A NEW DESIGN OF SPACE EQUIPMENT FOR RAPID DISINTEGRATION IN ATMOSPHERE AFTER REENTRY

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ABSTRACT

The present intensification of space activities generated an important problem: Disintegration of space debris after re-entry into Earth's atmosphere. After the end of operational life, satellites re-enter the Earth atmosphere and are disintegrated by the high temperature produced by friction with air. Final rocket stages become space debris after exhausting the propellant and are also disintegrated into air. On average, one piece of space debris enters the Earth atmosphere every day. In many cases, some solid pieces of space debris having a considerable mass were found on the ground. Complete disintegration of space debris into the atmosphere is absolutely necessary in order to prevent accidents caused by impacts on populated areas.
This paper proposes a new design for a rapid disintegration of space equipment after re-entry. During re-entry the configuration of space equipment is changing through opening of some articulated doors for reaching of high stagnation temperature of air captured inside followed by a rapid disintegration in air.

KEYWORDS: fast space debris disintegration, debris re-entry, increasing of disintegration speed of space debris

1. INTRODUCTION

Today, the growth of space activities is exponential. This growth generated an important problem: The need for rapid disintegration of space debris after re-entry in Earth's atmosphere. Space debris is non functional manmade objects or fragments of such objects. Only 6% of catalogued objects are functional, the rest of them are space debris. [1] At the end of operational life, satellites re-enter the Earth's atmosphere being disintegrated through burning initiated by the friction with air. This is happening for final rocket stages which become space debris after consuming of propellant. In many cases the space debris fallen on ground had large dimensions (helium tank, thrust chamber, propellant tank, pressure sphere). [2]
It is known that the lifetime on orbit of a manmade object can be very long. For example, satellites of the SPOT family which are placed on a Sun-synchronous orbit can orbit about 200 years at 822 km altitude representing a high risk for other satellites. [3] Although regulations were issued for direct deorbiting of satellites after finishing of operational life these regulations do not solve the need of rapid burning of satellite in atmosphere being possible as fragments to fall on ground. [4]. A proposal for solving this problem was issued by ESA through the so called 'design for demise' [5]. According to this concept, design of a space system must take into account the on-ground safety requirements. The design for demise proposes separation of satellite in components due to the centrifugal forces produced during re-entry. This concept does not respond to the need of rapid burning of satellite in atmosphere for reduction of possibility as large fragments to reach the ground.
In this paper, the authors propose a new design for rapid disintegration of space debris after re-entry. This new design is inspired by the cause leading to the disintegration of Space Shuttle Columbia, which occurred on the 1st of February, 2003 [6]. Columbia disintegrated over Texas and Louisiana when it re-entered the Earth atmosphere. During launch, a piece of foam insulation struck the left wing of the orbiter deteriorating its ablative protection. [6]. When the space shuttle re-entered the Earth atmosphere, this damage allowed hot air to penetrate into the wing creating an irregular hole. In this way, air entered the left wing with high speed, became very hot when stagnating and destroyed the internal structure of wing.

2. THE DISASTER OF SPACE SHUTTLE COLUMBIA AND LESSONS LEARNT

During re-entry, shock waves produced by hypersonic velocities and the frictional effect of the atmosphere began to heat the surface of Columbia space shuttle [7]. The temperatures varied depending on location: The orbiter's nose and leading edges of the wings experiencing temperatures greater than 1,538°C [7].
At this phase, the breach created during launching in the ablative protection of the left wing allowed to hot gases to penetrate the wing and to advance in same direction inside the wing and to the mid of fuselage (Fig.1). [7] This caused significant damages. This phase ca be named 'phase I' from 'Initialization'.

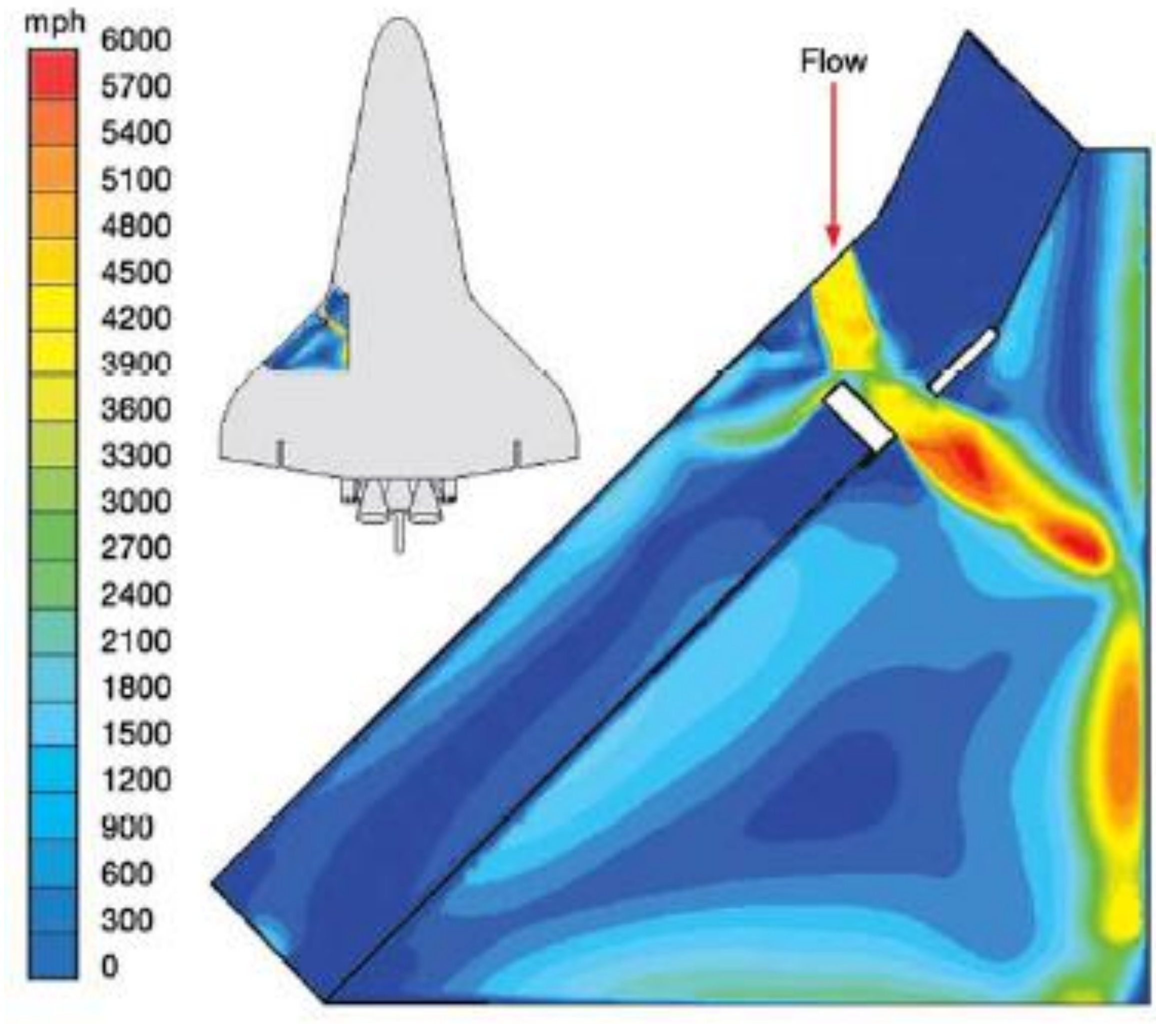

Figure 1:Temperature of left wing at the beginning of disaster (phase I) [7]

During this phase the wing lost its aerodynamic characteristics and the initiation of destruction process was extremely short, lasting from 13:59:37.5 GMT to 13:59:39.7 GMT (2.2 s)-Fig.2 [7].
After phase I, the process was accelerated as it is shown in Fig.3. [7] This phase can be named 'phase A' from 'Acceleration'. In the case of Columbia this phase lasted 0.07 s.
The destruction process continued with total dispersal of space vehicle and burning in atmosphere (Fig.4). This phase can be named 'phase D' from 'Dispersal'. In the case of Columbia this process lasted 55 s.

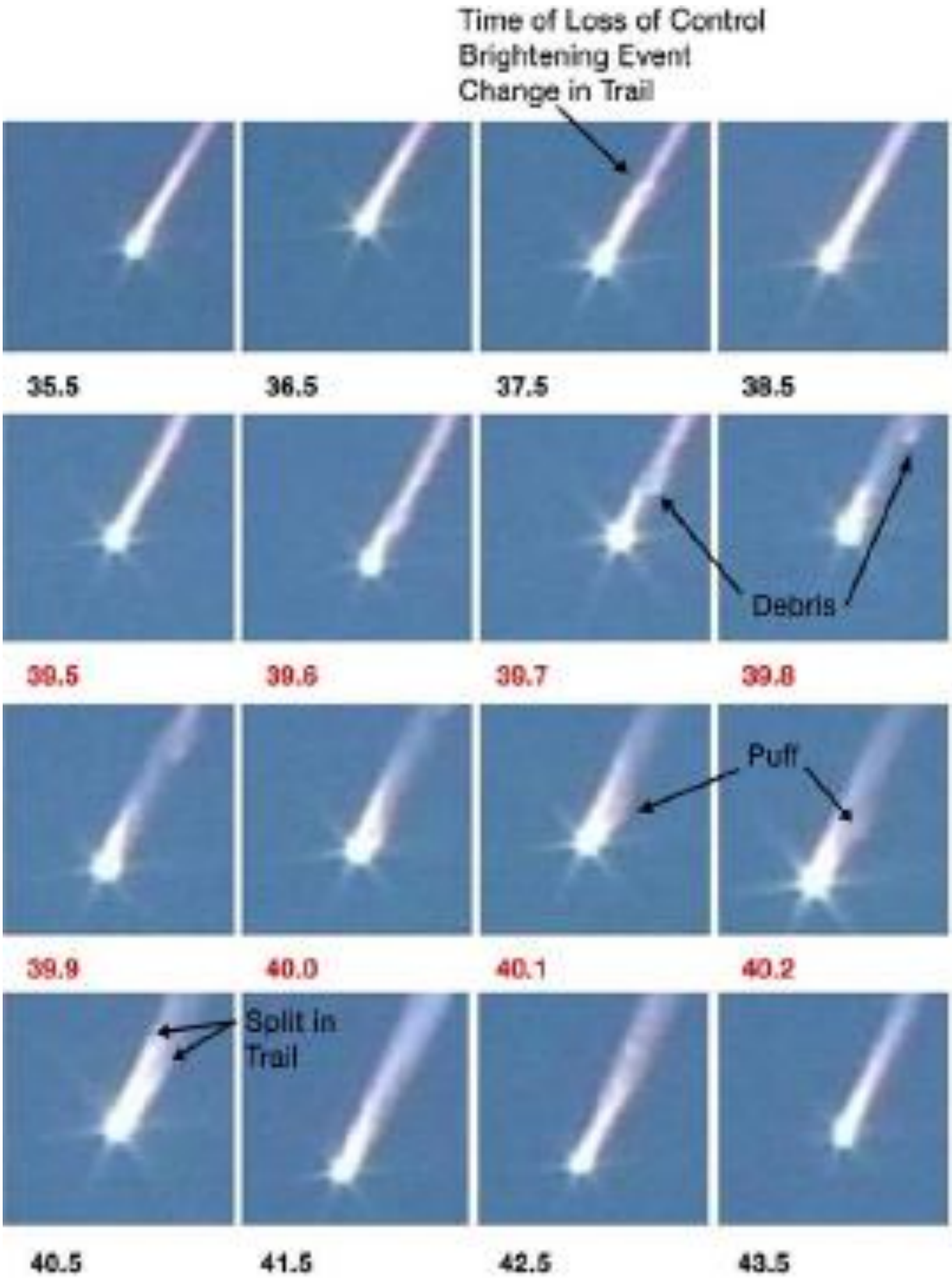

Figure 2: Sequences of initiation of destruction process (phase I) [7]

Figure: 3-Acceleration of destruction process (phase A) [7]

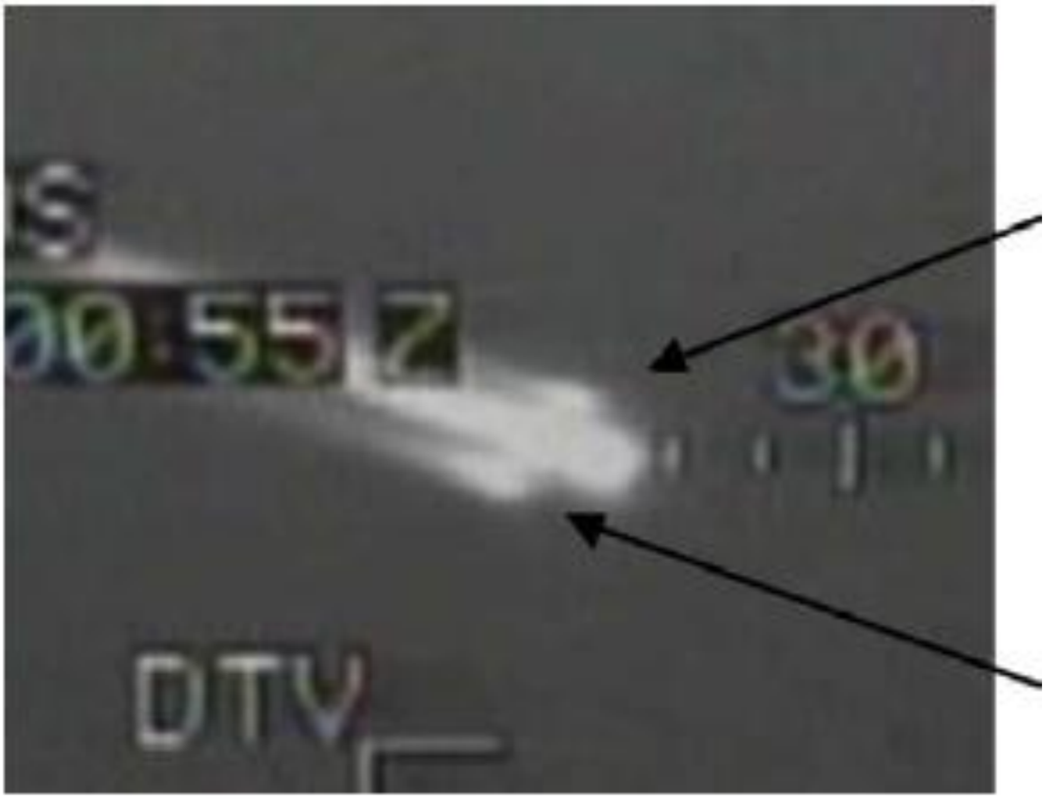

Figure 4: Total dispersal phase (phase D) [7]

3. PRESENTATION OF NEW DESIGN FOR SPACE EQUIPMENT

The difficulties of space removal led to 'Design for dismissal' concept. The present paper presents a new vision of this concept.

Taking as example a satellite, it is known that its equipments are covered by a protection box which shields them against environmental factors: cosmic radiation, solar wind, light (ultraviolet, visible, infrared), dust and rarefied atmosphere.

Usually this box is a prism which has a pretty low dynamic drag. As a result, the reaching of high temperatures on satellite surface is delayed, therefore satellite disintegration is delayed. The situation is even more critical in the case of the last stages of launching rockets which have a good aerodynamic shape for a low aerodynamic drag during ascending phase of rocket.

According to the space equipment design presented in this paper, special doors must be incorporated in the external fairing of space equipment. The holes in fairings can have any shape (rectangular, triangular, hexagonal, circular and other) depending on the position of the fairing of space equipment. Doors fitted on every hole must be articulated by the fairing of space equipment. The articulation must be cylindrical, i.e., to permit rotating of door around an axis. The articulation must permit opening the door to the interior of box when pressure on external face of fairing increases and closing the door when the pressure inside the fairing is higher than the external pressure.

The door has a special shape being fixed by fairing through brazing with low fusible metals or strong resins (Araldite, Loctite) which are decomposed at low temperatures (150…200°C to maximum 700°C in some special cases). Both the resins and metallic alloys must be extremely resistant at low temperatures but must lose their strength when temperature reaches several hundred of Celsius degrees. In the early stages of re-entry, the epoxy resins decompose at temperatures between 150…200 °C and the braze alloys are melting when the local temperature reaches 200…700 °C. As a result, the covers are pushed inside the fairing of space equipment and the external air enters inside where stagnates reaching extremely high temperatures. The new external geometry of space equipment leads to increasing of aerodynamic drag and converts kinetic energy into heat, which enhances burning of equipment in atmosphere.

There are more doors placed on the fairing of space equipment. Thus, no matter how space equipment might rotate during re-entry, when one door is opened by the dynamic pressure, the rest of doors are closed by the same dynamic pressure. Thus, the inside heating due to air stagnation is maximum, leading to the rapid disintegration of space equipment.
In the case when covers are not articulated, they are pushed inside the equipment by the pressure of ambient air. In this way, the air begins to flow through the interior around the components of space equipment. In such a situation the air does not stagnate inside the space equipment and dynamic drag is low. For this reason the heating rate will be lower than when articulated covers are used.
Disintegration of space equipment will be even faster if the components of satellites are wrapped in 0.05 mm thick foil made of aluminium or magnesium. These light-weight foils will be burned firstly leading to a fast disintegration and burning of the component of space debris. This new technology clearly can be clearly understood from Figs. 5…9. Applying of this design will determine space debris to be disintegrated according to phases I, A, D which were observed in the case of Columbia.

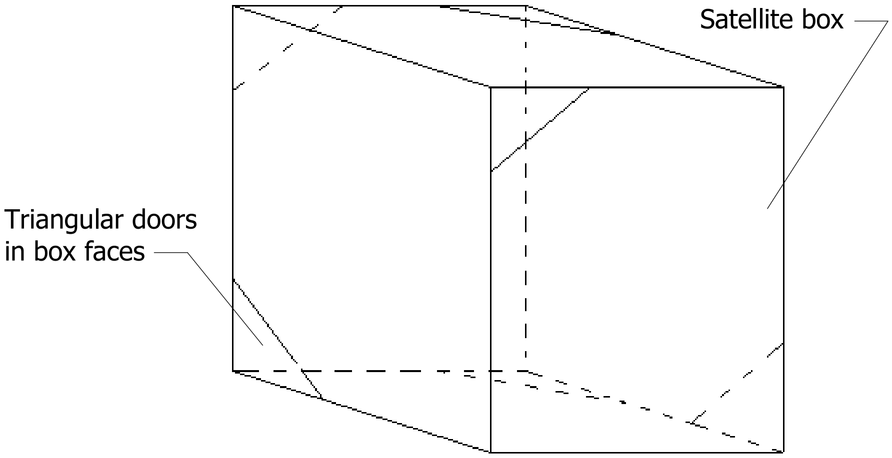

Figure 5: Example of satellite box with doors

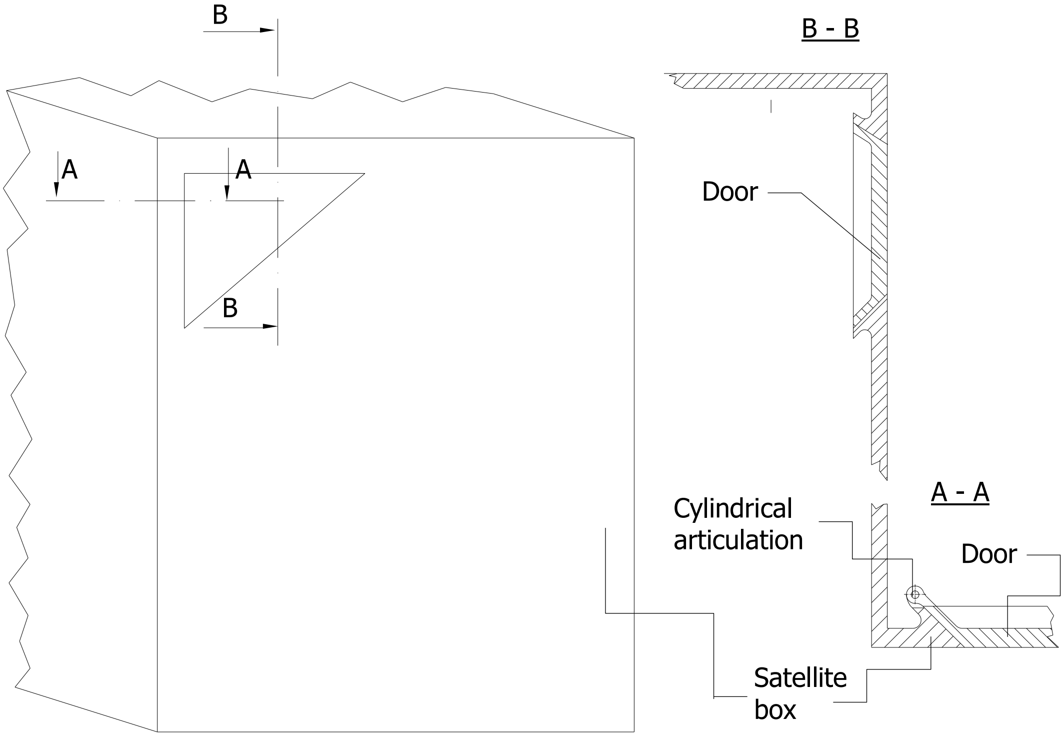

Figure 6: Design of doors

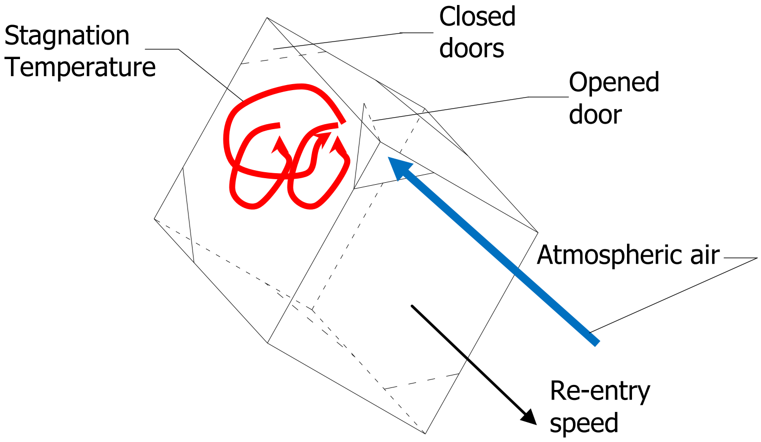

Figure 7: Reaching of stagnation temperatures inside a satellite box

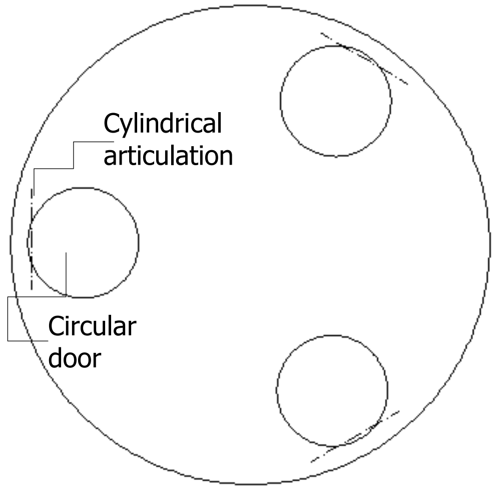

Figure 8: Example of fuel tank with circular doors

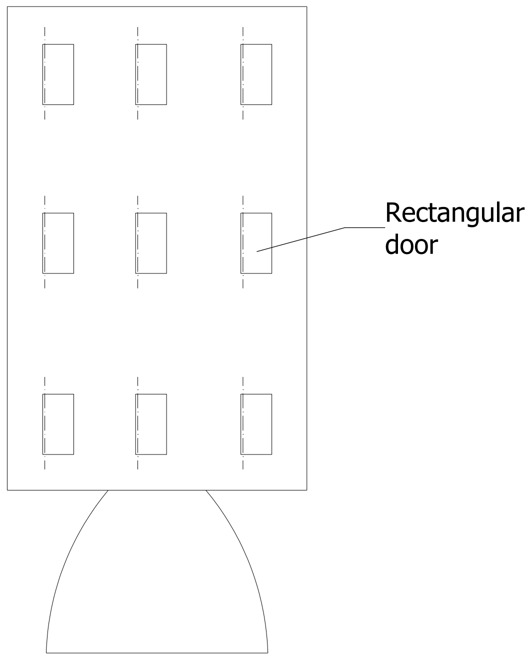

Figure 9: Example of last stage of rocket with rectangular doors

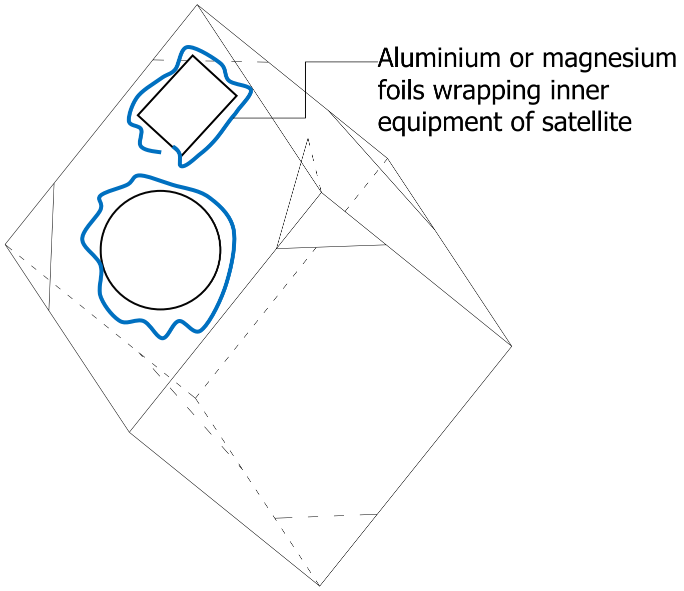

Figure 10: Example of satellite equipment wrapped by aluminium or magnesium foil

5. CONCLUSIONS

▪For rapid disintegration of dismissed space equipment, multiple doors must be placed on the external surface of equipment.

▪All the doors must open to the interior of equipment. In this way stagnation temperature are reached inside disregard the position of equipment during re-entry.

▪The doors are glued with strong epoxy materials or are brazed with low melting temperature metallic alloys. During re-entry these materials are decomposed or ate melted due heating freeing the doors.

▪For a faster burning, internal assemblies of space equipment can be wrapped in aluminium or magnesium foil.

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