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FROM SCREW TO SATELLITE - SPACE DEBRIS MITIGATION SOLUTIONS TO A MULTI-SCALE PROBLEM

Abstract

The atmospheric re-entry of satellites is a complex process that if not addressed properly can cause human casualties. The consequence for operators, agencies and satellite manufacturers is to consider corresponding requirements throughout the entire satellite lifecycle. This paper describes recent insights into the phenomenology of satellite re-entry on multiple geometric scales and highlights which technical solutions can help mitigate the associated risks. The paper focusses on highlighting the multi-scale and highly probabilistic nature of a re-entry and the fact that solutions on all levels need to take this into account in order to build a safe mission. It is concluded that the casualty risk requirement is best controlled by providing a casualty risk budget that evolves throughout the mission lifecycle.

The term design for demise encompasses a wide range of technical solutions that promote ablation or melting of spacecraft parts that could reach Earth's surface. The first and in many cases simplest solution is a design modification of the particular unit surviving re-entry. In some cases this might not be possible due to other constraints. Or, it might not be enough because the unit is well shielded within the structure when integrated on the satellite. In this case system-level design changes can provide additional benefits to the demisability. These can be implemented either by using existing units in a different way or by introducing new components to enforce better demisability. An example here is demisable joints. Such joints will need to be designed to work with a given reliability knowing that the level of heat transported to each joint during re-entry is highly random and depends on many uncontrollable parameters. Finally, the planning and execution of mission operations have to be considered when determining the casualty risk. In certain cases they can be a means to make a satellite mission compliant to requirements.

The goal of the casualty risk budget is to identify drivers for the on-ground casualty risk and track their evolution throughout the design lifecycle. With the knowledge of effects of design for demise techniques

the satellite manufacturer is then able to create a compliant design. At the same time the budget will also include margins to account for uncertainties related to the types of analysis tools used throughout the lifecycle.