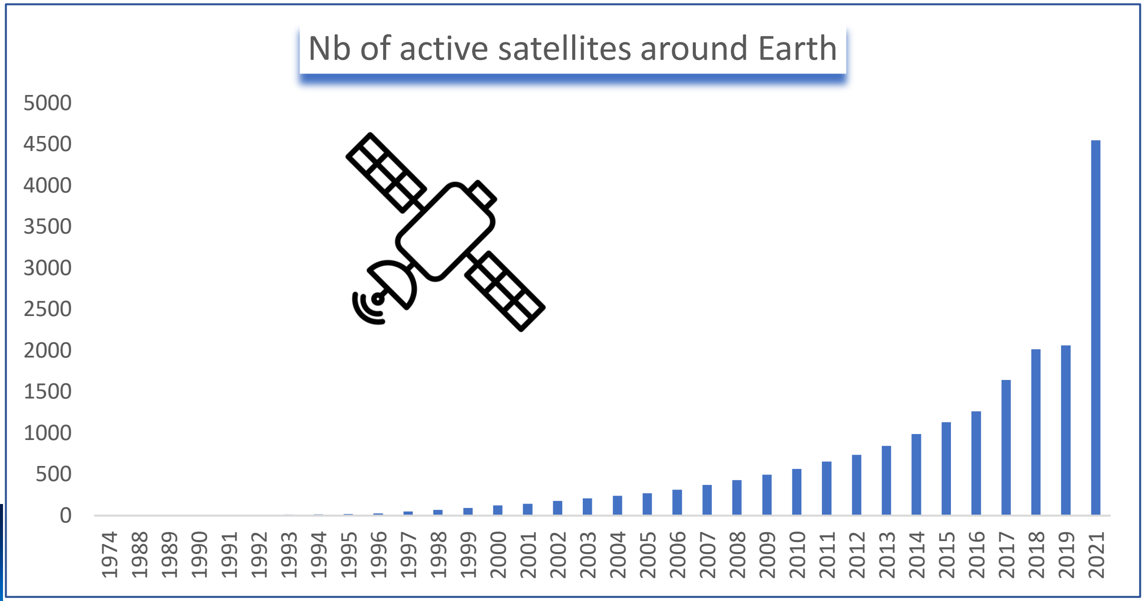
Radiation Hardness Assurance testing challenge at TRAD

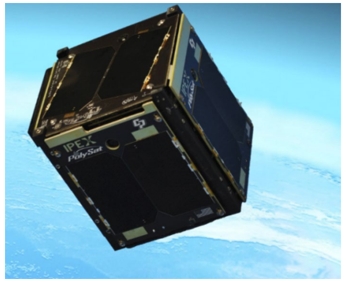
Presented by Pierre GARCIA

Outline

1. Introduction: context, definitions, purpose for this presentation
2. General steps for equipment development
3. Traditional qualification methods
4. Newspace approach & validation methods
5. Summary
6. Conclusion

Introduction: Context





NanoSat
CubeSat

- The number of satellites is constantly increasing, and even more in the coming years

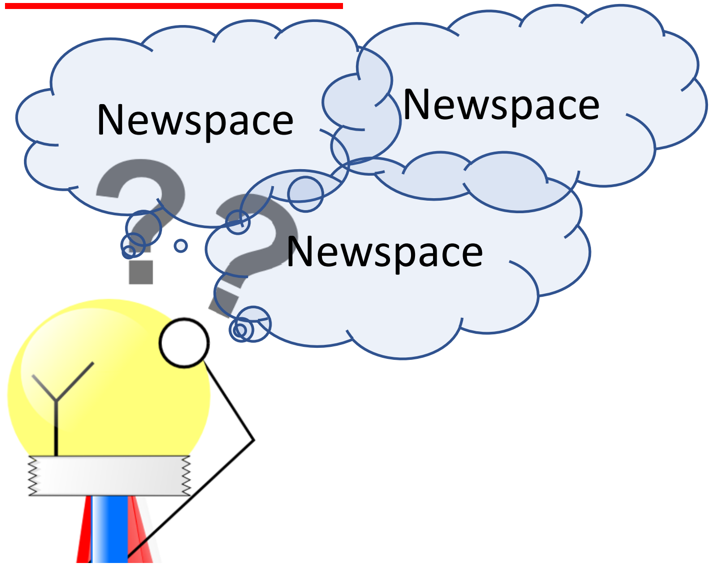
- But the size and the cost of these satellites is constantly decreasing

Introduction: Definitions

TRADITIONAL Components Qualification … easiest to define

- Fully qualified, ECSS25100, ECSS22900 (fully detailed by ESA)
- TID up to 100 krad on all parameters with a worst case for biasing conditions
- SEE with SEL free for a LET ≥ 60 MeV.cm²/mg & a complete qualification in SET, SEU, SEFI

NEWSPACE … now a term used by all … but applicable for what?



New radiation qualification methods

New test philosophy

→ At Board Level

→ At Component Level

What for the irradiation testing ?

Introduction: purpose for this presentation

This presentation will concentrate on two types of radiation testing:

TOTAL IONIZING DOSE

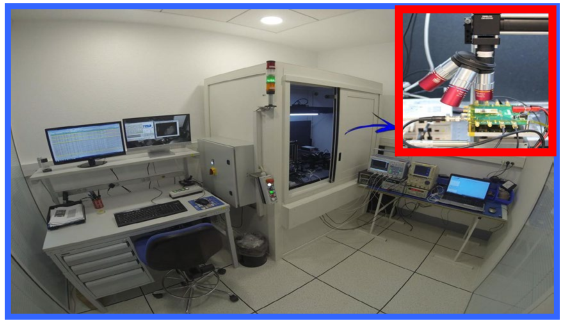
With Co60 Source
Parametric Tests
Biasing board during irradiation

SINGLE EVENT EFFECTS

With Heavy Ions, Protons & Laser
Functional Tests
Latch, Transient, Upset, Burnout, …

Gamray TRAD

UCL Belgium

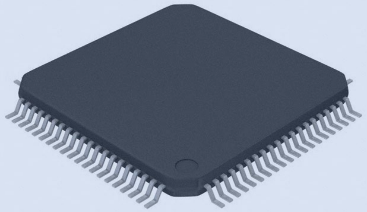


TRAD's Laser Nd:YAG

General steps for equipment development

At test level : Two different approaches

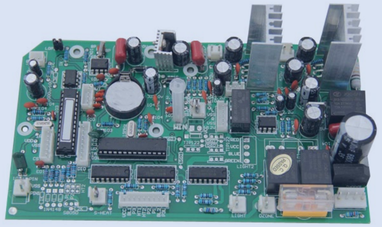
AT COMPONENT LEVEL



Design

Define the schematic and the function of the equipment

AT BOARD LEVEL



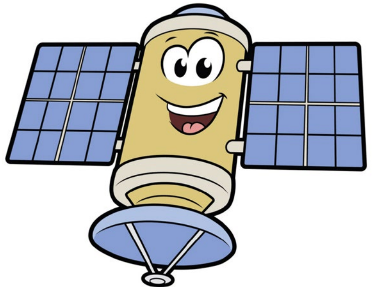
Engineering model

Validation of performance and functionality test

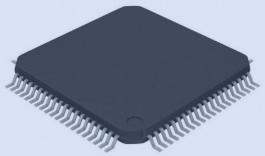
And often a Qualifying model

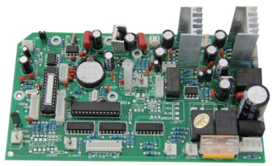
Flight model

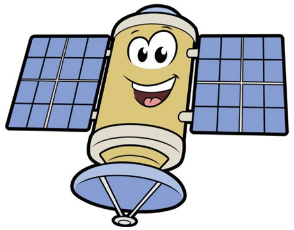
I'm ready to go !



Traditional qualification methods







Design

Define the schematic and the function of the equipment

Engineering model

Validation of performance and functionality test

Flight model

I'm ready to go !

AT COMPONENT LEVEL ONLY

TID testing

Co60 source

- 10 samples per lot minimum
- Dose rate
- Samples biased ON and OFF
- Maximum number parameters tested
- Worst case biased

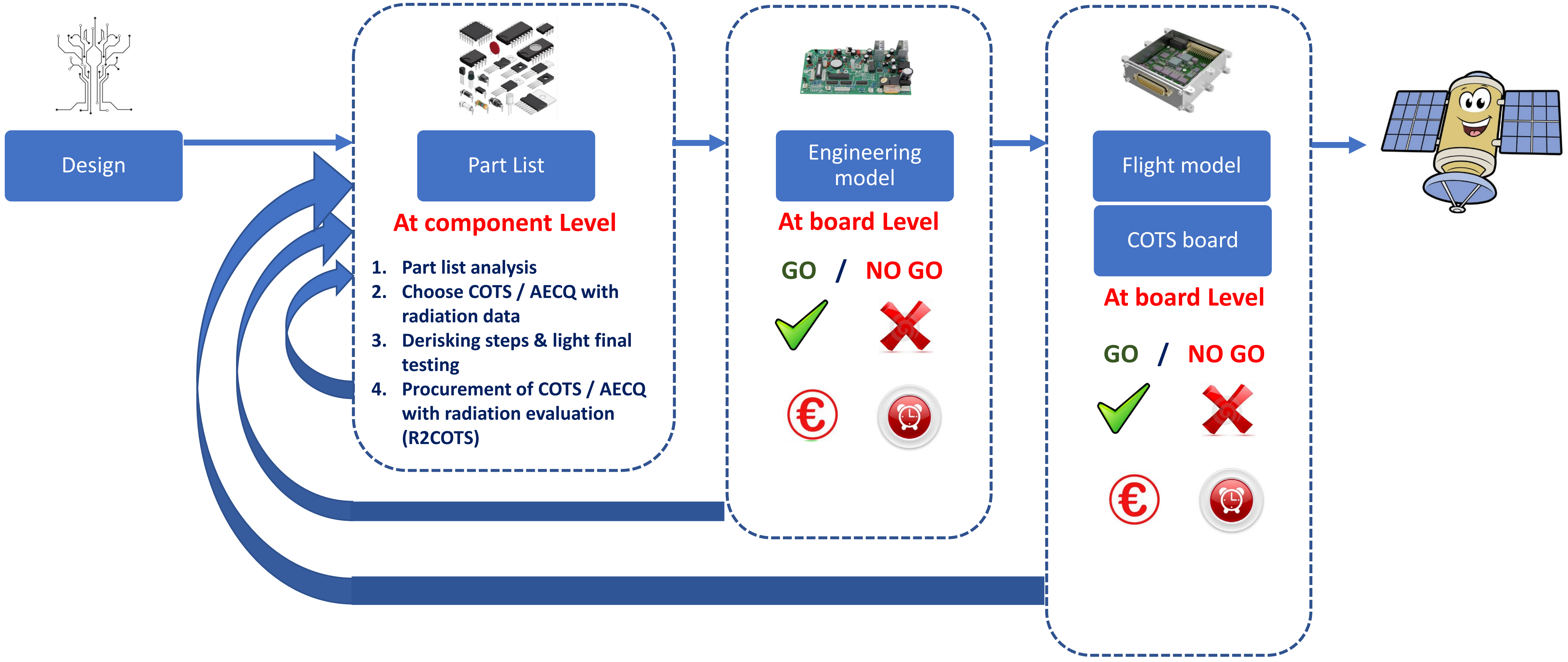
Heavy Ions

Protons or calculation If LETth ≤ 15

SEE testing

- 3 parts minimum for destructive event
- Maximum operating voltage and temperature SEL, minimum operating voltage and room temperature for other events
- 5 LETs to plot a cross section
- Plot the cross section for all types of events

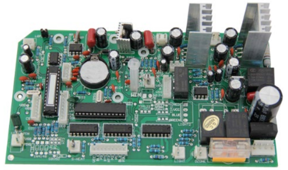
Newspace approach & validation methods



Newspace approach & validation methods

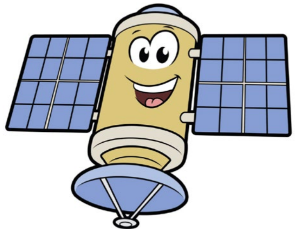
AT COMPONENT LEVEL

Part list



Engineering model

Flight model
COTS board

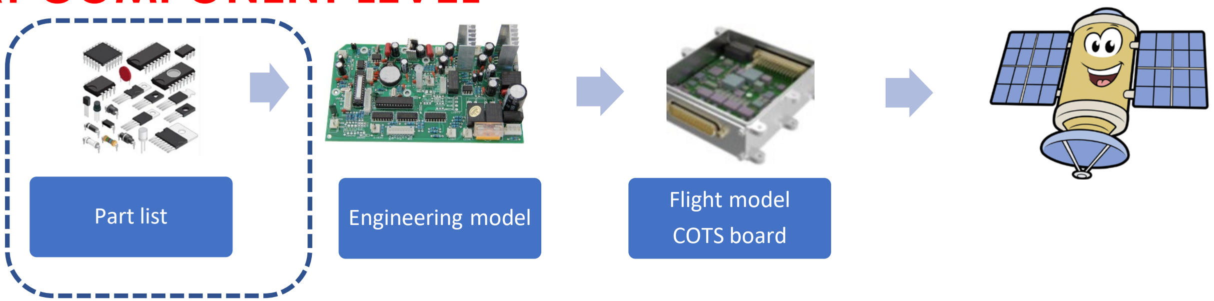


Key point is part selection derisking: radiation prescreening of one part type + (at <u>minimum)</u> one backup for each reference used in the design in order to find the best candidate

Objective: Reduce beam time, cost and delay to quickly find the best candidates

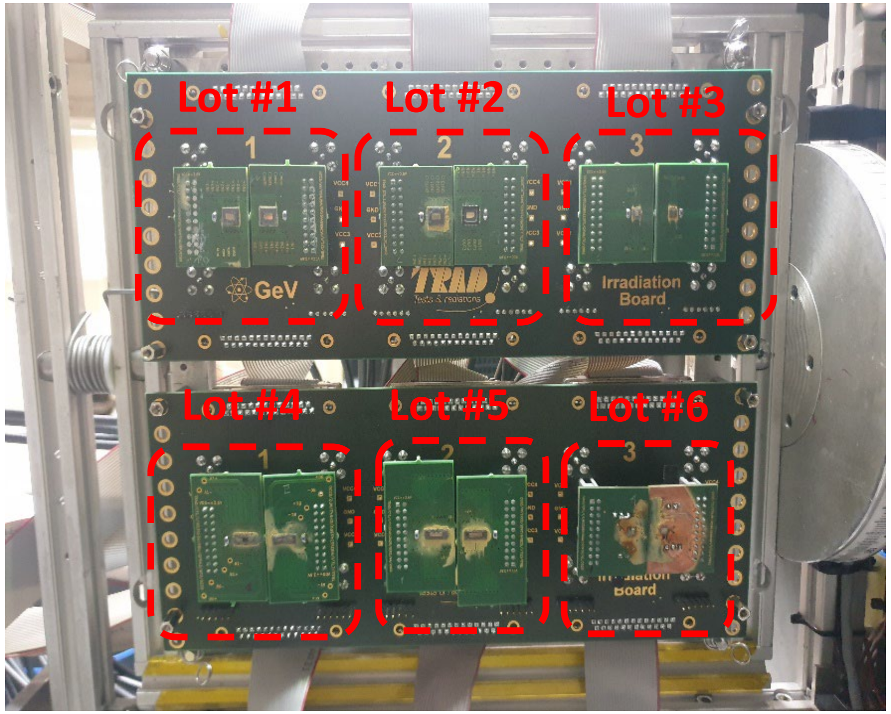
Newspace approach & validation methods

AT COMPONENT LEVEL



SEE derisking advantages

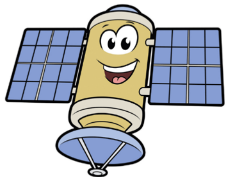
- 1 hour of beam time instead of 5 or 6 hours
- Test bench developed in a few days instead of few weeks
- It’s compatible with laser and Cf242



SEE testing on vaccum chamber at UCL

Newspace approach & validation methods

AT COMPONENT LEVEL



Part list → Engineering model → Flight model COTS board

TID Derisking Testing

- Reduce time measurement
- Reduce irradiation duration
- Simplify the test bench development

2NXXXX	Irradiation test	SOURCE	Co60		Location	GAMRAY		
NPN Bipolar Transistor	Irradiation steps:	Step1	Step2	Step3	Step4	Step5	Step6	Step7
Transistor	Accumulated dose krad(Si)	0	30	72	101			
Manufacturer	Dose rate rad(Si)/h	310	310	310	310			
UB		Step8	Step9	Step10	Step11	Step12	Step13	Step14
	Accumulated dose krad(Si)							
	Dose rate rad(Si)/h							
3	Annealing test	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
	Duration (h)	24	168					
3	Temperature (°C)	25	100					
1								

REFERENCE: This part is measured before and after irradiated components at each step.
easured on the REFERENCE and irradiated components.
e performed before irradiation, after each irradiation step and after each annealing period

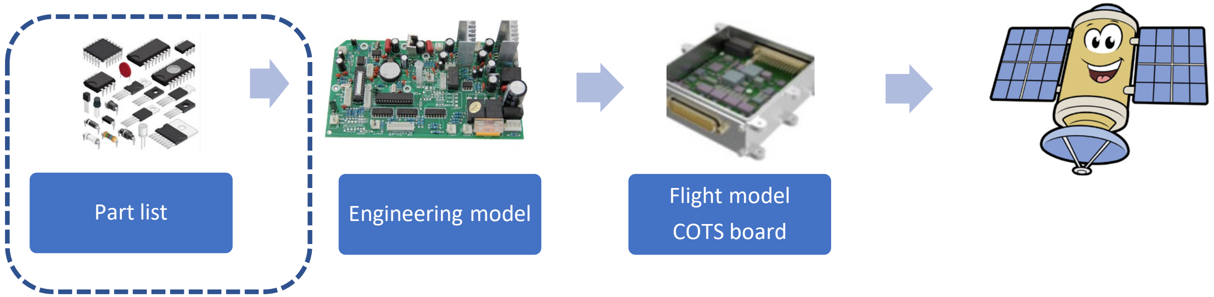
SYMBOLS	TEST CONDITIONS	Min	Typ	Max	Unit	Comments
V(BR)CEO	IC = 10mAdc	50			V	
ICBO	VCB = 60Vdc			10	nA	
IEBO	VEB = 4.0Vdc			10	nA	
hFE1	IC = 0.1mAdc, VCE = 10Vdc	50				
VCE(sat)1	IC = 150mAdc, IB = 15mAdc			0.3		

(APPLICABLE DETAIL SPECIFICATION or DATA-SHEET)

- 6 samples per lot minimum
- High dose rate (Xray, Co60), limited n# of steps
- Reduced number of parameters tested (Eval board can be used ?)
- Simplified biasing

Newspace approach & validation methods

AT COMPONENT LEVEL



SEE testing & TID testing

After the derisking a more accurate test has to be performed on the selected part types

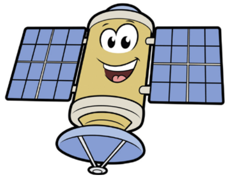
Newspace approach & validation methods

AT BOARD LEVEL

Part list

Engineering model

Flight model
COTS board



There are few guidelines for board testing vs radiation*

Advantages :

- Board design (schematic and layer) is based on chosen reference, that fits with the final application
- Only two boards have to be tested
- The whole application is tested in one shot, allowing to save beam time

Difficulties :

- Board design (schematic and layer) is based on chosen reference so project needs to be well advanced
- In case of significative design modification, new tests have to be performed
- Time to debug two boards can be more complex (in terms of observability and degradations)
- DUTs are validated only for one application
- In case of failure, design may need to be modified if no pin to pin alternative reference exists, and will have a huge impact in terms of planning

*** "Lessons and Recommandations for Board-Level Testing with Protons", SSC18-WKV-02, JPL, S. M. Guertin**

AT BOARD LEVEL

Flight model COTS board

Engineering model

SEE testing with **IOL**
- Impact of ions directly on the output (+)
- Delidded devices (−)
- SEL only on global power supply (−)

SEE testing **p+**
- All the board tested in one shot (+)
- Limited to an LET < 15MeV.cm²/mg (−)
- Not easy to identify the culprit if FAIL (−)

TID testing with **Co60**
- Limited number of parameter could be monitored (−)
- Simple and rapid implementation (+)

Summary

	Traditional Space	Newspace	
Level	At component	At component	At board
Advantages	Robust product, proven space-reliability, approved by space industry	good compromise between Traditional & NewSpace, widely available,	Heavy Ions : directly on the EM board TID : simple & rapid implementaion
Drawback	(Very) expensive, long lead time, less-advanced technology	components usable only on certain missions depending on the radiation results	Heavy Ions : delidding operations & SEL on the global power supplies TID : monitored parameters are limited (GO/NO GO test)
TID testing	11 parts (5 ON + 5 OFF + 1 REF) Low Dose rate ≤ 360 rad/h Worst case for biasing conditions ECSS22900	7 parts (3 ON + 3 OFF + 1 REF) Low Dose rate ≤ 360 rad/h Application case for biasing conditions	2 boards minimum
SEE testing	3 parts $1^{E}6$ #/cm2.s → SEU, SET, 25°C $1^{E}7$ #/cm2.s → SEL, 125°C 5 ions if sensitive ECSS25100	2 parts $1^{E}6$ #/cm2.s → SEU, SET, 25°C $1^{E}7$ #/cm2.s → SEL, Tapp 1-2 ions max	2 boards $1^{E}6$ #/cm2.s → SEU, SET, 25°C $1^{E}7$ #/cm2.s → SEL, Tapp 1-2 ions max

Conclusion

- For each chosen way, there is a solution !

A little guide for users

- First : A good analysis of missions and needs will allow to choose the best solution (constraints versus environment)

- Second : COST / BUDGET analysis ⇒ Solution

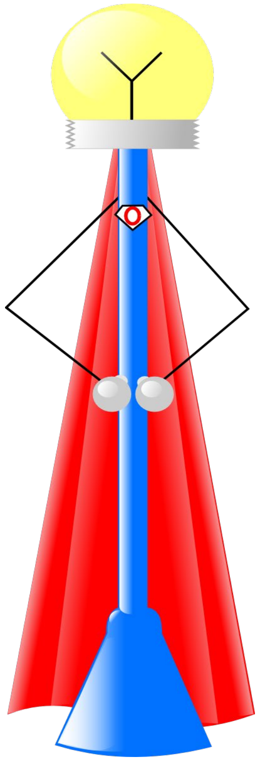
⚠ Planning impact according to the chosen solution

At component level ⇒ existing solutions as R2COTS

At board level (EM, FM, COTS board) ⇒ GO ⇒

⇒ NO GO ⇒

A last word from my friend



No magic solution but irradiation aspect have to be taken into account from the start of the project, you will save time, delay and money !

Thank you for your attention

For further information on:

www.trad.fr – www.fastrad.net
www.rayxpert.com – www.r2cots.com

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Introduction: Definitions

THE SPACE MARKET IS CHANGING !!

Almost exclusively CLASSE 1 - Hi-Rel components : Fully qualified & screened parts

- ✓ **Pros: Robust product, proven space-reliability, approved by space industry**
- ✗ **Cons: (Very) expensive, long lead time, less-advanced technology**

Classe 3+ → components for NEWSPACE applications

AEC-Q qualified & Enhanced Product (EP) and / or Industrial grade T° COTS

+ LAT (simplified if possible)& Irradiation tests

- ✓ **Pros: good compromise between HIREL & COTS, widely available,**
- ✓✗ **Pros / Cons : Traceability**
- ✗ **Cons: components usable only on certain missions depending on the radiation results**

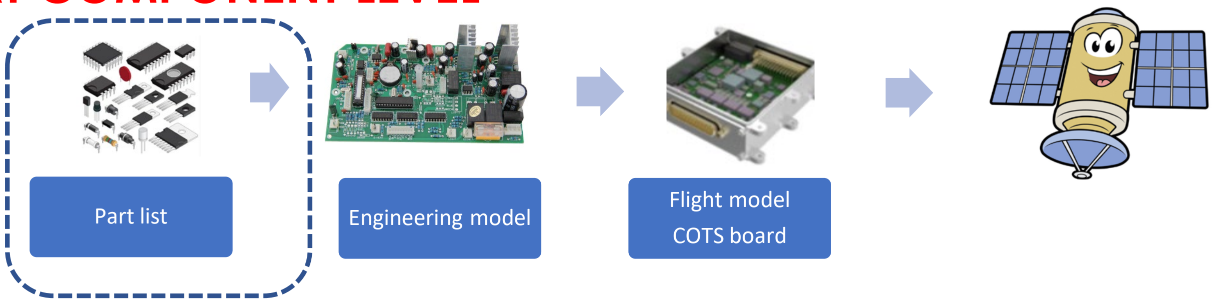
Classe 3 - COTS : Commercial-off-the-shelf

Commercial application – no part-level testing other than manufacturer control

- ✓ **Pros: Cheap price, widely available, technologically advanced**
- ✗ **Cons: Reliability for use in space, no screening & LAT performed, end-user acceptance**

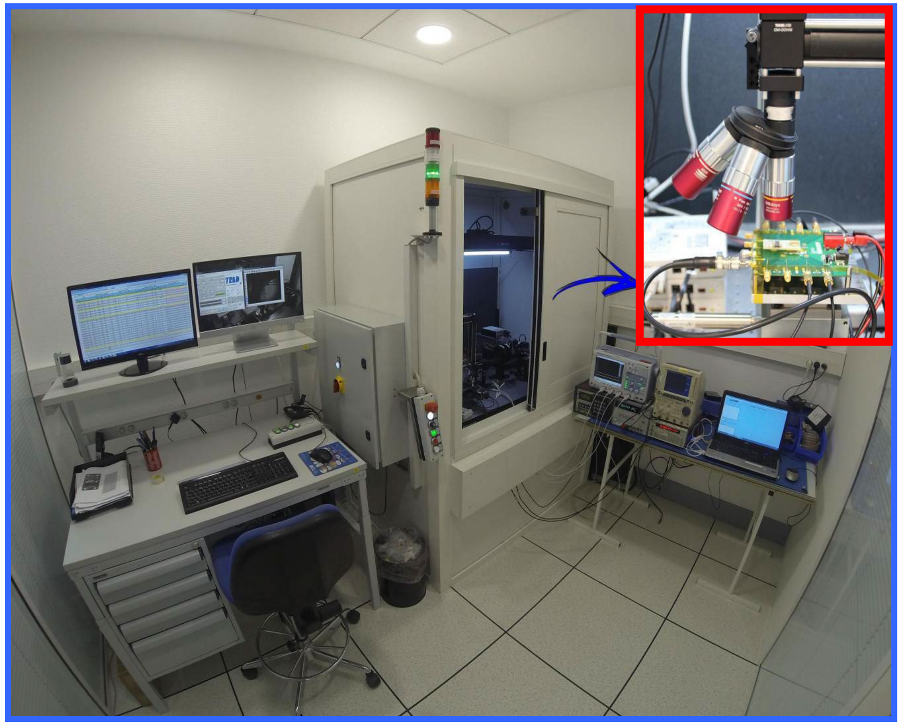
Newspace approach & validation methods

AT COMPONENT LEVEL



SEE derisking with laser or Cf242

- Can detect if part show sensitivity to SEL and directly remove this part
- Much less expensive than heavy ion/proton tests
- Laser can also be used for test at board level



TRAD's Laser Nd:YAG with wavelength 1064nm