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Responsive Development of Optimized Small Spacecraft through Balanced Ad-hoc and Strategic Re-Use with Model-Based System Engineering for Planetary Defence, Science and Emerging Applications

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ABSTRACT

Planetary Defence scenarions are perhaps most connected to responsive space projects in the popular mind. Some early studies envisaged ad-hoc re-use of the largest spaceflight infrastructures and devices on the planet. The expectation was to deflect or destroy km-sized asteroids on the final inbound leg of their trajectory.
Since, space has become more sophisticated, considered, standardized and efficient; detractors might say smaller, slower, less ambitious, less inclined to take a measured risk. Paradoxically, exercises at previous PDCs hinted at that the daily space buisiness approach so successful in scientific and commercial missions, when coupled with international decisionmaking could actually force the situation envisaged in the early days: the clear and present need for a borderline-late massive strike.

Clearly, a third way is needed to provide early confidence in decisionmaking by responsive characterization of the potential impactor through in-situ observation and support, e.g. planetary radar transponder placement. Likely, a chain of missions is required from first look to confirmed mitigation, with sequential development depending on previous missions' results.

Space missions are not one-of-a-kind. Venus Express demonstrated cost-effective reuse of existing hardware in a new context. Based on the Mars Express Flight Spare, it was a case of ad-hoc re-use.
The more re-use is handled strategically, the more gain is expected. The platform approach as in geostationary telecommunication satellites benefits from a strategic reuse of design knowledge and hardware in missions with high and pre-defined commonality. It requires strategic variant management, certain design principles, e.g. modularity, proper knowledge management, and accessibility of the system and domain engineering artefacts.
In between, there is a spectrum of re-use at unit-level granularity by flight heritage which applies to scientific instruments and bus units. Measured deviations from 1:1 copy-building are employed to adapt to the next mission. Still, comprehensive unit design information exists while the new mission is at the concept stage.

We describe re-use cases from our projects, including the MASCOT-follow-on and the S2TEP case. Currently, MASCOT's heritage generates strong interest for future small body missions; ad-hoc reuse with the potential to evolve into systematic reuse. Conversely, the Small Satellite Technology Platform (S2TEP), currently in its definition phase, can be classified as systematic reuse case. Its goal is to realise a set of rapidly recurring missions in low Earth orbit.

Responsiveness is desirable or required not only in unlikely Planetary Defence situations. The accelerated publication requirements of science evaluations as well as the emerging space start-up markets push an increasing importance of design re-use through fast mission cycles. Re-use needs to be fostered by effective engineering methods and processes. The MASCOT2 reuse case has provided insights into re-use requirements which are mapped to typical Model Based Systems Engineering (MBSE) features. MBSE thus promotes more effective re-use of heritage systems as compared to the classical Document-Centric Systems Engineering, leading to key areas where MBSE can provide benefits and an overall approach regarding tools and development processes.

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