Fly Your Satellite!
the ESA Academy CubeSats programme

Lessons Learned during the Critical Design Reviews

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Contents

ESA Education opportunities for University Student Teams

Hands-on

- Satellite projects
- Scientific experiments
- Technology demonstration

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Academic support

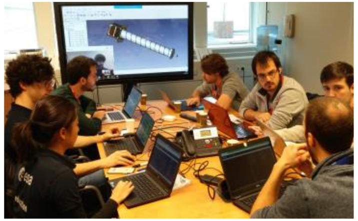
- Courses, schools and workshops
- Participation to conferences
- Lectures/seminars of ESA experts

Fly Your Satellite!

CubeSat Opportunities for University Student Teams

Objectives:

- **Better prepare students for careers** as space professionals in ESA and in European space industry
- **Transfer of experience and know-how** from experienced professionals to students
- Through **careful verification** and proper documentation, aim to increasing chances for mission success
- **Technology** but also **laws and regulations**

Phase C	Phase D1	Phase D2	Phase E1	Phase E2
				
Detailed Design	**Production & Ambient Test Campaign**	**Environmental Test Campaign**	**Launch Campaign & Deployment**	**Operations & Lessons Learned**

- Structured in phases with **intermediate reviews**, tailored from ESA projects, which the teams need to pass to continue to next phase.
- For University student teams from ESA Member States, Canada or Slovenia

Fly Your Satellite!

CubeSat teams participating in the programme:

- Receive direct support from **ESA specialists**
- Are introduced to the **importance of verification** and **good documentation**, as key methodologies to improve chances of mission success
- Have **access to environmental test facilities**
- Get acquainted with **standards and best practices** applied in ESA and European space industry
- Participate in **workshops, training courses, project reviews and test campaigns**

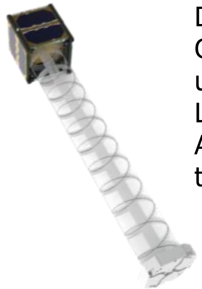
ESA offers the **launch opportunity** to teams that demonstrate the flight readiness of their CubeSat

Fly Your Satellite! 2 CubeSats

Beyond the educational mission

^{3}CAT-4

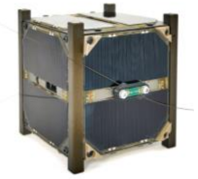
Technical University of Catalonia, Spain



Demonstrate Earth Observation capabilities using a GNSS-R and a L-band radiometer. An AIS receiver will also be tested.

CELESTA

University of Montpellier, France



Monitor the LEO radiation environment using SEU & SEL and perform in-orbit testing of the 1U CubeSat platform.

EIRSAT-1

University College Dublin, Ireland

In-flight demonstration of a gamma-ray burst detector, thermal coatings and a novel attitude control algorithm.

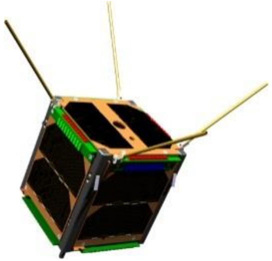
ISTSAT-1

Instituto Superior Técnico, Portugal

Characterize the performance of a compact ADS-B receiver in orbit

LEDSAT

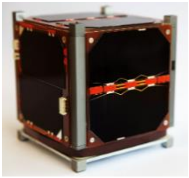
Sapienza University of Rome, Italy



Test a LED-based payload on-board a 1U CubeSat for improving LEO optical satellite tracking algorithms

UoS^{3}

University of Southampton, United Kingdom



Support atmospheric re-entry prediction tools and obtain images of Europe for outreach purposes

Critical Design Review 1/2

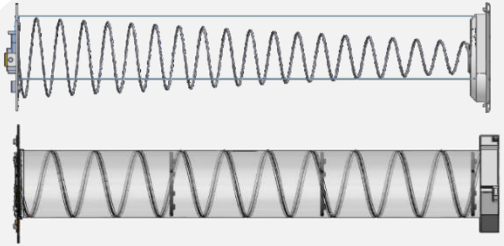
Consolidation of the spacecraft detailed design

Selection Workshop

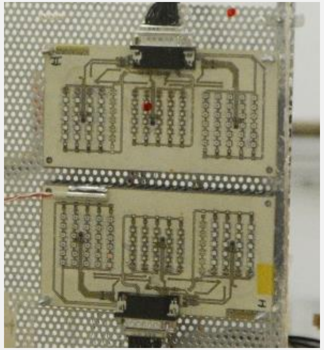
- ESA specialists deliver lectures to students in different space topics
- A panel of specialists assigns actions to teams to focus on critical aspects of their design

Data Package Delivery

- Students compile their design into a Data Package
- ESA Education distributes templates and guidelines to help; guidelines are tailored from ECSS (the European Space Standards)



3CAT-4 L-band Helix antenna
May 2017 (top), Dec 2017 (bottom)



LEDSAT payload TID tests

Critical Design Review 2/2

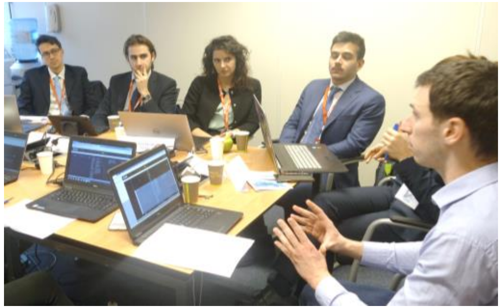
Consolidation of the spacecraft detailed design

Review process

- Based on identification, discussion & resolution of comments raised by ESA specialists.
- Issues are tracked as Review Item Discrepancies (RIDs)

Colocation meetings

- Student teams & ESA reviewers to discuss and agree on a corrective course of action for open issues

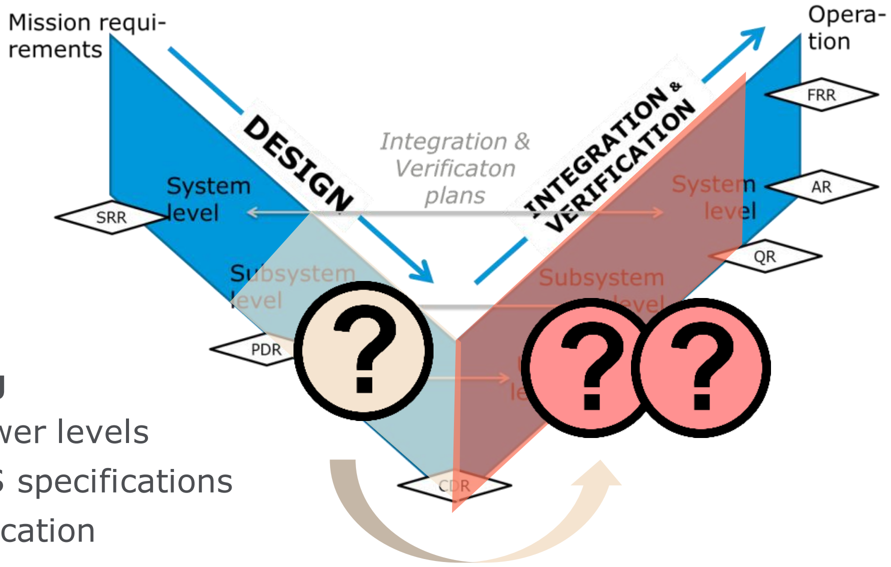


Actions closure

- Students carry additional analysis or tests to help to close actions.
- CDR is passed when review objectives are met

Lessons Learned

Lessons Learned
Systems Engineering



➔ Requirements definition & reverse engineering

Issue Insufficient flow down of requirements at lower levels

Sometimes requirements derived from COTS specifications

Impact Difficulties to later perform the system verification

Recommendations

- Define lower level requirements before selecting subsystems/ components
- Be systematic in flow-down of requirements
- A good requirement shall be: quantifiable, unique, identifiable, with tolerance, justifiable, singular, traceable, unambiguous, complete and verifiable

Lessons Learned
Operations

➔ Operational modes

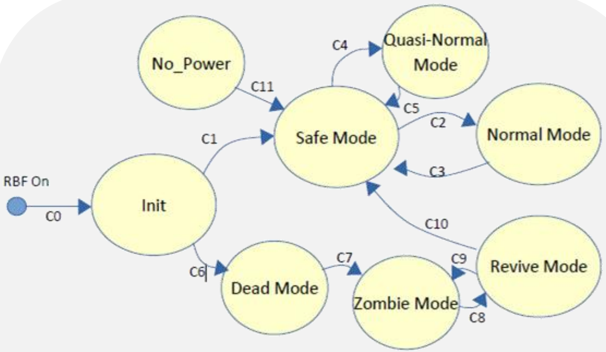
Issue Logic behind transitions underestimated or overcomplicated

Software modes ≠ operational modes

Recommendations

- Simple modes structure & robust Safe Mode
- Create a clear diagram: distinguish automatic & manual transitions

transition triggers well defined (e.g. Temp, Vbatt)



Pre-CDR OPS Modes State Diagram ISTsat-1

➔ Safe mode transition

Issue Student team proposed automatic exit from safe mode

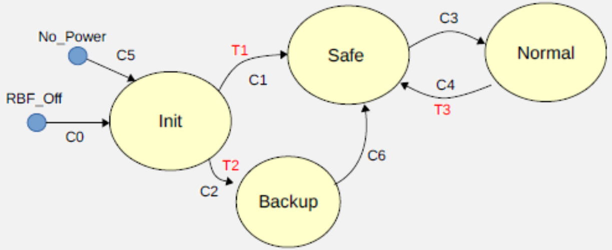
Impact What if safe mode root cause not identify and solved?

Undetected health issues remain unknown

– endless safe-not safe mode loop

Recommendation

- Safe mode exit preferably via telecommand



Post-CDR OPS Modes State Diagram ISTsat-1

Lessons Learned
Operations

➔ Maximise beacon usage

Issue — Some teams failed to include relevant housekeeping parameters in their beacons

Impact — Reduced observability of CubeSat health after deployment & during contingency operations

Recommendations

- Beacon should include as much housekeeping data as possible
- If power & link budget allow, consider to increase beacon frequency & to include some payload data

Example of poor beacon content				
Identification message	Battery Voltage	Antenna Deployment Status	Antenna Deployment Attempts	End of Transmission Index

➔ Software configurability & parametrisation

Issue — Limited flexibility during in-flight operations, also to cope with anomalies

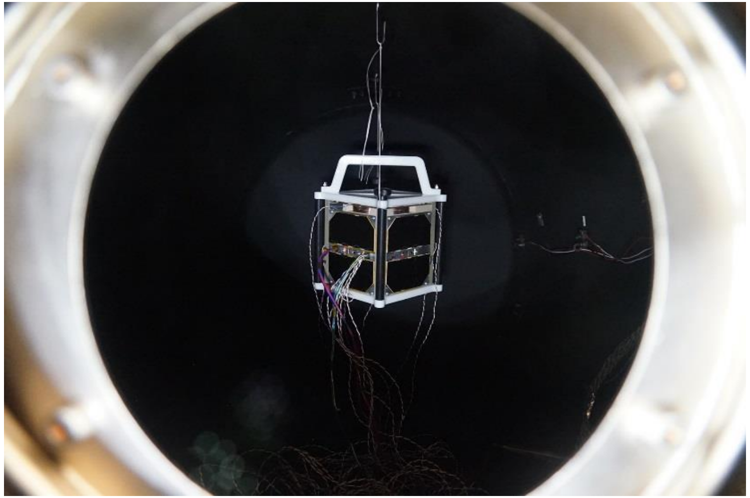
Recommendation

- Design on-board software that allows in-flight configurability through parametrisation of on board parameters

Lessons Learned
Assembly, Integration & Verification

➔ Design for TVAC

Issue	No remote switch on/off capability foreseen
	Data acquisition & commanding not possible through umbilicals
Impact	Functional tests within thermal vacuum tests severely hindered



Recommendations

- Include a bypass mechanism for the deployment switch
- Foresee umbilical for boot-up, battery charging & TMTC
- Routing coaxial cables (RF) might be an option

During design consider as well:

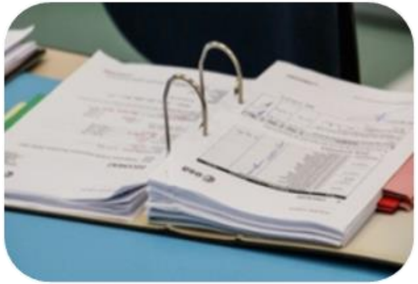
- MGSE for installation in thermal-vacuum chamber
- Installation of internal (calibrated) test thermocouples
- Vacuum compatible materials (also GSE within the chamber). Consult databases (ESA's ESMAT, NASA https://outgassing.nasa.gov). Consider bake-out

Lessons Learned

Project Management

Team composition

- Students from different disciplines/ departments
- Long term (graduation thesis, PhD research)
- Assign clear roles
- Plan handovers
- Involve professionals



Documentation

- Maintains traceability
- Helps with student handover
- Document as you would have liked it to be documented

Procurement activities

- Lead time for high level components can be very long
- Consider rules of University administration
- Manufacturing mistakes – always inspect upon arrival!

AIV schedules optimistic – don’t !

- Procurement & lead time not included
- No margins for anomaly investigation or test repetition
- 100% margin in system level tests not unreasonable

Lessons Learned

Product Assurance

➔ Datasheets

Issue: Sometimes missing product performance at representative conditions (e.g. battery performance often quoted at ambient T)

Impact: Performance of the system deviates & may affect budgets (e.g. power)

Recommendation

- Efficiencies quoted to be treated conservatively; critical functions / parameters to be tested

- Cycle life (20% capacity loss)	DOD: 100%, Temp 25degC Charge/discharge: 1C/1C		350		cycles

COTS Battery Datasheet extract

➔ Supplier specifications & workmanship

Issue: Student teams experienced mismatches between the product specification, ICD (Interface Control Document) or CAD and the final hardware as delivered

Additionally, some parts received showed workmanship defects

Impact: Delays caused by inspection & re-works on the hardware

Undetected functional modifications remain undiscovered on the initial testing phases. Larger impact later on.

Mitigation

- Perform detailed inspections & testing upon product delivery

Some recommendations
Regulations

Mission authorisation, ITU & IARU

- ✓ Consult national space law & establish early contact with national authorities
- ✓ Start coordination of frequencies as early as possible
- ✓ ITU Art. 22.1 Cessation of radio emissions by telecommand implemented & verified

Space Debris Mitigation

- ✓ CubeSats shall be designed considering the SDM regulations e.g. no parts intentionally detached in-orbit.
- ✓ Other considerations: avoid fragmentation in case of battery explosion, passivation at EOL, limiting orbital lifetime & re-entry casualty risk

Final considerations

- Work towards getting a **diversified set of skills** within your team. Engage students at different levels, some of them for longer durations

- Design a **flexible system** (orbit, launcher environments, link budget, re-programmability, observability, testing)

- **Inspect** outsourced products & processes in detail

- **Design a system that can be tested**

- **Test, test, test…**

Thank you!

Questions?

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