SRPROTEC – SPACE RADIATION SHIELDING IN MICROELECTRONICS THROUGH THE DEVELOPMENT OF ADVANCED COMPOSITE MATERIALS

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Proyectos en Colaboración Público-Privada
CPP2021-008565

CONTENTS

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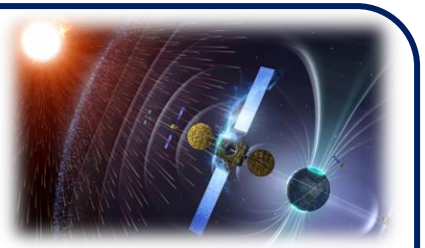
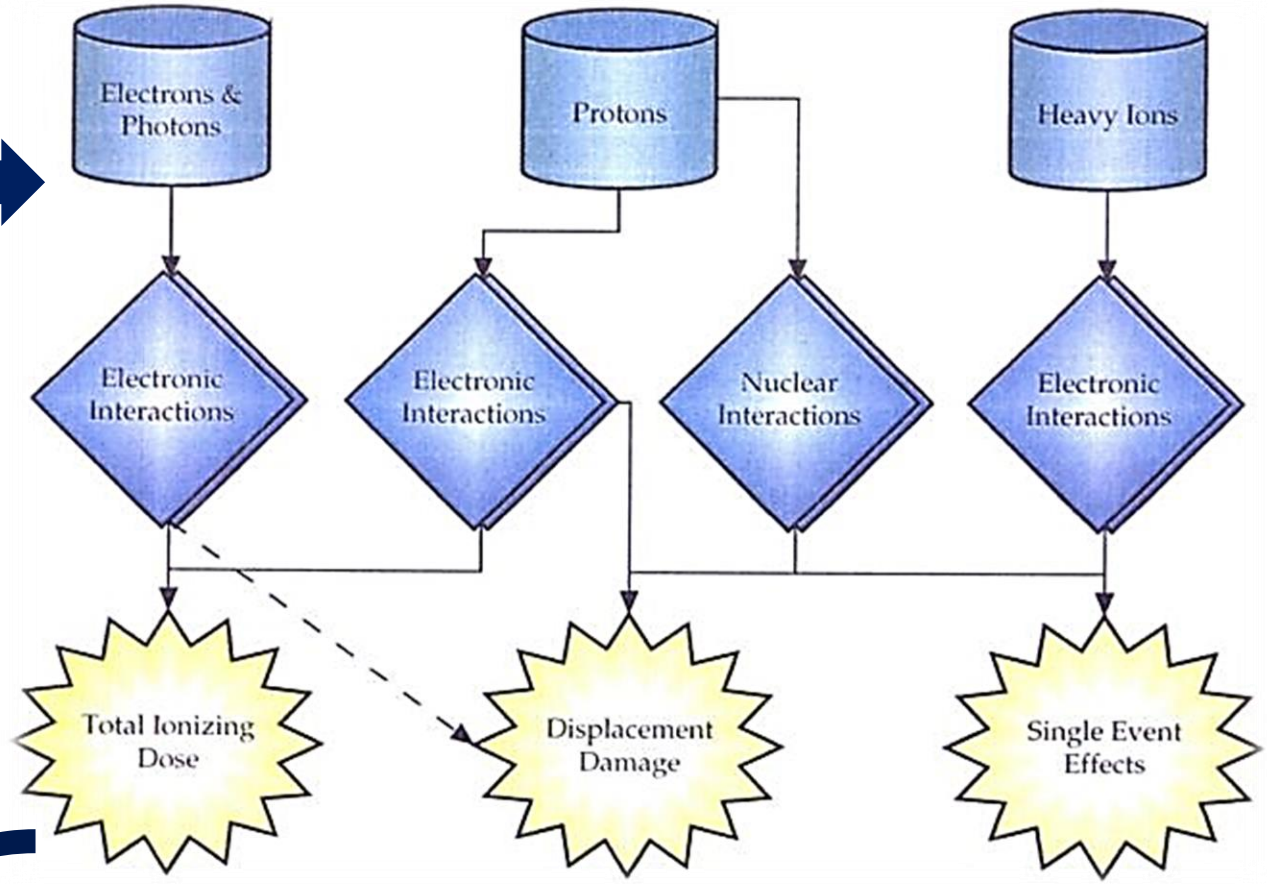
1. Introduction and objective

- ✓ GCRs
- ✓ SEPs
- ✓ Trapped particles in Van Allen belts





J.W. Howard, Jr. And D.M. Hardage. Spacecraft Environments Interactions: Space Radiation and Its Effects on Electronic Systems

Failures: Parametric and functional

- ✓ Leakage current
- ✓ Threshold voltage
- ✓ ...

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1. Introduction and objective

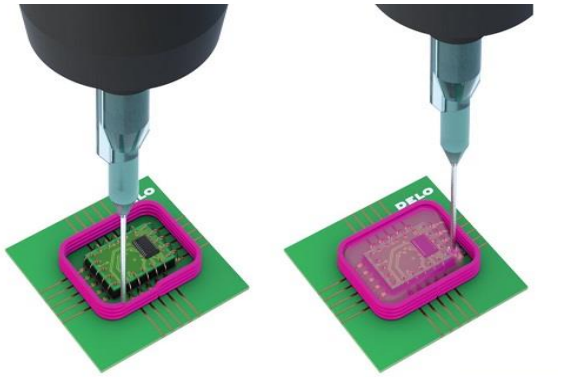
Protection of microelectronics

Passive shielding

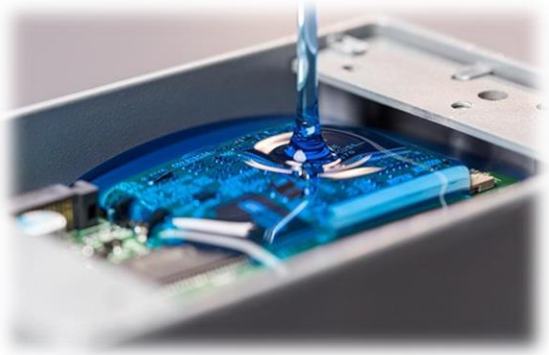
✓ **Development**
✓ **Validation**

- **New composite materials with space radiation shielding performance**

Dam & Fill



Potting process



Process integrated light weight solution for space radiation

+

Keeping desired MC properties

+

Applicable as potting compound

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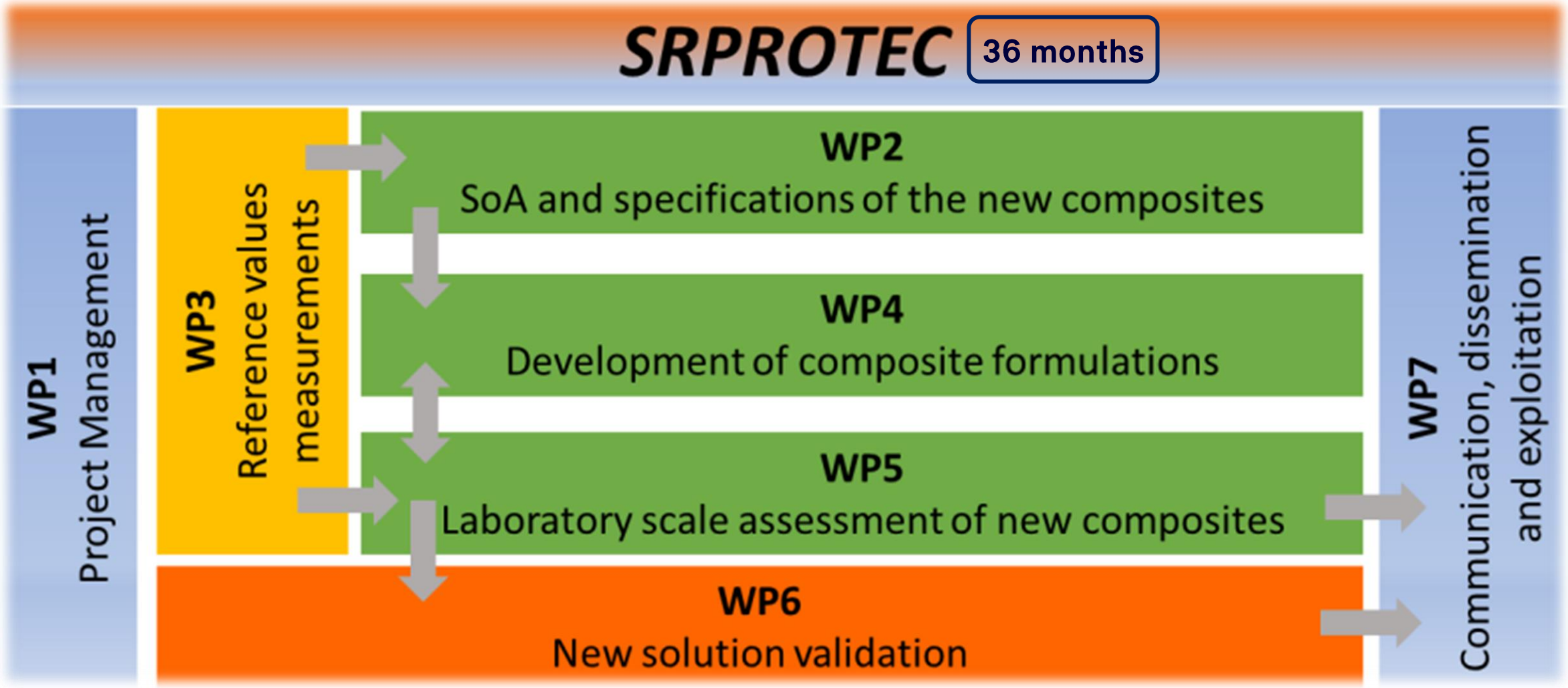
2. Project structure



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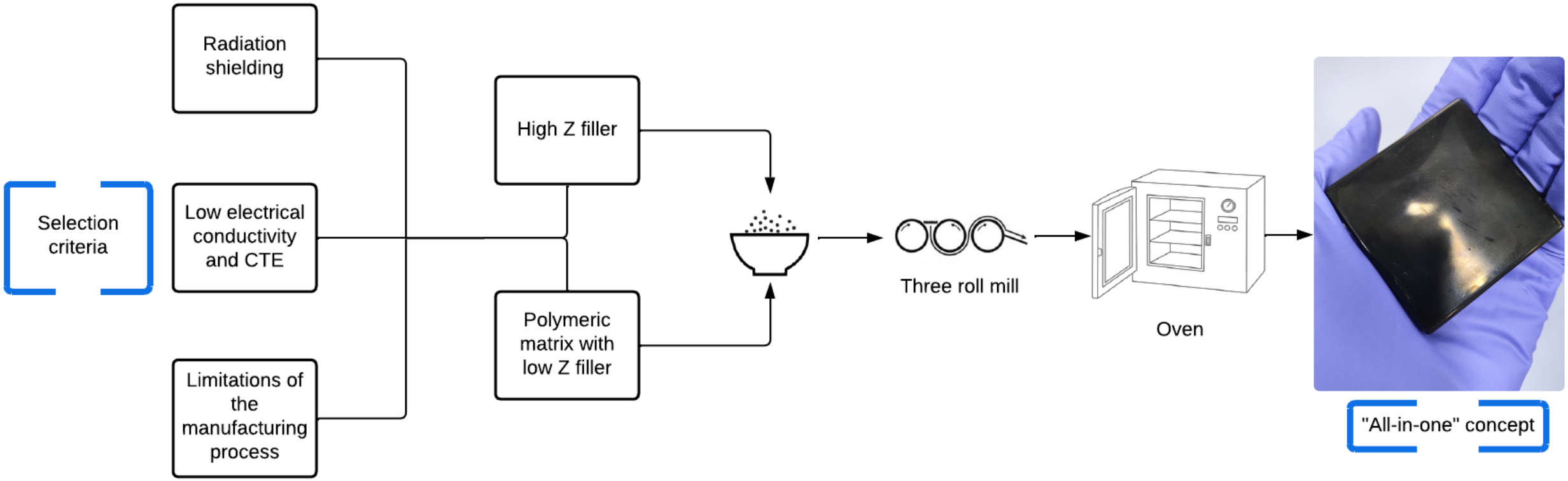
3. New composite materials development (WP2-WP4)



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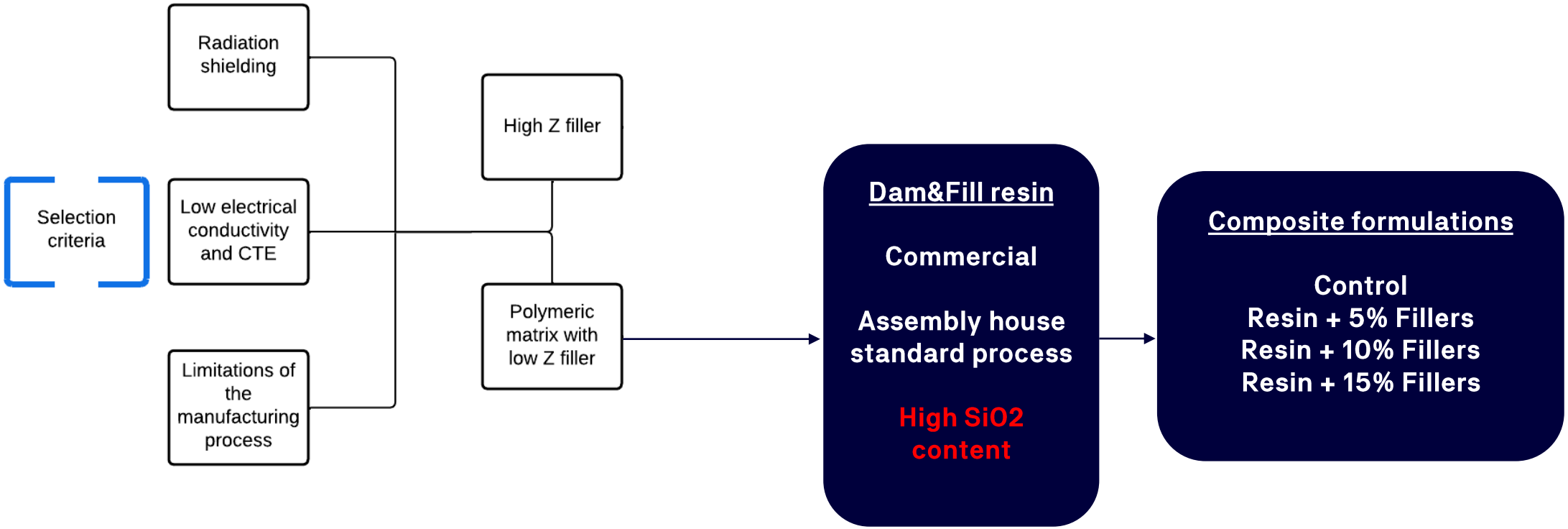

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4. Materials characterization (WP5)

WP5
Laboratory scale assessment of new composites

*TMA: Thermomecanical Analysis
*EVI: External visual inspection
*TVAC: Thermal Vacuum Cycling
*TS: Thermal Shock
*RH: Relative humidity (humidity exposure)

Material test plan elaborated considering

ECSS-Q-ST-70C Rev. 2: Materials, mechanical parts and processes

Screening tests
Control formulation
5% Fillers
10% Fillers
15% Fillers

Critical properties characterization: Material & Application

Viscosity | Outgassing | Radiation shielding | TMA → EVI

Composition Characterization

Cross section + SEM-EDX

→ Critical properties for the material itselft and the application → Final formulation selection

Degradation tests

Final formulation assessment

EVI → Flexural Test

EVI | EVI

TVAC | TS + RH

EVI → Flexural Test | EVI → Flexural Test

TVAC | TS + RH

EVI → TMA | EVI → TMA

→ Final formulation testing → Degradation resistance

Final Physical Characterization

Final formulation assessment

Density | Thermal conductivity | Electrical conductivity | Moisture absorption

→ Final formulation testing → Other relevant properties for the application

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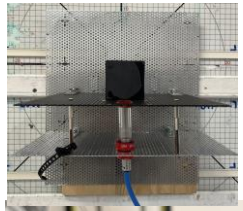
5. Radiation shielding characterization (WP5)

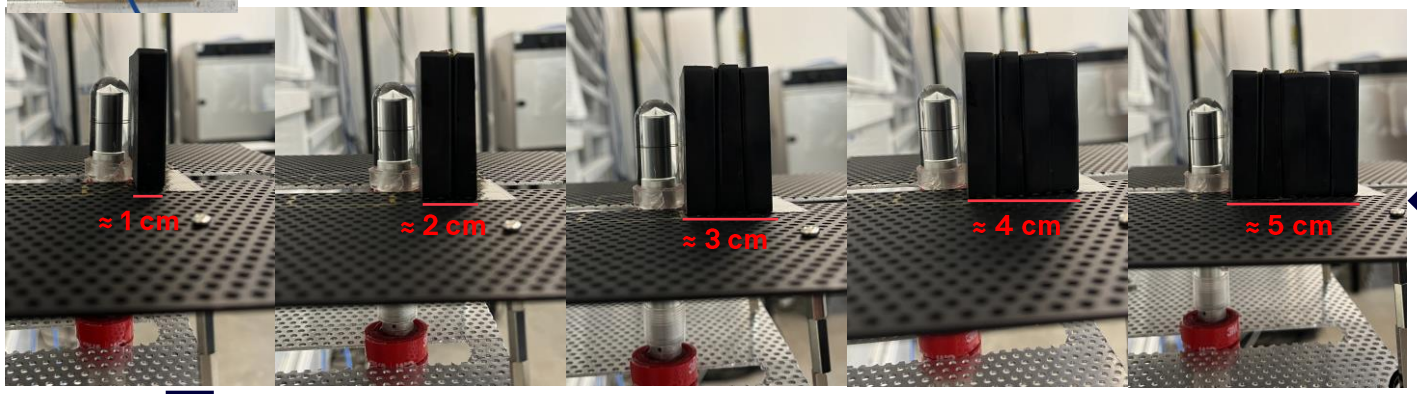
Direct measurements set up

WP5
Laboratory scale assessment of new composites



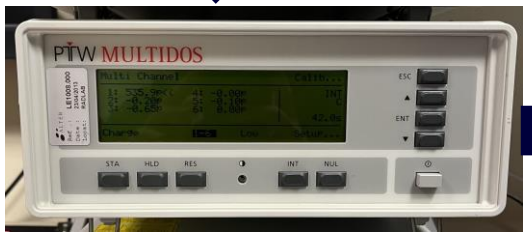
Gamma radiation shielding test set up development

Goal: To measure a property to quantify radiation shielding for each formulation



Radiation source (Co60)

RadLab
ALTER-CNA
^{60}Co radiation source



Electrometer: Live monitoring of charge

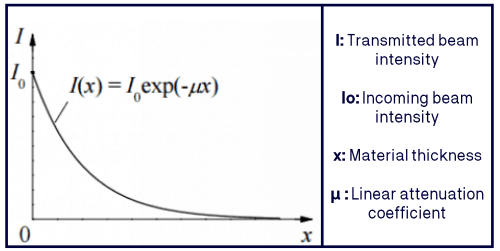
Data treatment

Nk conversion factor
P-T correction factors

Radiation dose obtained for each measurement

Data treatment

Beer-Lambert Law



Linear Attenuation coefficient for each material

μ [cm-1]

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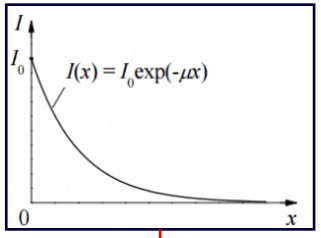
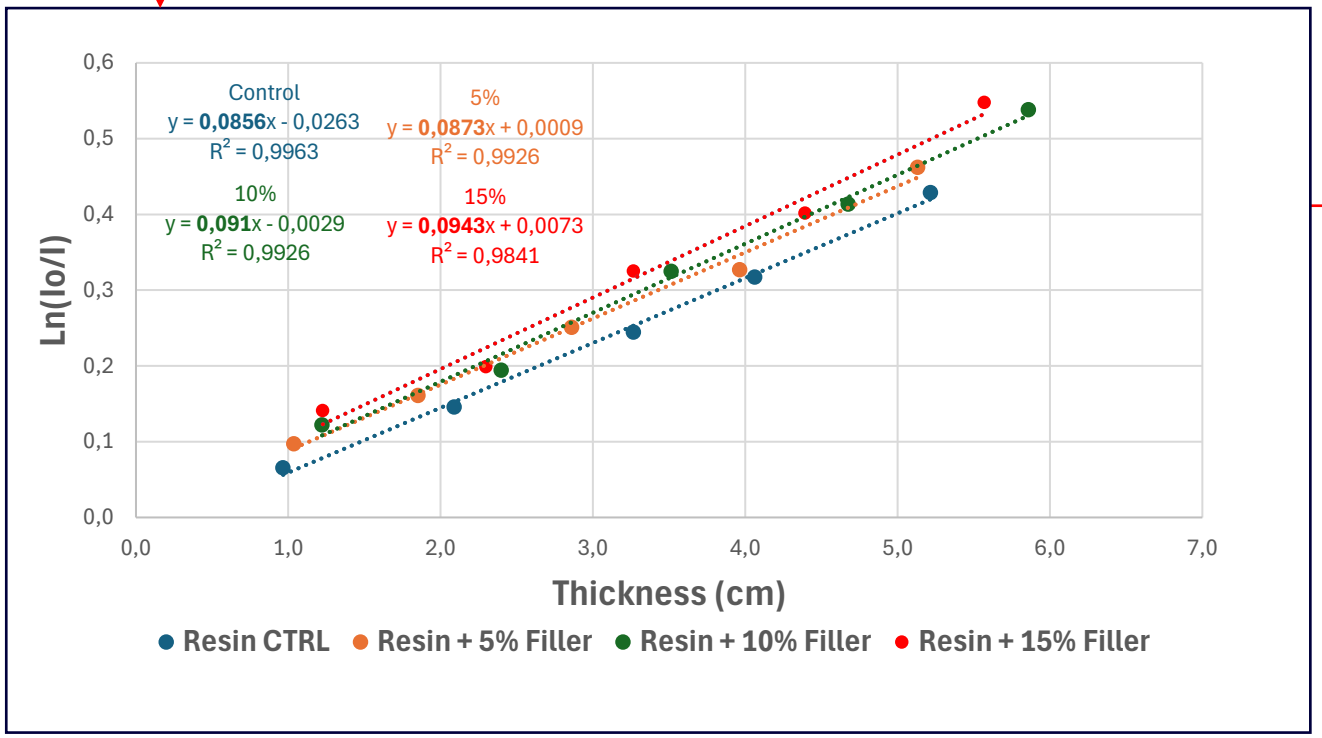
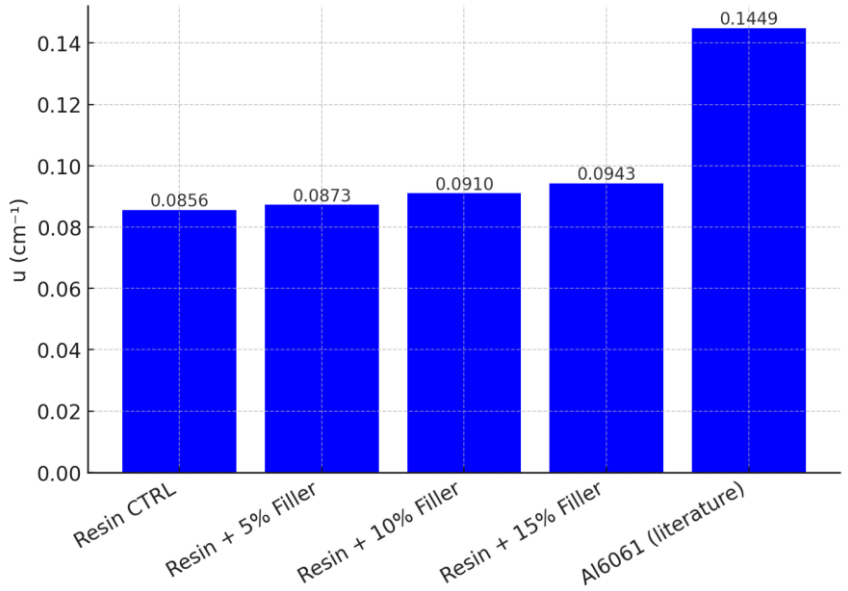
6. Materials characterization results (WP5)

Radiation shielding



Ln (Io/I) vs x (thickness) → μ (slope)





Filler content (%)	μ (cm-1)	μ Formulations / μ Al6061 (%)
0%	0,0856	59,06
5%	0,0873	60,24
10%	0,0910	62,79
15%	0,0943	65,07

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6. Materials characterization results (WP5)

TMA

Average values			
Formulation	CTE 1 (T<Tg) [µm/°C]	Tg (°C)	CTE 1 (T>Tg) [µm/°C]
Resin (control)	19,27	135,46	51,60
Resin + 5% Filler	18,01	135,08	47,82
Resin + 10% Filler	17,84	130,91	44,88
Resin + 15% Filler	17,53	144,67	46,50

CTE decreases for formulations with filler content when compared with control formulation → **CTE mismatches decreased**

Si ≈ 2,6 µm/°C
Cu ≈ 17 µm/°C

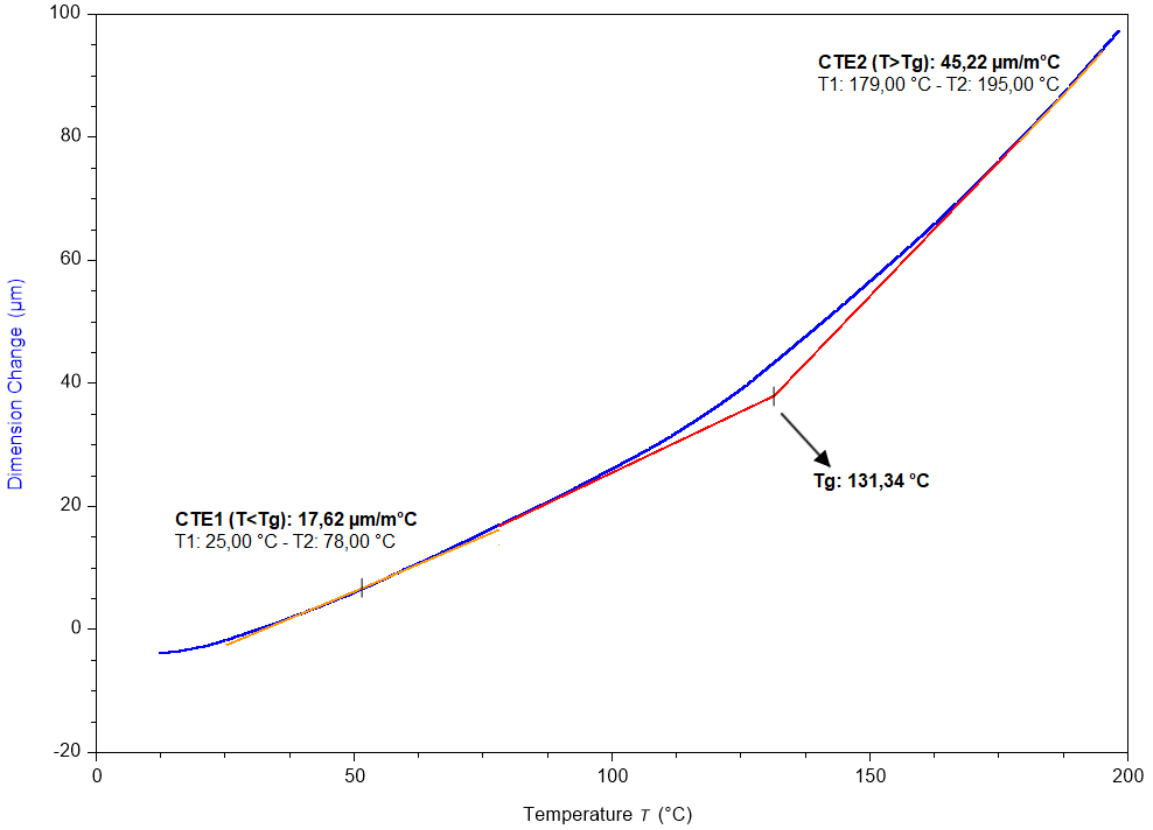
DS Tg (DMTA) = 187 °C

Measured Tg (TMA) < DS Tg (DMTA)

↓

DSC comparison

Resin + 10% (SN 10)



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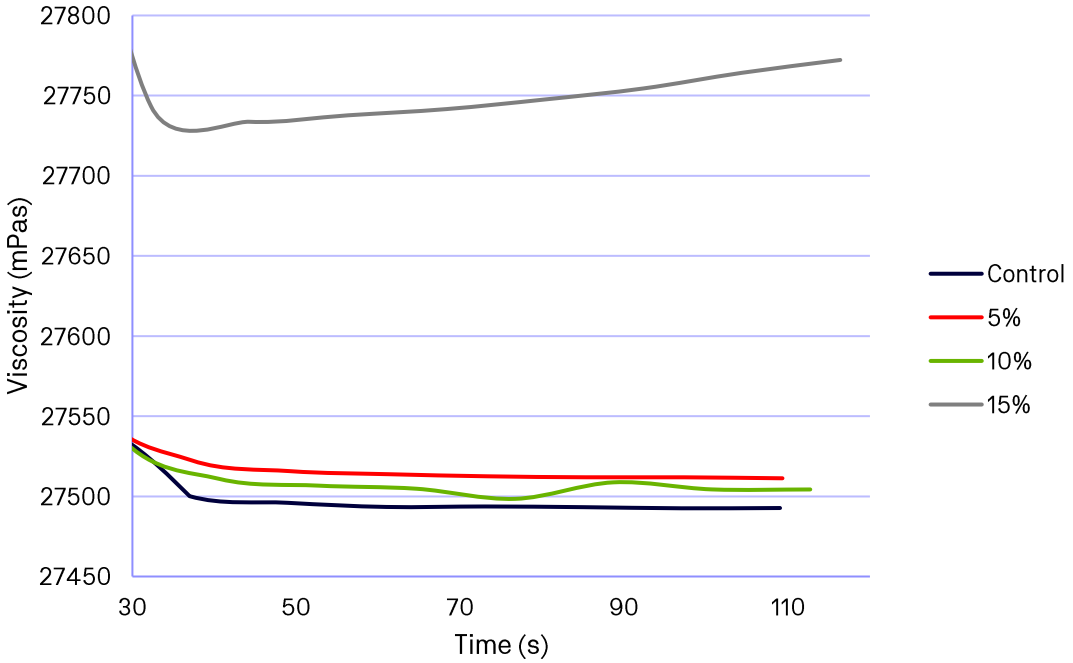
6. Materials characterization results (WP5)

Viscosity



Test conditions	
Equipment	Rotational Viscometer Fungilab™
Speed (RPM)	5
Time (s)	120

Outgassing

The samples tested are **compliant** with general limits of acceptance for material selection according to **ECSS-Q-ST-70-02C**: RML < 1,00%, CVCM < 0,10%.

Sample	TML (%)	SD (%)	RML (%)	SD (%)	CVCM (%)	SD (%)
Control	0,412	±0,004	0,295	±0,003	0,003	±0,002
5%	0,349	±0,021	0,205	±0,019	0,003	±0,003
10%	0,323	±0,010	0,171	±0,025	0,005	±0,001
15%	0,277	±0,013	0,170	±0,008	0,003	±0,001

TEST CONDITIONS-STANDARD	
Material sample temperature:	125 °C
Condensable collectors (CVCM) temperature:	25 °C
Test vacuum:	range 10^{-6} - 10^{-7} mbar
RT airconditioning of samples before test:	22 ±3 °C, 55 ±10 %HR, 24 h
RT airconditioning of sample after test:	

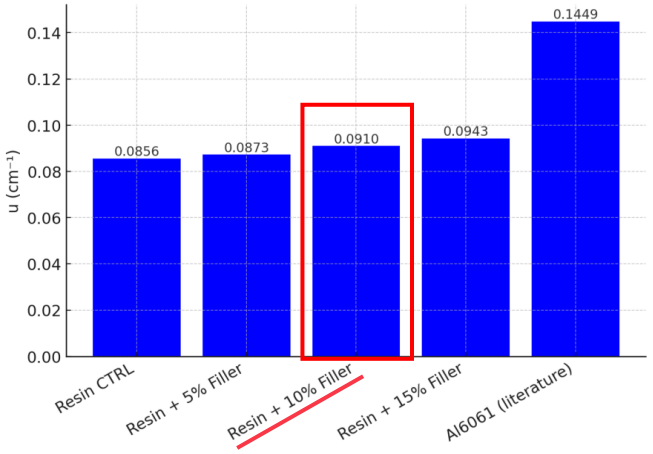
7. Final formulation selection (WP5)

Screening tests approach

Critical properties characterization:

- **Material & Application**
- **Approach valid for other combinations of materials**

Radiation shielding



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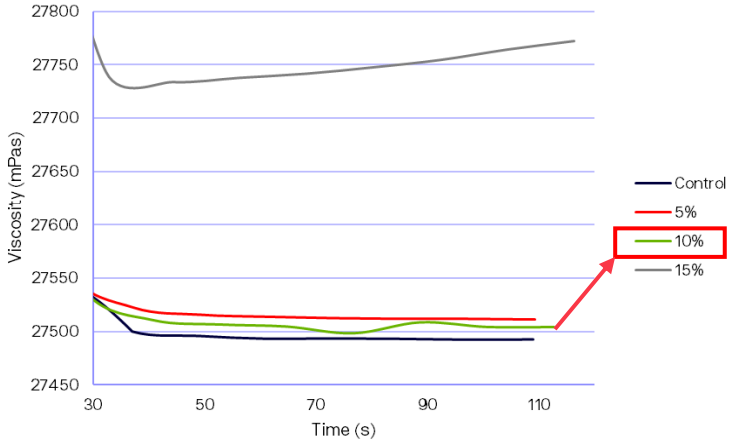
Viscosity



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Resin + 10% Fillers vs Control

Slight radiation shielding improvement

Thermomechanical properties enhanced (lower CTE)

Compliant with ECSS outgassing limits

Not excessively high viscosity

8. Test vehicles definition: Part types selection (WP6)

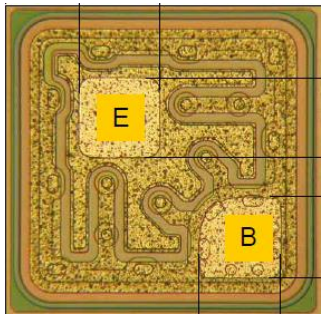
WP6
New solution validation

Validation of the composite in target application:
Resin for encapsulation of microelectronics

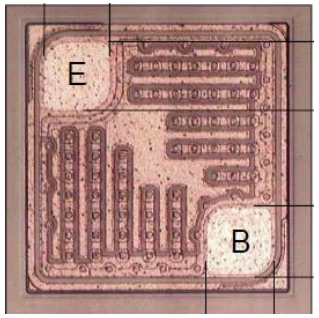
Part type requirements

- ✓ Die format
- ✓ Homogeneous TID response (same wafer)
- ✓ High TID sensitivity
- ✓ Available TID data (ALTER data base)
- ✓ MOQ & LT
- ✓ Manufacturing capabilities
- ✓ Simple electrical test set up

2N2222A NPN Transistor



2N2907A PNP Transistor



Dam&Fill encapsulation

ALTER UK

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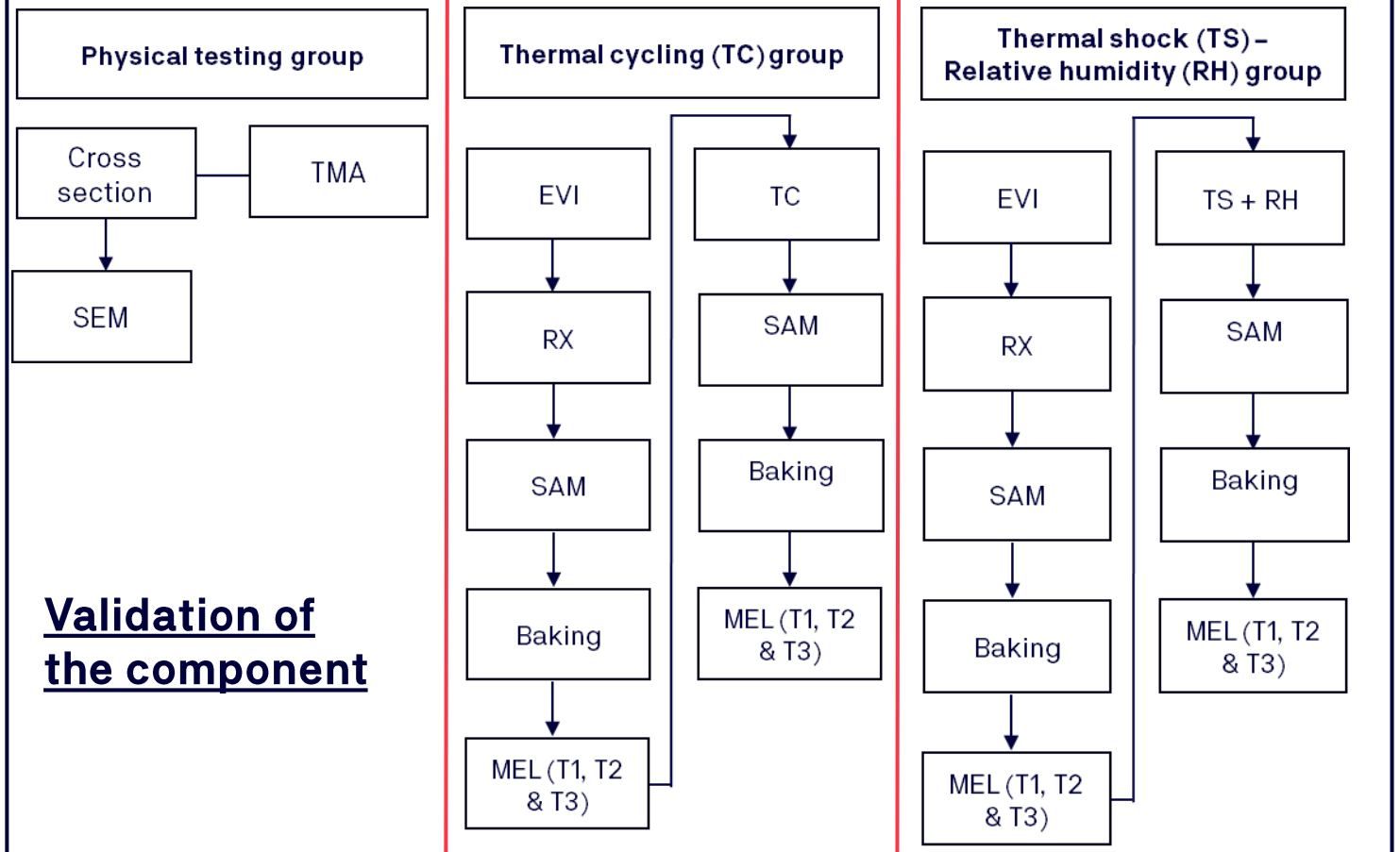
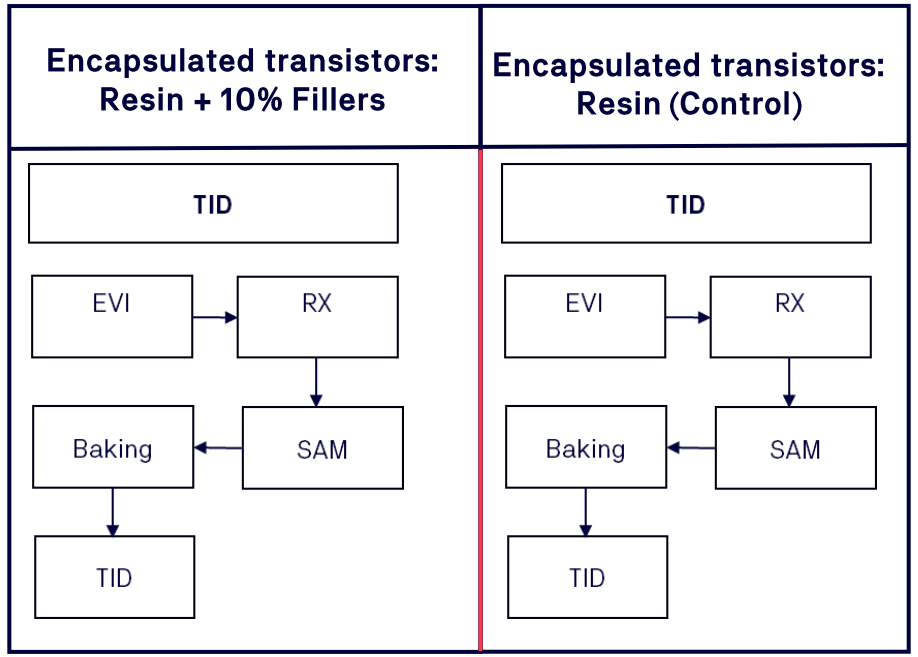
9. Test vehicles characterization (WP6)

Test plan: 2N2222A & 2N2907A

Encapsulated transistors: Resin + 10% Fillers

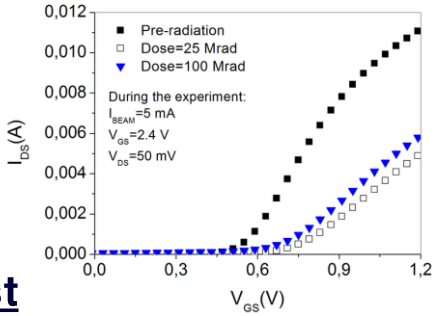


Validation of the component



Radiation shielding performance through electrical response:

Composite vs Control test vehicles



A. Marcilei, M. Nilberto, R. Valéria and N. Added. Brazilian facilities to study radiation effects in electronic devices.

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10. Potting compound approach (WP6)

Advantages

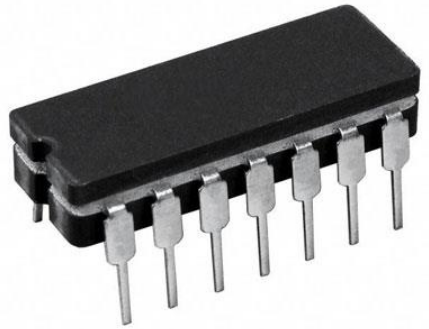
Customized protection: For the whole assembly or selective

Thickness can be increased, improving radiation shielding properties

Part type selection

- ✓ Encapsulated: Real assembly scenario
- ✓ High TID sensitivity
- ✓ Available TID data (ALTER data base)
- ✓ MOQ & LT
- ✓ Simple electrical test set up

OP470AY/883C: Operational amplifier

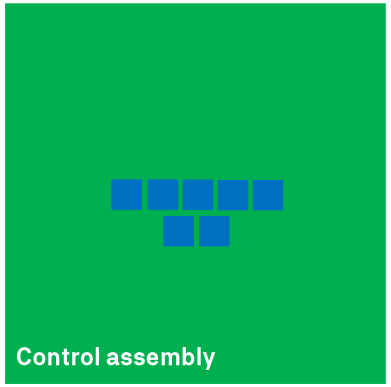


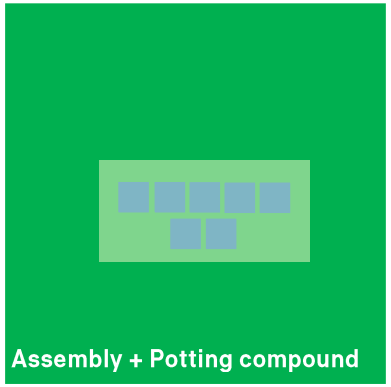
Potting compound approach testing

Control assembly:
TID

Assembly + Potting compound:
EVI + SAM + Baking + TID + Cross section

Detection of radiation shielding improvement through TID response





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11. Project status & Future developments

- ✓ **Materials, fillers, proportions and manufacturing processes: Defined**
- ✓ **Composites manufactured and final formulation selected.**
- ✓ **Part types for test vehicles manufacturing: Procured.**
- ✓ **Adaptable methodology for material selection and characterization successfully developed and implemented: Valid for other material combinations.**
- ✓ **Adaptable gamma radiation shielding characterization setup successfully implemented: Valid for other materials.**
- ✓ **Extrapolation to other manufacturing processes at assembly level (potting): On going**
- ✓ **Radiation shielding simulations will be perform and will be compared with experimental results. Simulations can be extended to other combinations of materials to widen the scope of the study in the future.**
- ✓ **Expertise acquired during this project could lead to light weight solutions that allow to solve other radiation related issues in space like crew protection, structural protection, etc.**

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11. Project status and future developments

Project completion

September 2025

A lot of work and research can still be done:

- ✓ Different materials and proportions
- ✓ Improvements and modifications in the radiation shielding characterization set up
- ✓ Simulations comparison
- ✓ Potting approach study

We are actively seeking partners and funding opportunities to ensure the continuity of the project!

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Thanks for your attention

Questions and collaborations:

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