A Generic Framework for the Miniaturization Of Satellites

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Summary:

Miniaturization is a recurrent challenge during the design and the development of Cubesat missions. However, as of today, there is no generic framework suggesting common operations for miniaturization. Instead, each Cubesat project addresses the challenge in a rather singular way, depending on the specificities of its mission.

This poster suggests a generic framework for the miniaturization, drawing from the experience of the development of the UPSat, which has been part of the QB 50 project.

The framework consists of three generic operators, as compared to established space industry standards.

The operators were induced by an in-depth comparison of the actual UPSat design with the Functional Requirements of the ECSS-E70-41A standard.

1. **Adhering** to the standards.
2. **Ignoring** the standards.
3. **Transforming** the services.

This generic framework provides a common language for the operations to undertake during Cubesat development among different missions. This way, knowledge sharing and a the further development of a common knowledge base across Cubesat missions is facilitated.

Context:

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.

Specificity:

1. An Open Approach
   a. DIY (max. of elements developed in-house)
   b. Open software & hardware
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.*

Studies on the same case:

- 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.
- Chrysos, P. (2017). Identifying the role of the element in the collaboration

Methodology:

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:

- Source code freely available online.
- Standard freely available online, too.

Data Analysis:

Comparison of the actual code with the specifications of the standard.

8 services ignored

ECSS Standard / UPSat Design	Test Service	Function Management	Telecom-mand Verification	Large Data Transfer	Housekeeping & diagnostic data reporting	On-board operations scheduling	Time Management	On-board storage and retrieval	Other mission specific (Load)
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

TRANSFORM (a, b, c, d)

- 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.

a) introduce: embed a new element

E.g. the load :

- **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.

c) expand: do similar things in different context

E.g. 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.

IGNORE

- It's in the Cubesat DNA
- Not everything is required (mission specific requirements)
- Can't/Shouldn't always adhere (see transform)

Ignored Services*

1. Device Command Distribution Service
2. Parameter Statistics Reporting Service
3. Event Reporting Service
4. Memory Management Service
5. On-board Monitoring Service
6. Packet Forwarding Control Service
7. On-board Operations Procedure Service
8. Event-action Service

* these services were ignored in the UPSat design. Other designs may require ignoring other services.

b) alter: do other things

E.g. 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).

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).

ADHERE: do the same thing

E.g. Test Service

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

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

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