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THE EUROPEAN SPACE AGENCY STANDARD FOR SPACE PACKET UTILISATION

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ABSTRACT

This paper presents the ESA concept for the use of CCSDS defined Telemetry and Telecommand Packets at the application level. These Packets are used to monitor and control remotely a spaceborn application. This concept is defined in a Packet Utilisation Standard (PUS) which should become applicable for all ESA missions using Packets. The production of this standard is under the responsibility of an ESA standardisation group called "COES".

Keywords: Packet Utilisation, Packet Type, Parameter, Packet Structure, COES.

1. INTRODUCTION

The usual way to monitor a spacecraft, is to get parameters via the Time Division Multiplexed Telemetry. Similarly the control function is performed by telecommand frames containing basic instructions to the spacecraft. This constitutes actually a remote monitoring and control of on-board electronics.

However, on-board software is used more and more to address specialised complex functions which could otherwise hardly be operated from ground.

Up to now, because of no other choice, on-board software is remotely monitored and controlled using the classical electronic oriented sampling mechanism and bus commands. Rapidly it became clear that this imposes heavy constraints on the on-board software implementation, limiting its flexibility and consequently hampers the trend towards more on-board intelligence and autonomy.

In order to overcome this situation, the Consultative Committee for Space Data Systems (CCSDS) recommended the use of Telemetry (TLM) and Telecommand (TLC) Packets and specified precisely how such Packets should be transmitted between space and ground. Those Packets will mostly contain software data of which structure and format will have a significant impact on the software architecture on board, but also on ground.

However, making things more flexible leads to the possibility of implementing a given control function in many different ways. Anticipating this potential problem, ESA decided to address this point in one standardisation committee (COES) and to produce a Packet Utilisation Standard which recommends to users of Packets general rules governing the exchange of Packets between space and ground, as well as the data structure and format to be used within the Packets. It also recommends specific Packets for specific but commonly used functions.

This standard should also enable the implementation of a clean software architecture on board and on ground much more adapted to on-board intelligence and autonomy.

2. PROBLEM CAUSED BY THE USE OF PACKETS

Until a few years ago, satellites had only limited on-board processing capabilities. The Telemetry was essential on-board device digital readouts (e.g. sensors, switches, payload hardware etc.) sampled at fixed regular intervals and multiplexed at fixed positions in a telemetry frame. Similarly the Telecommand contained fixed length data words which were supposed to load on-board registers (for a specific device) or to enable/ disable switches. With this technique it was possible from ground to monitor and control remotely on-board devices (Fig. 1). However, the as-

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sociated space-ground communication technique of the Telemetry and Telecommand data did not guaranty a safe and complete transmission of data.

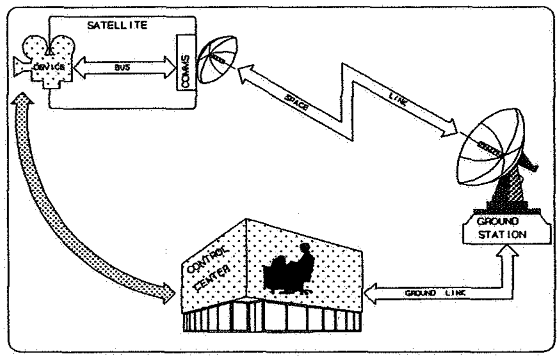

Fig.1 : Remote Control of a Device

With the advent of more complex on-board processors and thus software, the need arose to exchange data of a different nature (generated by software) between space and ground which requires a more flexible transmission capability (e.g. variable content, asynchronous generation) and consequently a transmission technique of better quality (e.g. error-free and complete). In fact, one does not control on-board devices directly but rather through on-board software. What was needed is a technique to enable a remote monitoring and control of on-board software (Fig. 2).

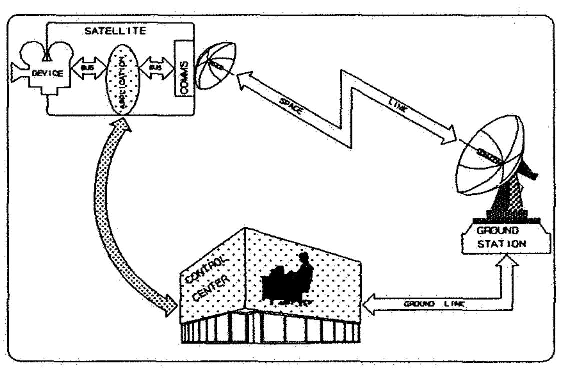

Fig. 2 : Remote Control of an Application

The Consultative Committee for Space Data Systems (CCSDS) has defined and recommended the use of Telemetry Packets (Ref. 4) and Telecommand Packets (Ref. 5) which is a space-ground high quality communication technique enabling a flexible exchange of data between an on-board Application (usually software) and a ground system (also software). However, nothing is said on the content of these Packets and according to which principle they should be exchanged.

This is now the key problem. Since this aspect will largely determine the system architecture on board and on ground and also to some extent the functionality, it will not be possible to achieve common infrastructures (e.g. ground control centres) reusable for different missions, in absence of recommendations on the content of Packets and the way they are exchanged.

3. ROLE OF THE C.O.E.S. STANDARDISATION GROUP

In 1987 an intra-agency standardisation group was created; the Committee for Operation and EGSE standardisation (COES). The objectives were to define and specify the common functions between a satellite checkout system (EGSE) and a satellite control system. Even if these systems are used for a different objective in a different project phase, a large amount of functions are similar and the logical interface to the satellite is identical. Therefore, a common system could be used for the checkout and operation within a given project (vertical commonality) but also across projects (horizontal commonality).

It was also decided to define such a common system for missions using the newly defined Telemetry and Telecommand Packets. It became rapidly clear that this task was only feasible if a clear satellite-ground interface is specified, based on the use of Packets (Fig. 3).

Consequently, the first task of the COES was to produce a standard which defines precisely the use of Packets from an application viewpoint. Such a document (Packet Utilisation Standard STD-07-101) has been produced by the COES and is presently undergoing an Agency-wide review.

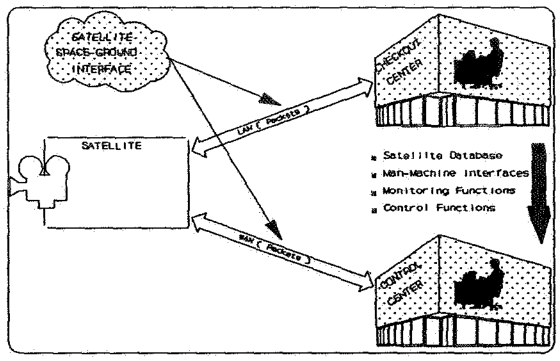

Fig. 3 : Checkout / Operation System Commonality

4. SCOPE OF THE STANDARDISATION

The Packet Utilisation Standard (Ref. 1) serves to complement and extend the Packet Telemetry Standard (Ref. 2) and the Packet Telecommand standard (Ref. 3), in order to satisfy the requirements of electrical integration and testing and flight operations. The term Utilisation is used to cover all what should be known around Packets (e.g. their content, how it is generated, which functionality they convey, etc.) in order to operate a remote Application.

An Application is an on-board logical entity which generates Telemetry Packets and also receives Telecommand Packets for the purpose of monitoring and controlling the Application. The Application is identified by an Application ID used to establish an end-to-end connection between this Application and the Ground. An Application can be any (or part of) platform of payload subsystem.

The standard is an interface document defining the relationship between space and ground. It, therefore, contains:

- requirements relating to satellite monitoring and control functions and to testability;
- Telemetry and Telecommand Packet types and sub-types (depending on the functionality);
- Packet data structures and format.

To the maximum extent, this standard utilises techniques emerging from modern software engineering trends.

This standard is in principle applicable to the full variety of mission classes, ranging from a satellite of relatively simple on-board design in an orbit with continuous ground coverage like a geostationary communication satellite, to a more complex mission like a low-earth orbiting scientific satellite or a deep-space mission.

The three principal driving factors which place the strongest demand on Telemetry and Telecommand are the degree of on-board complexity, the degree of on-board autonomy (these two factors being inter-related) and the link transmission capacity.

5. OPERATIONAL REQUIREMENTS

Telemetry and Telecommands must be provided to enable the safe and reliable execution of all nominal and contingency operations which are required to achieve the mission objectives.

The general principles of the operations model are as follows:

- Nominal operations

  The Application generates the relevant housekeeping information (depending on the mission phase) either whenever a significant event occurred on-board or at regular intervals.

  In the former case this information may also be generated on request by the ground. The information is composed of a suite of parameters (e.g. on-board variables, indirect device read-outs etc.).

  The Application generates information reports to indicate special events and any actions taken autonomously by the on-board system.

  On reception of a Telecommand the Application responds systematically on the validity status of it, and execution progress until completion.

  When accurate parameter time correlation is required, this is achieved either by associating explicitly a time-tag with the parameter or by reconstructing of the time on ground from the Packet time with implicit knowledge of the on-board "sampling" mechanism used.

- Contingency operations

  The Application has a diagnostic mode which enables to investigate short timescale phenomena of transient effects.

  The Application logic may be modified or reprogrammed from ground in case of malfunctioning.

  The Application may also be operated in an off-line manner in order to check its correct functionality before switching it to the operational mode.

  Any Application protection logic may be disabled from Ground and thus overruled.

6. PACKET TYPE AND SUBTYPE

For a given Application, the information contained in a Packet may correspond to different functionality. This is identifiable from the Packet Data Field Header (PDFH) which has a fixed structure for Telemetry and for Telecommand (Fig. 4).

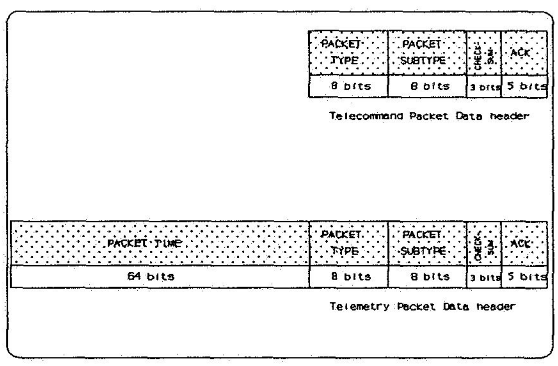

Fig. 4 : Packet Data Field Header

The two most important fields in the PDFH are the Packet Type (PT) and the Packet Subtype (PST). The PT identifies the higher level of a Packet category whereas the PST identifies a lower level within this category. The couple (PT, PST) has a unique definition and applies across different Applications.

All Packet contents (the Packet data field) are composed of fields (here called parameters) coded according to standard formats and organised according to a standard structure.

For well-defined monitoring and control functions, specialised Packets are defined, to which specific (PT, PST) pairs have been assigned, and which Packet content conforms to the general rules. Of course, those Packets are mandatory only if these functions are needed.

However, growth capability of the standard is ensured by expanding it with the introduction of new function categories or new subfunctions within an existing function category.

The presently defined categories of Packets are shown in Table 1 and Table 2.

TELECOMMAND PACKETS		
Type PT	SubType PST	FUNCTION
1	1	Device Command
2	1...5	Control Process
3	1	Software Command
4	1,2,3	Load Memory
5	1,2,3	Dump Memory
6	1,2	Diagnostic
7	1...7 11...17	Telemetry Generation
8	1...12	Master Schedule
9	1...9	On-Board Monitoring

Table 1 : List of Defined Telecommand Packets

TELEMETRY PACKETS		
Type PT	SubType PST	NATURE
1	1	Housekeeping
2	1	Report
3	1	TC Verification
4	1	Time
5	1,2,3	Memory Dump
6	1,2	Diagnostic
7		(Not defined)
8	1	Master Schedule
9	1,2,3	On-Board Monitoring

Table 2 : List of Defined Telemetry Packets

7. PACKET STRUCTURE AND FORMATS

The structures and formats adopted for this standard are oriented towards modern software language (e.g. Pascal, C, C^{++}, ADA) data structures. Thus they can be handled conveniently by the on-board or ground software, and offer the required flexibility. The interpretation of the Packet requires an implicit knowledge of the Packet content by the application supposed to process it. This is achieved by specific in-line coding (e.g. data statements) or better by an on-line interpretation of data description tables. The description information refers to Parameter Names (like variable names in a programme) which associates the Parameter Type, the position within the structure, and its interpretation (e.g. unit, calibration, scaling, attached procedure etc.).

The Parameter Type defines a class of encoding of the parameter value. For a given Parameter Type there are possible variations in the length of the value encoding. The only Parameter Types allowable for Telemetry and Telecommand parameters are those listed in Table 3.

PARAMETER TYPE	LENGTH	DEFINITION
Boolean	1 bit	0 = False , 1 = True
Logical	8/16 bits	Used in logical operations
Integer	1/2/4/8 octets	Signed or unsigned (ISO)
Real	2/4/6/8 octets	(ISO)
String	0 - 255 octets	ASCII (ISO) character string
Time	1 - 8 octets	CCSDS time (CUC or CDS)
Address	2/4 octets	Offset, base or offset + base

Table 3 : List of Parameter Types

A Record is a logical grouping of different Parameters or Arrays or other Records. An Array contains several instances of the same Record. By this definition the Packet Data Field is a Record. Consequently there could be several levels of nesting of Arrays and Records, although this flexibility should not be abused.

An Array can either be a Fixed-Array of a fixed number of instances (known implicitly by the application according the structure definition) or be a Variable-Array of a variable number of instances indicated in front of the Array. The structuration rules are presented in a "syntax diagram" form on Figure 5.

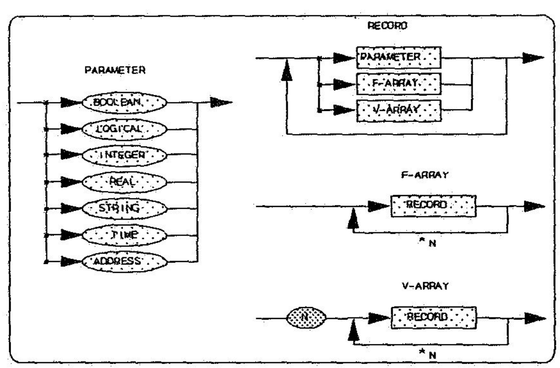

Fig. 5 : Data Field Structure Rules

8. VALIDATION

Before approving this standard, and before implementing supporting infrastructures, it was necessary to ensure its correctness, its practicability and operational usefulness. This has been achieved by a prototyping exercise completed in early 1992, which has validated the standard and at the same time given some indication on the implementation technique.

The Packet communication technique has not been addressed in this prototype since this is already demonstrated. Rather the application end-to-end aspect was implemented, emulating the Spacecraft Application behaviour in relationship to the Ground Application (e.g. control system) in control of it.

This prototype (called PUSV) runs on one or two SPARC workstations and permits at the same time to model different on-board Application architectures. A reference satellite model (called PUSSAT) was implemented for demonstration purposes.

9. FUTURE PERSPECTIVES

The PUS draft standard will be reviewed at Agency level and it is expected that it will become an Agency approved standard in the first half of 1993.

Furthermore, this standard is expected to evolve in the future in an incremental way when some commonly used monitoring and control functions are mature enough to be generalised and thus standardised.

ESA plans to develop the necessary ground infrastructures (e.g. mission control kernel system) to support this standard but also more generally the operational functions of such a system in order to achieve in reality the vertical and horizontal commonality of a generic system to be used for checkout and operation across different projects.

10. REFERENCES

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