ESA Mission Classification: focus on RHA tailoring & recommendations for COTS projects

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RHA standardisation activities at ESA

Currently, several on-going standardisation activities are on-going related to the RHA topic:

1. Update of the **ECSS-Q-ST-60-15C** (to 2nd issue) standard with the Radiation Working Group (on-going)
2. Update of the **ESSB-AS-Q-008** (to issue 4) which tailors the ECSS-Q-ST-60-15C to ESA projects (on-going)
3. Participation to the **ESA COTS Guidelines** for the RHA part (done)
4. RHA chapter for the **ESA CubeSat design guidelines** (first release on-going)

And…

5. **RHA tailoring for the 5 ESA mission classes** (on-going)

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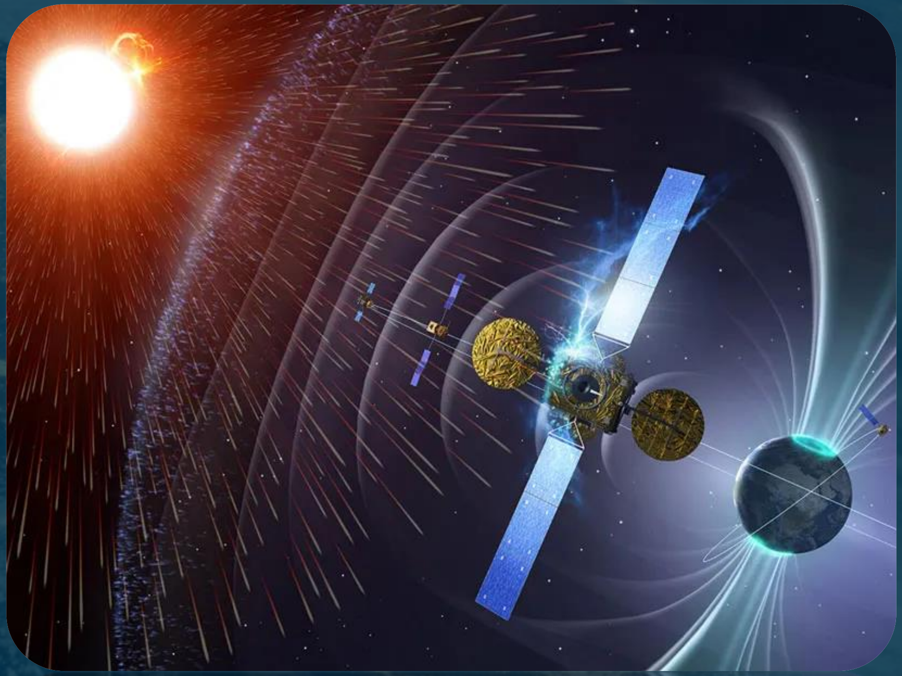


ESA Mission Classification

Why?

- Higher effectiveness & efficiency (e.g. systematic approach, harmonisation from one project to another, etc…)
- Part of new working methods to reduce cost & development time
- To address a large variety of mission types (except mega-constellations)
- Growing continuous interest in use of COTS

What?

- Pre-Tailoring of ECSS Management, System Engineering, PA according to criticality, mission objectives, cost, lifetime & complexity. In PA, pre-tailored PARD.
- The higher the number the higher the risk…
    - but sub-units can be of a different class than the overall mission class (e.g. non-critical equipment)

When?

- Started in 2020 (by ESA Executive Board).
- Currently in used in « pilot missions » for 2 years, pre-tailoring activities on-going
- Fully implemented in 2025 onwards (pending EB decision)

ESA Mission Classification

Class type	I	II	III	IV	V
Mission Criteria and Marking					
Criticality to Agency strategy (Flagship mission, Internationnal cooperation, Impact on ESA strategic goals, and image)	Extremely high Criticality	High Criticality	Medium Criticality	Low Criticality	Educational purposes
Marking					
Mission Objectives (Directorate priority and purpose, e.g in orbit demonstration, educational)	Extremely high Priority	High Priority	Medium Priority	Low Priority	Educational purposes
Marking					
Cost (Cost at Completion, Including Phase E1)	>700 M€	200 - 700M€	50 - 200M€	1- 50M€	< 1M€
Marking					
Mission Lifetime (Nominal mission life duration)	> 10 years	5-10 years	2-5 years	1-2 years	1 year
Marking					
Mission Complexity (Design interfaces unique payloads, New technology development)	High	High to Medium	Medium	Medium to Low	Low
Marking					

CLASSES:

I. Critical strategy/safety (e.g. manned missions) (High level of requirements and low risk)

II. Performances should be met whatever it takes

III. Finding the best compromise between risk and cost to deliver the mission

IV. Mission is designed according to a hard cost limit (affordability approach)

V. Almost full delegation to industry (Minimum requirements but increased risk)

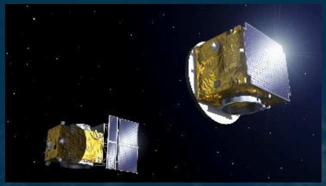
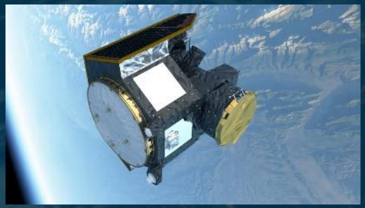
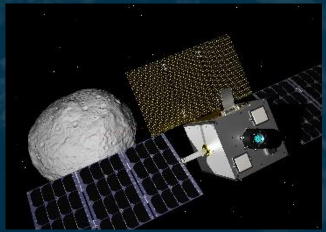
Criteria: 5 different criteria (criticality to Agency, Mission Objectives, Cost, Lifetime, Complexity)

Weighting factors: Each criteria has a weighting factor used to establish the overall project's mission classification

Modified from : « ESA Mission Classification », L. Marchand, S. da Mota Silva, J. Krompholtz, March 2023

ESA Mission Classification

Examples of a classification exercise:

	Class I	Class II	Class III	Class IV	Class V
Examples	ERO **JUICE** **MTG** Argonaut	**Proba III** Flex VIGIL ARIEL TRUTHS **SENTINEL-2**	FORUM **CHEOPS** **Comet-I** HARMONY HummingSat	AWS SCOUTS Probe B2 (on Comet-I) **GOMX-5** **M-ARGO** GX-5 ESA Edu. FYS (EIRSAT-1, SOURCE)	YPSat **ESA Edu. FYS** (AcubeSat/ UCAnFly/ LEDSAT/ 3Cat-4/ ISTsat-1)
Pictures	 	 	 	 	 FLY YOUR SATELLITE!

ESA Mission Classification – RHA classes 1/2

On-going tailoring. Current simplified status:

	Class I/II	Class III	Class IV	Class V
Traceability				
TID				
TNID				
RDMmin (TID/TNID)				
RVT				
SEE HI				
SEE proton				
DSEE LETth				
SEE Mitigations				
Rad. Review/Analysis				
“Summary”				

ESA Mission Classification – RHA classes 1/2

On-going tailoring. Current simplified status:

	Class I/II	Class III	Class IV	Class V
Traceability	High	High but low acceptable	Low OK	Low OK
TID	As ECSS	As ECSS & board possible	If TIDL > 5 krad (DDC) & board ok	No TID assessment required
TNID	As ECSS	As ECSS & board possible but only focused beam	If opto critical (if proton env.) & board ok but only focused beam	No TNID assessment required
RDMmin (TID/TNID)	As ECSS/ESSB	2 if low traceability or board test 1 if high traceability	2 if low traceability or board test 1 if high traceability	No RDM required
RVT	As ECSS/ESSB	TID: As ECSS except. Bipolar ICs TNID: Opto or if RDM < 2*RDMmin	No RVT required	No RVT required
SEE HI	As ECSS & compo only	All & board possible	Critical parts & board ok	Only if power MOSFET (part >200V or embedded) & OC protection parts, board ok
SEE proton	As ECSS & compo only	All & board possible	All & board ok	All critical boards or when no SEE mitigation & board ok
DSEE LETth	As ECSS (60 MeV.cm²/mg)	< 38 MeV.cm²/mg	< 38 MeV.cm²/mg	< 38 MeV.cm²/mg
SEE Mitigations	As ECSS	As ECSS, NDSEL accepted if demonstrated by test	No proton DSEE, derating, NDSEE mitigation/no prop. & SET assessment	Same as Class IV but SET assessment not required
Rad. Review/Analysis	Yes: As ECSS	Yes: Almost as ECSS	Yes: based on test data & mitigations & criticality analysis & SET analysis & rates	Yes: based on test data & mitigations & criticality analysis
"Summary"	"ECSS Classes"	"Traceability can be relaxed, board level testing possible with LETth=38 MeV.cm²/mg"	"Low traceability OK, TID > 5 krad, board level testing OK, SEE HI if critical, proton for the rest, no RVT"	"Like Class IV & testing reduced to DSEE or when no mitigation impacting overall mission, *mostly risk-avoidance* & proton"

ESA Mission Classification – RHA classes 2/2

As often in RHA, the « devil is in the details », some examples:

- Obviously, tailoring is the set of **minimum requirements** – the more the better ;)
- **Board level testing** - number of boards may required a careful trade-off:
  - Class III: e.g. 3+2 boards are required (TID) & 3 (TNID), 2+1 (for SEE incl. spare)
  - Class IV: e.g. 1+1 boards are required (TID) & 1 (TNID), 2+1 (for SEE incl. spare)
  - Test data shall be provided at CDR ➔ board will be ready? What if part fails on the board?
  - In general in TNID: board level OK but focused on part

- Definition of **critical** for Class IV & V:
  - Critical parts in terms of radiation risk
  - But also in terms of "mission impact": specific from one project/design to another, defined by the project team!
  - This also includes the protection devices (e.g. overcurrent protection)
  - For NDSEE, even if not critical, demonstration to be done to ensure "no failure propagation".
- **RVT for Class IV**: No RVT is misleading: meaning is "no RVT based on diffusion lot" (but on "procurement batch")
- "Low traceability": (= procurement batch) means that multiple samples of a same part reference is procured from the same manufacturer either directly or via a reliable distributor and at the same time.
- **Class V approach**:
  - Though educational mainly – approach shall not be to « close-eyes »
  - Encourage a good design & adequate selection of parts & adequate mitigation – otherwise testing required!
  - Concept of safety barrier is highlighted (as also mentioned in the ESA COTS Guidelines)
- **Class IV limit of 5 krad**:
  - Only if dose Depth Curve is used, otherwise (Ray Tracing or 3D MC) 2.5 krad shall be used
- All classes required to provide a **radiation analysis** (level of details adapted) but WCA analysis only for Class I to IV

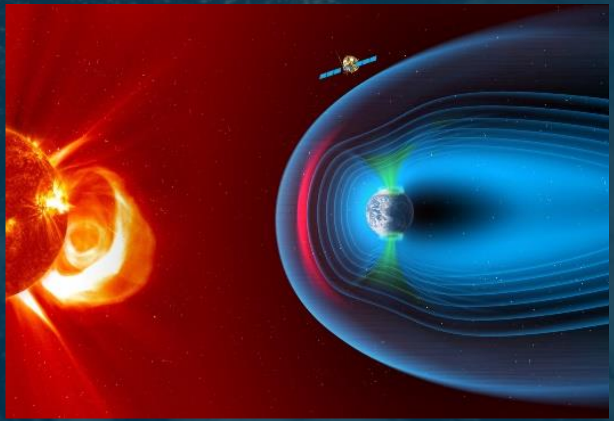
Concrete example on the use of a COTS equipment 1/3

Context:

- **SMILE**: joint mission ESA/CAS for understanding the Sun-Earth interactions
- Orbit: 5000 km x 121000 km, high inclination, 3 years
- ESA/Airbus provides the payload module (soft X-ray & UV images, Light Ion Analysed, Magnetometer) & ESA provides the launch
- The payload module embarks a X-band Transmitter (XBT)

Challenge:

- Due to regulation restrictions & other constraints, only a full COTS-based XBT was selected



Current situation:

- XBT has heritage only in LEO missions (e.g. Proba-V,….)
- Not built for a HEO orbit
- Impossibility to apply a full “traditional RHA” approach on the entire equipment

NOTE: Pre-ESA classification exercise

Concrete example on the use of a COTS equipment 2/3

RHA Objective:

- Reduce "as much as possible" the risk
- RHA requirements cannot be fully applicable

Configuration:

- Cold redundant XBT
- Switched ON 10 min every orbit when between 5000-20000km
- SEL protection system implemented in the design
  - ➡ Some level of radiation-induced risk is mitigated by design
  - ➡ Additional RHA activities still required
  - ➡ Acceptance of a certain level of risk

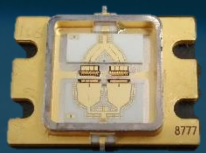
Selected equipment:

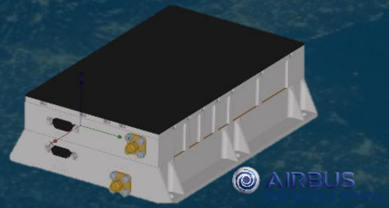
- XBT GaAs EWC28 from Syrlinks

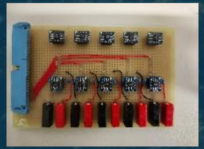
Concrete example on the use of a COTS equipment 3/3

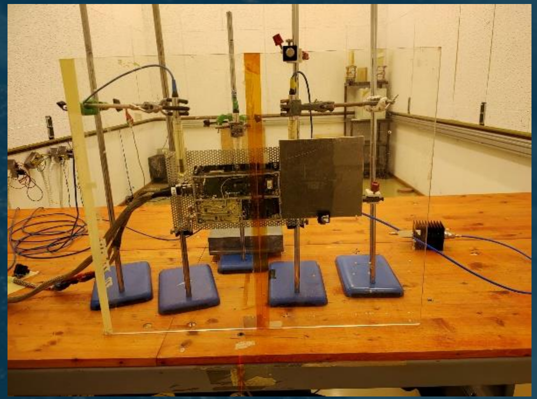
RHA activities performed:

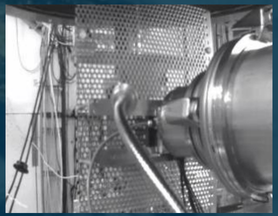
- Iterations between ESA-Airbus-Syrlinks:
  - Selection of the most critical parts
  - Confirmation of procurement lot & DC traceability (higher level not possible)
  - Use of previous tests (TID, heavy-ion) where applicable
  - Consolidation of the approach
- TID/TNID:
  - Increase of the top panel thickness to reduce TIDL
  - TID testing of the weakest equipment part (based on previous tests)
  - TID & TNID testing of the opto-coupler
  - TID testing at “equipment” level in application conditions + Margin (~3)
- SEE:
  - HI testing on some critical components (power MOSFET, RF amplifier, potentiometer)
  - Proton testing on some critical components with previous HI data (uC, CPLD, optocoupler, PWM)
- Radiation analysis consolidated + SET analysis on potentially sensitive parts ➔ availability estimation











Lessons learned working on small COTS-based projects

- In most COTS-based projects, RHA considerations happen too late…

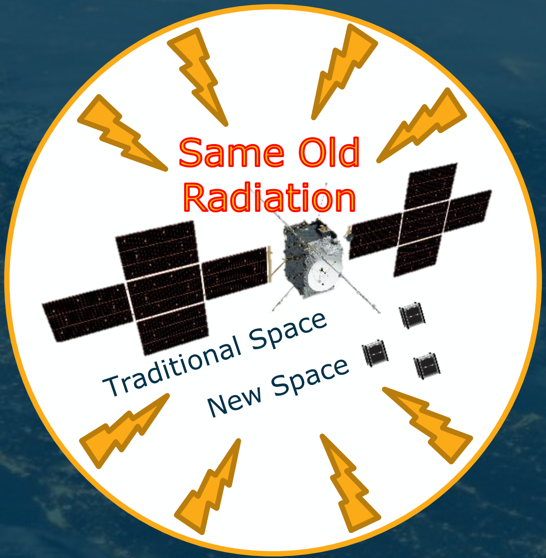
  …and sometimes not much considered at all!

- In some cases:
  - RHA = Radiation environment description!
  - RHA = similar to an environmental testing (occurring in Phase D)
- Risk is not understood
- Concept of heritage is also not understood
- RHA impact of scaling from a prototype up to a recurrent unit/satellite is, as well, not understood
- Amount of activities to be performed is also underestimated (cost, human resources, time)
- …etc…

Important RHA concepts for COTS-based projects

As common as it may be those "in the field", the pieces of advice/reminders below are particularly addressed to new industrial players with little knowledge in the field of RHA:

- New Space but… "Old" radiation
- There are no miracles solution!
- COTS are not cheap ("hidden cost of COTS"):
  - Testing cost, traceability (impact on procurement)
  - What if the part fails? Need to find an alternative
- No applicable test data = No RHA
- Be careful with heritage
- Be inquisitive when buying off-the-shelf equipment
- If high-risk equipment: check propagation of error ("safety barrier")
- **RHA considerations start very early**:
  - Impact on project resources based on RHA type (e.g. Class V vs. Class IV vs. Class III….)
  - Selection of parts & design iterations at EARLY stages of the design & keep it compatible with alternative parts
  - Did you know there are COTS parts some companies/manufacturers sell with SEE/TID test data & traceability guarantee?
- Have a radiation expert…or ask help to specialised companies (part selection, testing, etc…)



Conclusion

- There is an increase in the number of « higher risk » missions…

  …but this is not an excuse to blindfully & simply trust the « radiation Gods! »

- In the frame of the ESA mission classification, the RHA requirements are being tailored in order to guide on minimum level of RHA to be performed in each class

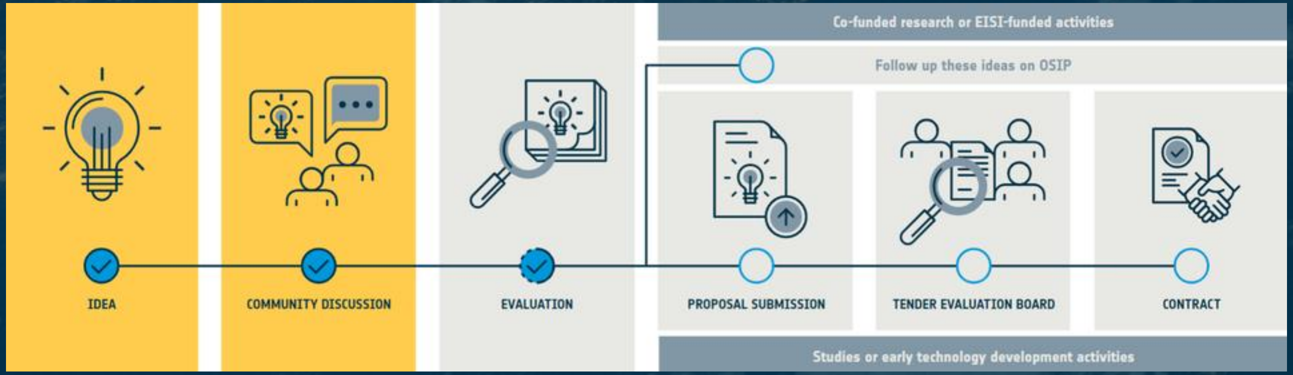
- There are 5 classes, allowing to address low to higher risk missions (from Class I down to Class V)

- ESA has been working and is working with COTS for a long time, however one of the RHA challenges nowadays appears to be with new companies & convincing them to have a proper « RHA plan vs. risk approach ». As such, somme lessons learned & most common recommendations were shared!

Thank you for your attention ☺…one more thing…

OSIP – Open Space Innovation Platform

- Link: https://ideas.esa.int/
- Launched in 2019
- Purpose: new space technology & applications
- Main entry point for novel ideas:
  - In response to specific problems (Campaigns)
  - Open calls for ideas (Channels)
- Process:



<u>Three main implementation paths</u>:

1. Co-sponsored research (20 - 90k€)
2. System studies (20 - 100k€)
3. Early technology development activities (50 - 175k€)