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On the concepts of a highly integrated payload suite for use in future planetary missions: The example of the BepiColombo Mercury planetary orbiter

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Abstract

Future low resource payload concepts will need to be developed from the viewpoint of a standard integrated payload suite where resources are dramatically reduced through high levels of integration and resource sharing. The study of this approach, its gains together with its limitations was the key objective of this work. The highly compact integration of a specific payload suite was carried out during a reassessment of the technical realisation of all instruments required to form part of the BepiColombo planetary orbiter payload (MPO) for the exploration of Mercury. A study of the heritage of other instruments developed for other missions such as Mars Express and ROSETTA was the precursor to enable identification of typical resource drivers and related problems or technology requirements. Innovative technologies aboard SMART-1 or other technology demonstration reference missions were also taken into account for their potential in miniaturisation without sacrificing performance. In the specific example of the BepiColombo Mercury Planetary Orbiter (MPO) the resource reduction by a Highly Integrated Payload Suite (HIPS) was addressed. Here we give a review on the basic concept and a comparison to the classical approach.

1. Introduction

On most recent missions such as e.g. ROSETTA, Mars Express, SOHO, and Herschel/Planck, individual instruments were developed usually on the basis of the heritage of instruments from former missions. This concept reduces in principle development times and development costs to a minimum while allowing a maturing of instrument capability and performance through actual flight performance assessment. On the other hand, only a limited evolution through new technologies can be supported and these have both cost and technical difficulties to be implemented in the usually tight schedules associated with Payload (P/L) and Spacecraft (S/C) developments. Additionally, the

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weight of typical payloads is considerably larger than what would be possible if both P/L and S/C would be assessed from a system level in the very beginning in the assessment or concept phase, before the design phase of all instruments starts. The idea of a small S/C is not new and was addressed earlier [1–3] and several missions were initiated or developed in order to demonstrate the feasibility of the small satellite concept. A historical overview of the developments in the United States is given in [4]. Here the costs of μSats are compared to the costs of larger satellites with higher performance. Of course one obvious advantage of small satellites is that within the same budget, more satellites can be launched, which reduces the risk of failures (at all mission levels). This approach could allow a phased and systematic approach to the exploration of the planetary bodies of the solar system. The other main advantages of small satellites are:

- (I) Reduced mission preparation time.
- (II) Smaller effective project and industrial teams.
- (III) Interface reduction and standardisation.
- (IV) System level aspects are addressed in a timely and multi-mission manner.
- (V) Reduced number of different components (space qualification facilitated).
- (VI) Reduced launch costs.
- (VII) More frequent and faster launch possibilities (more recent technologies can be employed).

Although there is a general consensus on the potential for resource reduction through sharing and miniaturisation, there is still a debate about the effectiveness and the associated risk, if new technologies need to be employed. As an example the Clementine mission to the Moon was built within 22 months according to a μSat concept and has cost only $\frac{2}{3}$ of a conventional mission, although it has a rather complex payload [4]. It is also well known that the integration, testing and documentation of missions with payloads comprising discrete separate instruments is tremendous and that interface definition can take years; in fact the mass of the interface control documents exceeds sometimes that of the spacecraft.

Since a change in this P/L concept influences the whole chain involving P/L and S/C development including technology issues as well as P/L procurement approaches, it is also highly desirable to understand the impacts of such a new approach. For this reason these aspects of such a system level P/L concept are studied by deriving a preliminary architecture of a Highly Integrated Payload Suite (HIPS) for the BepiColombo Mercury Planetary Orbiter (MPO) with a view to establishing the development, assembly and verification tasks required. This MPO payload serves as a typical example, which could be designed either in a classical manner or using a highly integrated (HIPS) approach. A miniaturised or highly integrated P/L does not necessarily fit the conventional S/C, so that it may demand also a revised S/C architecture. This could become expensive if proven S/C technologies (such as for example communications or AOCS) have to be adapted or miniaturised. One has therefore to be aware of the consequences and the need of a general technology development programme dedicated to P/L and S/C technologies. And to be fair, squeezing of the payload resources must be balanced by the measures taken for the S/C. Last but not least the procurement approach and the integration into the S/C must be adapted so as to facilitate the process so as to maximise the full benefit from this approach. A careful balance must be found, which allows the utilisation of the simplest P/L and S/C design, while not reducing the resources too much, and retaining the overall performance such that the scientific requirements can be met. Finally, if multiple missions become affordable, these could be tuned to different scientific requirements and purposes, such that negative interactions (e.g. EMC, magnetic or thermal environment) of instrumentation can be reduced through more focussed missions with dedicated tasks.

2. Payload instrumentation

The initial accommodation of the scientific payload onboard of the MPO was based on the concept of a collection of independent instruments provided by Principal Investigators. In an alternative new approach these instruments are merged onto one platform sharing resources as much as possible. This, together with the introduction of new advanced technologies has led to a significant reduction in mass and power requirements. Clearly, physical principles have to be respected and cannot be changed such as aperture diameters and collection areas. The instrument performances have been addressed and are presented elsewhere within this