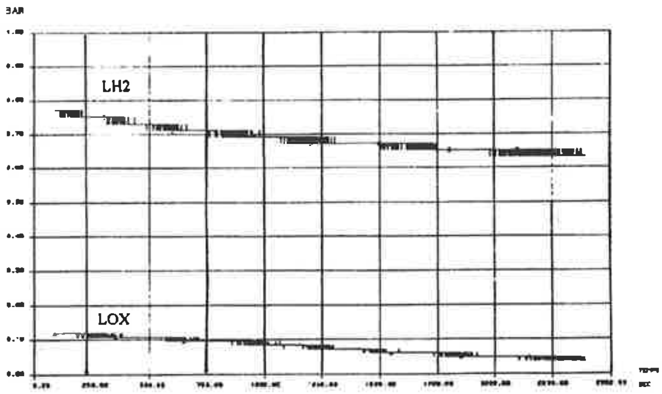



FIG. 13 : H10 TANK PRESSURE EVOLUTION

REFERENCE TIME H0+7000 s ( H0 : FIRST STAGE IGNITION )

The next application is foreseen with V59 / SPOT3 in SSO ( Sept. 93 ). Afterwards, from V60 ( Oct. 93 ) onwards, all the ARIANE 4 launchers will include this passivation means which will be systematically applied for all the missions, including GTO missions.

| | LAUNCH | LAUNCHER VERSION | ORBIT | LAUNCH DATE | PASSIVATION SYSTEM PERFORMANCE |
|---|---|---|---|---|---|
| PERFORMED | V35<br>V44<br>V52 | AR 40<br>AR 40<br>AR 42P | SSO<br>SSO<br>QUASI CIRCULAR (approx. 1330 KM - 60°) | JAN 90<br>JUL 91<br>AUG 92 | OK<br>OK<br>OK |
| PLANNED | V59<br>V60<br>SUBSEQUENT FLIGHTS | AR 40<br>AR 44LP<br>ALL | SSO<br>GTO<br>ALL | SEP 93<br>OCT 93<br>etc. | |

FIG. 14 : APPLICATION STATUS OF THE ARIANE 4 3rd STAGE PASSIVATION SYSTEM

This achievement is the ARIANE 4 contribution to the European efforts which are made for limiting the creation of space debris.