



**HAL**  
open science

# **A Generic Framework for the Miniaturization Of Satellites**

Paris Chrysos, Nikitas Chronas-Foteinakis, Apostolos Masiakos

► **To cite this version:**

Paris Chrysos, Nikitas Chronas-Foteinakis, Apostolos Masiakos. *A Generic Framework for the Miniaturization Of Satellites*. 2018 NASA Academy of Aerospace Quality Workshop, Sep 2018, Cleveland, United States. halshs-01877557

**HAL Id: halshs-01877557**

**<https://shs.hal.science/halshs-01877557>**

Submitted on 20 Sep 2018

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# A Generic Framework for the Miniaturization Of Satellites

Paris Chrysos (ISC Paris, paris.chrysos@iscparis.com)  
 Nikitas Chronas Foteinakis (TU Delft, N.ChronasFoteinakis@tudelft.nl)  
 Apostolos Masiakos (Systems Engineer, amasiakos@cubesat.gr)

## 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.

	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 (Load)
UPSat Design	ADHERE	ADHERE	ADHERE	ADHERE	MINIMIZE	ALTER	EXPAND	ALTER	INTRODUCE

8 services ignored

## 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.

### b) alter: do other things

E.g. Onboard Storage and retrieval service

According to the ECSS:	In the UPSat case:
<ul style="list-style-type: none"> <li>• Service for the storage of telemetry and telecommand packets</li> <li>• Operations for retrieving and deleting packets based on different properties.</li> <li>• Reports for the packet store status (e.g. packets stored).</li> </ul>	<ul style="list-style-type: none"> <li>- Altered for storing and retrieving logs and parameters.</li> <li>Solution developed (Chronas, 2017):                             <ul style="list-style-type: none"> <li>• Multiple delete operations (soft/hard).</li> <li>• Added custom hardware dependent operations (e.g. SD card format).</li> </ul> </li> </ul>

### d) minimize: do less

Eg. Housekeeping and diagnostic data reporting service

According to the ECSS	Solution developed
<ul style="list-style-type: none"> <li>• Mechanism for a periodic (or filtered) housekeeping report generation.</li> <li>• Services for creating new, modifying, enabling/disabling and changing the time interval of a housekeeping report.</li> </ul>	<ul style="list-style-type: none"> <li>• Defined fixed housekeeping reports (no real time modifications enabled).</li> <li>• 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).</li> </ul>

## 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.

## 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.

## 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., Kottzokolos, 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 OBC software for the UPSat cubesat. MSc Thesis, National and Kapodistrian University of Athens, School of Science, Department of Informatics and Telecommunications, Athens, Greece.
- Chrysos, P., Chronas-Foteinakis, N., & Masiakos, A. (2018). Design Miniaturisation: transposing a proposed standard to meet the requirements of a nanosatellite. In 15th Cubesat Developers Workshop, San Luis Obispo, CA, USA: California Polytechnic State University.
- 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.
- Chrysos, P. (2017). *Contribution Matrix: A Method to Analyze Individual Participation in Research Collaborations Developing Technologies - An Application on the Case of the Development of UPSat*. Phoenix, Arizona.
- Crews, A., Payne, C., Kennedy, A., Holden, B., Allan, G., Dave, P., ... Bishop, R. (2018). Nanosatellite Passive Microwave Radiometers: Microwave Radiometer Technology Acceleration (MiRaTA) and the Micro-sized Microwave Atmospheric Satellite (MicroMAS-2A). In 15th Cubesat Developers Workshop (p. 25). San Luis Obispo, CA, USA.
- Da Silva Curriel, R. A., & Sweeting, M. N. (1998). Two Decades of Small Satellite Missions at Surrey. In *PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON SPACE TECHNOLOGY AND SCIENCE* (Vol. 21, pp. 125-135). AGNE SHOFU PUBLISHING INC.
- 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 *AAUUSU 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 Polytechnic Institute.

2018 NASA Academy of Aerospace Quality Workshop NASA Safety Center/ Ohio Aerospace Institute Cleveland, OH, USA, Sep. 7, 2018

