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Improved Representation of Destructive Spacecraft Re-entry from Analysis of High Enthalpy Wind Tunnel Tests of Spacecraft and Equipment

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Abstract

The assessment of casualty risk in destructive re-entry has historically been performed purely by simulation using heating correlations, which only have verification on basic shapes, and estimated phenomenology for fragmentation. As the application of space debris mitigation requirements is expected to result in a higher number of re-entries, this has brought a stricter enforcement of the casualty risk guidelines to proposed missions. In turn, this has increased the interest in designing spacecraft to demise in re-entry in order to allow uncontrolled re-entries to be performed. Initial testing of spacecraft materials and basic structures has demonstrated that the destructive re-entry tools do not capture the correct physics to be able to assist design in a meaningful way, and therefore, some means to improve the representativeness of the tools is required. The current understanding of the phenomenology of the fragmentation and demise processes is limited. As a consequence, it is vital to perform appropriate tests in order to improve the capability of the tools to assist the design process. To this end, a set of destructive tests on spacecraft materials, structures and components has been performed in an arc-heated supersonic wind tunnel. These tests include the first destructive wind tunnel tests ever performed on a complete nano-satellite and on a reaction wheel. From these tests, it has been determined that the failure of aluminium structures is highly dependent upon the behaviour of the protective metal oxide layer, and that this can be catastrophic in nature. The tests on the nano-satellite have shown that the structure can be supported by stainless steel spacers between the electronics cards, and that glass fibre reinforced plastic PCBs are more resistant to melting than had been anticipated. The reaction wheel test has shown that the connections between parts are critical to the fragmentation and demise processes, as the glued housing separates quickly, well before melt temperature is reached at the joint. It has also demonstrated the importance of radiative cooling, as the flywheel and ball-bearing unit have survived a test at over 800kW/m^2 with little damage.
Keywords: aerothermodynamics, aerothermal testing, design for demise, spacecraft equipment