Design Miniaturisation : transposing a proposed standard to meet the requirements of a nano-satellite

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Introduction: From “normal” satellites to the Cubesat level

Context	Specificity	Studies on the same case
Cubesats: historically a pedagogical concept, limiting the size also enabled students to actually complete a satellite (Twiggs, Puig-Suari). UPSat: « A Cubesat that worked » A Cubesat of 2U by the University of Patras and the Libre Space Foundation in the framework of the QB 50 mission, which was coordinated by the Von Krauman Institute.	1. An Open Approach a) DIY (max. of elements developed in-house) b) Open software & hardware Source code available at the URL: 2. Use of “normal” satellite standards at the integration phase The ECSS-E70-41A protocol was used to develop & integrate the elements of UPSat during the last phase.	Ampatzoglou (2017), Ampatzoglou et al (2014) on the use of composite material on the structural part. Chronas, N. (2017) on the software and computer design.

Methodology of this poster

1. Study of the "**traces**" of the actual design process, conceptualizing (Chrysos, 2016a)
2. An adaptation of Systematic and Axiomatic Design (Kim and Suh, 1991; Pahl, Beitz and Grote, 2007):
   a. **Comparison** of the Functional Requirements of the Cubesat with the Design Parameters of the ECSS protocol.
   b. Not only interested on ***whether*** they are related, but also on ***how*** they are related.

→ Outcome: a proposal of three operators for design miniaturization.
(note: it's a way to miniaturize, but not necessarily the optimal way.)

Data Acquisition	Data Analysis	Result
- Source code freely available online https://gitlab.com/librespacefoundation/upsat - Standard also freely available online	Comparison of the actual code with the specifications of the standard.	Three ways to miniaturize: 1. Ignore 2. Adhere 3. Transform

Ignored : 9 services (see slide 8)

		ECSS Standard								
		Test Service	Function Management	Telecommand Verification	Large Data Transfer	Housekeeping & diagnostic data reporting	On-board operations scheduling	Time Management	On-board storage and retrieval	Other mission specific
UPSat Design	Test Service	ADHERE								
	Function Management		ADHERE							
	Telecommand Verification			ADHERE						
	Large Data Transfer				ADHERE					
	Housekeeping & diagnostic data reporting					MINIMIZE				
	On-board operations scheduling						ALTER			
	Time Management							EXPAND		
	On-board storage and retrieval								ALTER	
	Science Unit									INTRODUCE

A simple example of expansion (code - time management)

The Code

```
...
}  else if( ser_subtype == TM_REPORT_TIME_IN_QB50) {
        /*allocate a new packet in memory*/
        tc_tm_pkt *time_packet = get_pkt(PKT_NORMAL);

        /*populate the packet with time in QB50 time format */
        time_management_report_time_in_qb50( time_packet,
pkt->destination_id);

        /*send the packet*/
        route_pkt(time_packet);
    }
```

Demonstrating an expansion of the ECSS standard to take into account the specific time format used in QB50 mission.

Sample of the analysis undertaken for this poster: explicit review of each dimension of the ECSS Standard from the standpoint of the actual code of the UPSat

		ECSS Spec
minimum c		
Enable Diag		
Telecomma		
Additional c		
Telecomma		
Telecomma		
Telecomma		
Telecomma		
Telecomma		
Telecomma		

Time management service		
minimun cap. set:		
Subtype:	**Service cap.**	
1	Time Set In UTC	INTRODUCE
2	Time Set In QB50 Epoch	INTRODUCE
3	(TC to trigger a)Time Report In UTC	INTRODUCE
4	(TC to triggger a)Time Report In	

minimum capabilities		
Housekeeping Parameter Report	25	IGNORE
Define New Diagnostic Parameter Report	2	IGNORE
Clear Diagnostic Parameter Report Definitions	4	IGNORE
Enable Diagnostic Parameter Report Generation	7	IGNORE
Disable Diagnostic Parameter Report Generation	8	IGNORE
Diagnostic Parameter Report	26	IGNORE
Additional capabilities		
More additional not listed		IGNORE
Report Unfiltered Housekeeping Parameters	21	ADHERE
Unfiltered Housekeeping Parameters Report	23	ADHERE

Adhere: do the same thing

Usually adhere to minimum, as suggested by the standard for the implementation of each feature (or service).

Example

Test Service **: The UPSat just adhered the minimum**

Ignored Services

- Device Command Distribution Service
- Parameter Statistics Reporting Service
- Event Reporting Service
- Memory Management Service
- On-board Monitoring Service
- Packet Forwarding Control Service
- On-board Operations Procedure Service
- Event-action Service

Transform - a) introduce

In general:

- **Each mission has its own instruments**
- Introductions are embraced from ECSS-E-71-41-A

In the case of UPSat:

- **Science Unit m-NLP**
- Addition of a new Service Type and new Service Subtypes

More specifically:

- Minimum capability set consists of:
  - Science Unit Power On
  - Science Unit Power Off
  - Science Unit Reset
  - Science Unit Script Load
- Additional capability set consists of:
  - 14 actions, modeled as service subtypes.

Transform - b) Alter : do other things

(Onboard Storage and retrieval service)

According to the ECSS:

Service for the **storage** of telemetry and telecommand packets

Operations for retrieving and deleting packets based on different properties.

Reports for the packet store status (e.g. packets stored).

In the UPSat case:

Altered for storing and retrieving **logs and parameters.**

Solution developed (Chronas, 2017) :

- Multiple delete operations (soft/hard).
- Added custom hardware dependent operations (e.g. SD card format).

Transform - c) expand : do similar things in different context

(eg. Time Management)

ECSS Design Parameters	UPSAT time management service
“Change Time Report Generation Rate”	Not implemented
Time report with CCSDS Unsegmented code format.	Implemented with custom format

Mission related challenge:

- Needed custom time formats and conversions to drive the Science Unit scripts (QB50 epoch = seconds elapsed from 2000)

Alternative solution developed:

Every subsystem that needs time information makes an explicit request to the OBC, which runs an instance of the Time Management Service. This instance makes use of the OBC’s microcontroller Real Time Clock.

Transform - d) Minimize - do less

Eg. Housekeeping and diagnostic data reporting service

According to the ECSS

- Mechanism for a periodic (or filtered) housekeeping report generation.
- Services for creating new, modifying, enabling/disabling and changing the time interval of a housekeeping report.

Solution developed

- Defined fixed housekeeping reports (no real time modifications enabled).
- Assigned to the OBC: OBC requests and collects the housekeeping reports for each subsystem in a **master-slave configuration** and in a predefined interval (no mechanism for automated housekeeping).

Discussion

IGNORING

- It's in the Cubesat *DNA* (goes back to the days when Prof. Twiggs and Prof. Puig-Suari conceived the concept of Cubesat)
- Not everything is required (mission specific requirements)
- Can't/Shouldn't always adhere (see transform)

ADHERING

- Feature fully conforms to the specific requirements of the mission
- Standard represents the "best practices"
- Not reinventing the wheel.

TRANSFORMING

- Generic of-the-shelf electronics have capabilities that may support some functions by default (e.g. BCD support)
- Limited resources sometimes push to the reinvention of the wheel, nonetheless (e.g. Mass Storage)
- New practices emerge at the nano-level.

References

Ampatzoglou, A. (2017). Design, analysis and optimization of a micro-satellite for the study of lower thermosphere and re-entry conditions, Ph.D Dissertation, University of Patras, Department of Mechanical and Aeronautical Engineering, Patras, Greece.

Ampatzoglou, A., Baltopoulos, A., Kotzakolios, A., & Kostopoulos, V. (2014). Qualification of Composite Structure for Cubesat Picosatellites as a Demonstration for Small Satellite Elements. Int J Aeronautics Aerospace Res, 1(1), 1-10.

Chronas-Foteinakis, N.(2017), Design and implementation of telemetry and telecommand standard, subsystem services and O.B.C software for the UPSat cubesat, MSc Thesis, National and Kapodistrian University of Athens, School of Science, Department of Informatics and Telecommunication, Athens, Greece.

Chrysos, P. (2016a). Handshakes and Monuments : Internet design as a breakthrough from network ontologies,. First Monday, December.

Chrysos, P. (2016b). Autour des travaux d'Anne-Françoise Schmid : le potentiel scientifique d'un courant épistémologique. Natures Sciences Sociétés, 24. Kim,

Heidt, H., Puig-Suari, J., Moore, A., Nakasuka, S., & Twiggs, R. (2000). CubeSat: A new generation of picosatellite for education and industry low-cost space experimentation. In *AIAA/USU Conference on Small Satellites* (p. 19). Logan, Utah, USA.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K.-H. (2007). Engineering design : a systematic approach. (K. Wallace, Trans.). London ; New-York: Springer.

S.-J., Suh, N. P., & Kim, S.-G. (1991). Design of software systems based on axiomatic design. Robotics and Computer-Integrated Manufacturing, 8(4), 243–255.

Twiggs, B., & Puig-Suari, J. (2003). CUBESAT design specifications document. Stanford University and California Polytechnical Institute.

Appendix : Overview of the operations summary

	Minimum		Additional		New	**OPERATION**
TS	ADHERE		(no additional)			ADHERE
FM	ADHERE		(no additional)			ADHERE
VER	ADHERE			IGNORE		ADHERE
LD	ADHERE		ADHERE	IGNORE		ADHERE
HK	IGNORE		ADHERE	IGNORE		MINIMIZE
SC	ADHERE	EXTEND	ADHERE	IGNORE	INTRODUCE	ALTER
TM	MINIMIZE				INTRODUCE	EXPAND
MS	MINIMIZE		MINIMIZE	IGNORE	INTRODUCE	ALTER
SU					INTRODUCE	INTRODUCE