Reference:

L.Fournier, *PFAS use mapping across ESA projects & update on obsolescence risk mitigation activities*, 7th ESA REACH Workshop, ESA ESTEC, Noordwijk, the Netherlands, 2nd June 2026

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PFAS use mapping across ESA projects & update on obsolescence risk mitigation activities

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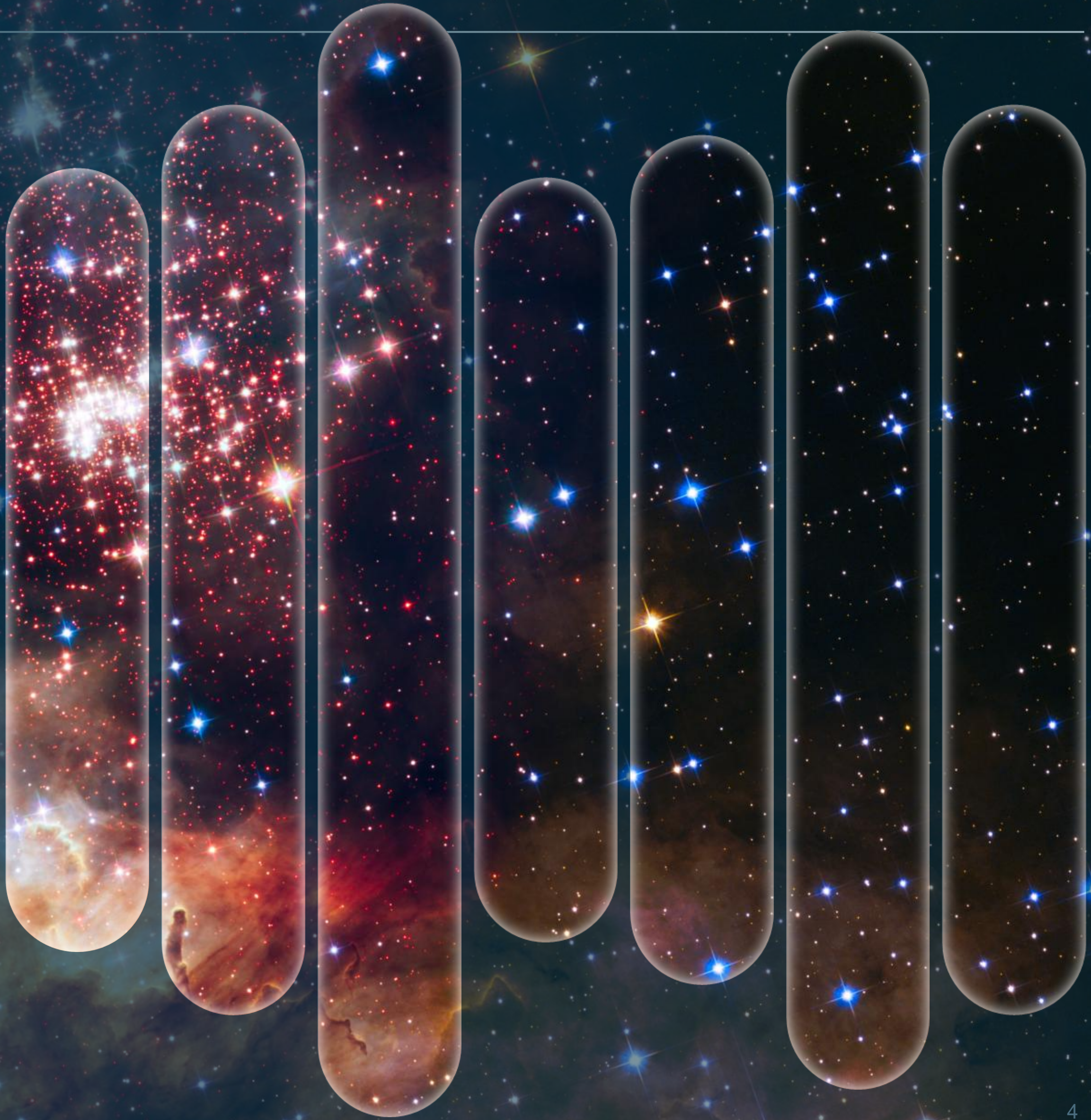
Reference:ESA-TECSFS-HO-2026-001745

OUTLINES

1. Introduction
2. PFAS mapping and mass estimation *across ESA projects and applications*
3. Obsolescence risk mitigation activities
    i. Beta®Cloth: full exposure conditions
    ii. PFPE fluids: hermeticity testing
4. Conclusion

PART 1:
INTRODUCTION



1. Introduction

PFAS phase-out / Potential ban

2023: regulatory acceleration, initial mapping launched

- Strong regulatory pressure
- Major impact on materials & processes

Analysis performed

2025: extended and consolidated mapping & testing

- PFAS mapping & mass estimation
- Obsolescence management
- Alternatives

Impact & Actions

2025+ : mitigation & adaptation

- Identify PFAS use & quantify impact
- Support risk mitigation & future readiness




PART 2:

PFAS mapping and mass estimation

across ESA projects

2. PFAS mapping and mass estimation

1
2
3
4
5

Objective: Provide a first estimation of PFAS presence and associated mass across space systems

Methodological choices:
→ Focus on DML data (time constraints & system-level consistency)
→ Broad multi-project analysis (not single detailed case)
→ Focus on mass of PFAS-containing materials

Approach: combine material-level data with PFAS mapping to identify impacted products and uses

Outcome: Deliver statistical indicators
→ To support prioritization, regulatory impact assessment, ESA response to PFAS restriction scenarios
→ To quantify PFAS masses and support the sector response to potential bans
→ Focus on quantification of PFAS mass to assess potential impact of a total ban

2. PFAS mapping and mass estimation

01

Methodology

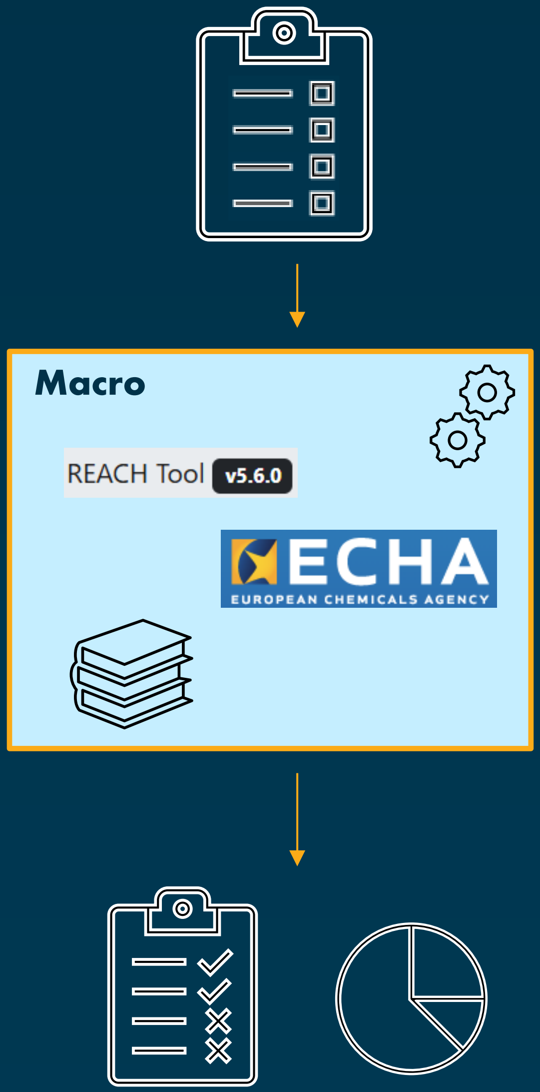
Which inputs do we use
What do we have as
outputs ?

1

Based on Declaration Materials List (DML)
- Chemical Nature
- Material identification
- Mass

Run a macro to crosscheck DML with:
- ESA REACH Tool
- Chemical names
- Acronyms & Abbreviations
- All information we have about PFAS

Outputs: mass estimation and statistics on information we received



2. PFAS mapping and mass estimation

02

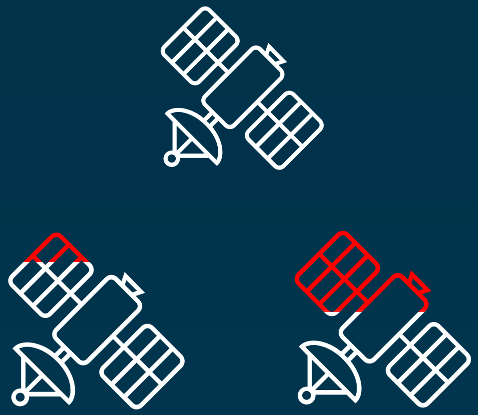
Results

2

Mass estimation and statistics

Results of our macro (based on DML) :

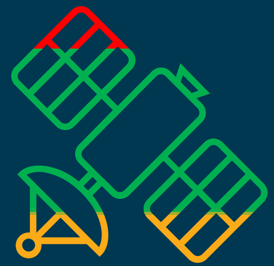
- Low & high estimates Total mass of satellite
- Low & high estimates of PFAS-containing materials



- Total DML items
- Items without mass indicated
- Items containing PFAS
- Which kind of PFAS
- What type of product

PTFE, ETFE, PFA, PVDF…

Cables & Wires, seals and gaskets, thermal protection, lubricants…



2. PFAS mapping and mass estimation

03

General numbers

Based on 8-months of case studies on satellites

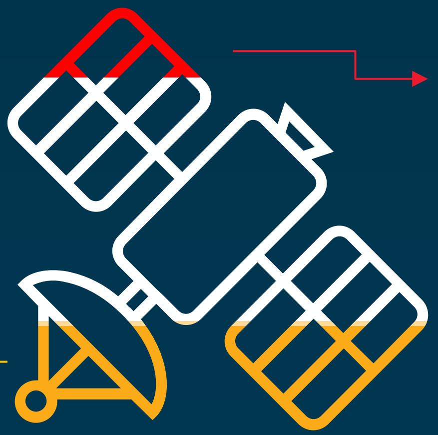
3

Mock example based on 8-months of case studies representing more than 17 000 items analysed:

Mock Spacecraft:

Total weight: 1260kg
DML: 1725 items

~16% of materials do not have mass indicated



9% of materials are impacted by PFAS*, i.e. 155 items

Representing between 7.3 and 77 kg of materials

* Standard deviation of 1.3%

- PFAS-containing materials represent a limited share of total spacecraft mass
- Critical functions and high-performance materials
- PFAS content varies significantly depending on application

2. PFAS mapping and mass estimation

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04

Strengths and limitations of the method

?

4

Limitations

- Accuracy limitations
- Manual validation required
- Data dependency, sensitive to:
  - Incorrect chemical information
  - Manufacturer declarations
  - Existing knowledge of PFAS-containing products
- Wide range estimation
- Limited quantification: impacted materials identified, but not actual PFAS mass content

Strengths

- Provides a broad overview of impacted products types
- Identifies main PFAS families and applications
- Enables quantitative indicators to support regulatory impact assessment and risk evaluation
- Can support decision-making for replacement
- Repeatable and scalable methodology
- Contributes to PFAS mapping in space applications

2. PFAS mapping and mass estimation

05

Key takeaways

5

Consistent PFAS impact

- Similar % of materials impacted
- Impact consistent but limited in overall mass
- Robust results despite time constraints

Knowledge significantly improved

- Better understanding of PFAS type & products
- Case studies enriched the knowledge base

Actionable Outcomes

- Support substitution, obsolescence, and regulatory adaptation strategies
- Full material replacement often required, highlighting complexity under PFAS restriction

System-level insight

- Necessary to assess impact of broad regulatory scenario (e.g. PFAS ban)
- Trade-off: higher uncertainty vs completeness

Small mass contribution but high functional criticality

PART 3:

Obsolescence risk mitigation activities

3.i. Beta®Cloth

Full exposure conditions

3.i. Beta®Cloth

Context

- Beta®Cloth: PTFE-coated fiberglass fabric
- Used in spacecraft, ISS, spacesuits,…
- Formerly manufactured by Saint-Gobain (Merrimack, USA) → Production discontinued in the early 2020s

Study framing

- Old samples provided by CNES, new samples provided by company
- Objective: test new Beta®Cloth performance
- Initiative from european industries and agencies
- Exposure to representative space environment conditions
- Test report completed → Results not presented (not yet public)

Results are guidance only, not a qualification. Each project must verify its own mission requirements

3.i. Beta®Cloth

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Material characterisation

DSC, TGA, outgassing, Foldability

Thermal Vacuum Cycling

Simulates vacuum and extreme temperature cycles in orbit

UV-VUV exposure

Reproduce solar radiation

Atomic oxygen exposure

Simulates LEO atomic oxygen erosion

Intermediaries check

Thermo-Optical
Mass measurements
Visual inspection

BoT- Full space exposure conditions -EoT

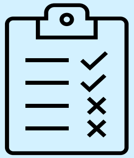
3.i. Beta®Cloth

Results not shown

Material characterisation

DSC, TGA, outgassing, Foldability

Assess thermal stability, composition and space compatibility of candidate fabrics

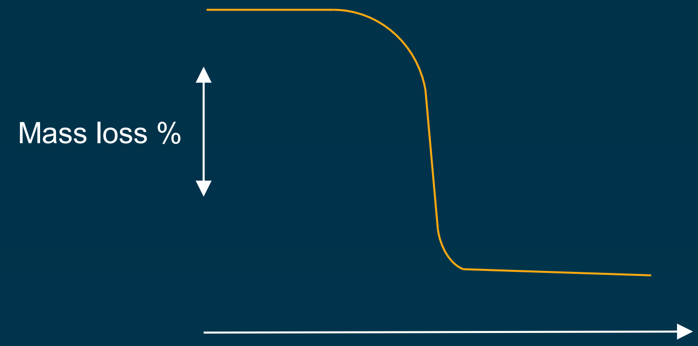


Samples tested:

- **Old Beta®Cloth**
- **New Beta®Cloth**
- **New uncoated Beta®Cloth (without PTFE impregnation)**

Tests performed

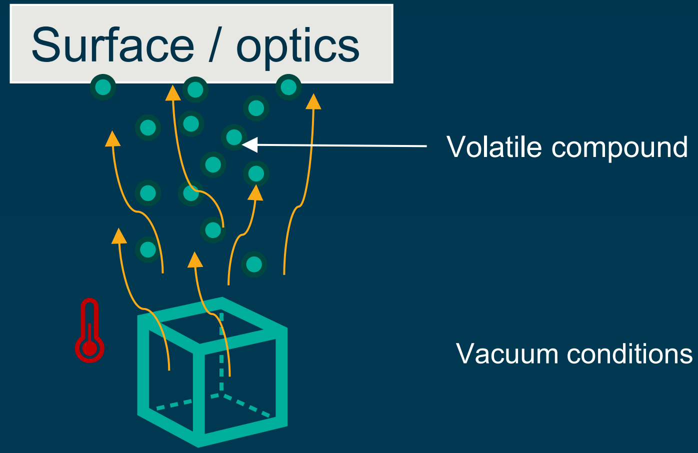
- DSC/TGA: Thermal stability and degradation behaviour
- Outgassing: compliance with space environment constraints
- Foldability: Mechanical integrity under handling



Mass loss under temperature (TGA)

Conditions

- TGA: Thermal ramps up to 1500ºC, 10ºC/min, (N_2 atmosphere)
- DSC: Heat-cool-heat cycle (-150ºC to +350ºC) 10ºC/min (N_2 atmosphere)
- Outgassing: vacuum 10^{-5} mbar, 125ºC, 24h (ECSS like)
- Mechanical: folded >100 folding cycles with visual/ UV inspection



Outgassing under vacuum and temperature

3.i. Beta®Cloth

Results not shown

Full scenario exposure

TVAC, UV/VUV exposure, ATOX exposure

Assess material behaviour under representative space environment conditions

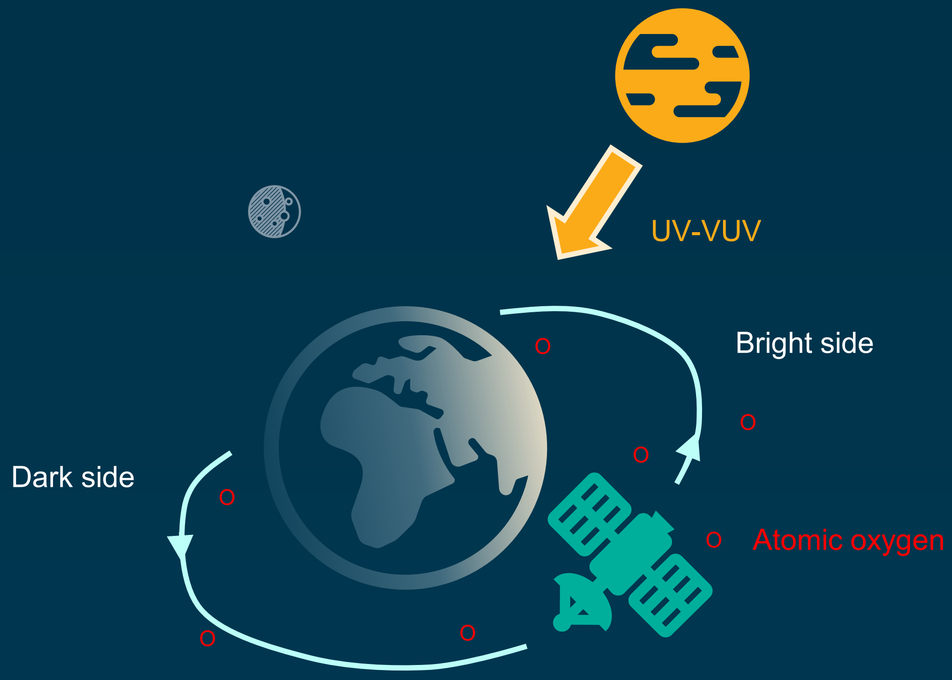
Samples tested:
- **Old Beta®Cloth**
- **New Beta®Cloth**

Tests performed

- TVAC: Thermal cycling in vacuum
- UV/VUV exposure: Solar radiation effects
- ATOX exposure: erosion in LEO environment

Conditions

- 5 cycles, -150ºC to +150ºC, high Vacuum
- >3000 ESH (UV), >2500 ESH (VUV)
- LEO simulation, fluence ~ 1.3x10^{22} at/cm^2



Simple representation of space environment in LEO (ISS altitude)

3.i. Beta®Cloth

Results not shown

Intermediaries check

Thermo-Optical
Mass measurements
Visual inspection

Tack material evolution and detect early degradation mechanisms

Samples tested:

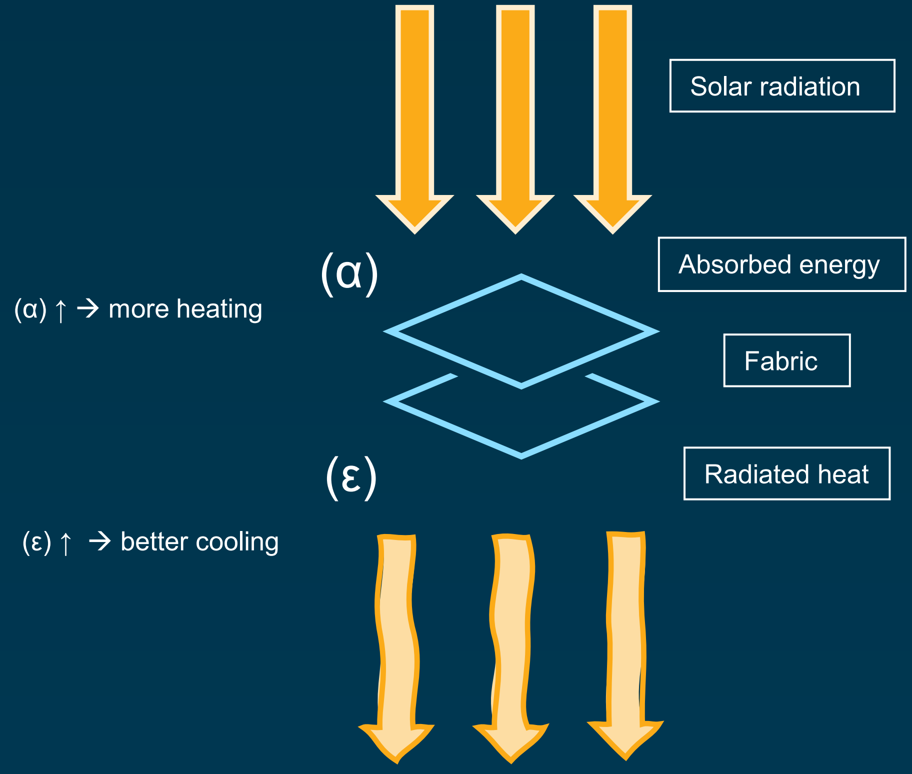
- **Old Beta®Cloth**
- **New Beta®Cloth**

Checks performed

- Thermo-Optical properties measurements: Solar absorptance (α) and thermal emittance (ε)
- Mass measurements
- Visual inspection

Approach

- Performed before, between, and after exposure
- Thermo-optical properties (α,ε) tracking
- Microbalance under controlled environment
- Visual inspection for surface degradation



Thermo-Optical behaviour (α/ε)

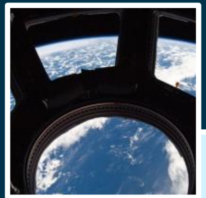
3.ii. PFPE fluids

Hermeticity testing

3.ii. PFPE fluids

Obsolescence Issue

- 3M announced discontinuation of PFPE fluids (2025)
- Critical dependency for:
  - ➢Standard hermeticity test methods
  - ➢Existing space qualification processes



Context

- Hermeticity test rely on fluorocarbon (PFPE) fluids as detector liquids
- Used in Type I & Type II gross leak detection methods
- Principle:
  - ➢Based on boiling point differences between PFPE fluids
  - ➢Enables detection of leaks through vapor formation

Key implication for testing

- Current standards are dependent on PFPE-based fluids
- Replacement solutions are required to:
  - ➢Ensure continuity of hermeticity testing
  - ➢Maintain compliance with existing standards

3.ii. PFPE fluids

1. Analysis performed using MSDS and TDS data
→ Covering 12 MFRs, and more >15 product families

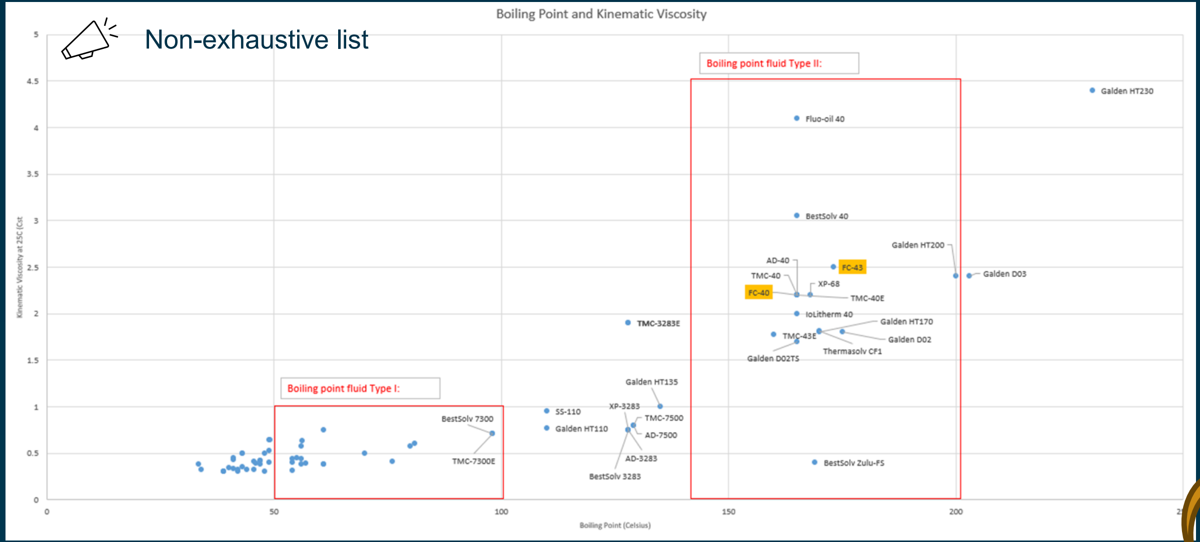


Fig.1: BP vs Kinematic viscosity @25ºC

Type I detector fluid : 3M FC-72
Boiling Point : 50 < X < 100 ºC
Low Viscosity
Density @25C: >1,6 g/mL
Dielectric strength: >300 Volts/mil

Type II detector fluid: 3M FC-40 or FC-43
Boiling Point : 140<x<200 ºC
Low Viscosity
Surface tension: <20 dynes/cm
Dielectric strength: >300 Volts/mil

2. Initial wide panel reduced to a shortlist of approximately 20 candidate fluids
→ Based on compliance

Type I detector fluid:
Graph Density vs BP

Type II detector fluid:
Graph Surface tension vs BP

3. Final selection:

2 alternative fluids (Galden, Daisave)
1 reference baseline (3M Fluorinert)

3.ii. PFPE fluids

Objective: Compare fluid performance for gross & fine leak test detection

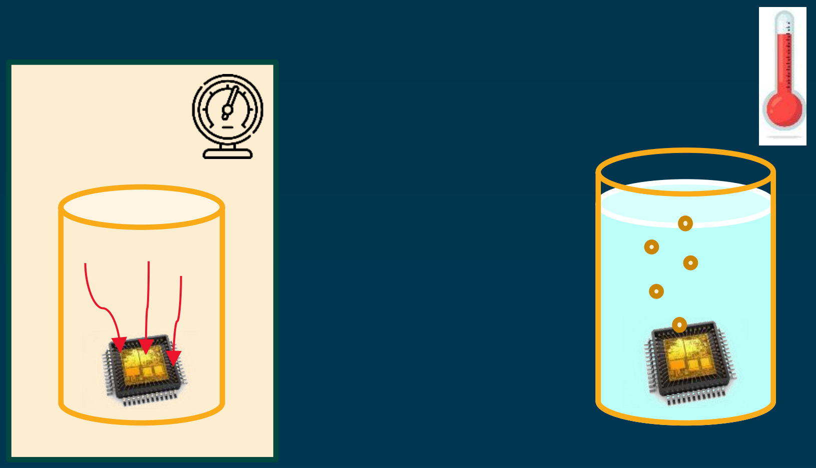
Product to be tested:
2 alternative fluids (Galden, Daisave)
1 reference baseline (3M Fluorinert)

Test capabilities

- Test performed at Materials & Electrical Components Laboratory at ESA/ESTEC
- Equipment for: Gross leak test & Fine leak test

Key parameters compared

- Boiling Point: Critical for detection principle
- Viscosity: Fluid behavior/penetration
- Chemical composition: PFAS characteristics



Step 1 | Step 2

Principle of Hermeticity testing using PFPE fluids

PART 4:

CONCLUSION

4. Conclusion

01
PFAS mapping

- Provides a first system-level overview with mass estimates and statistical indicators
- Identifies key products areas while highlighting remaining data gaps and uncertainties

02
Obsolescence

- Testing campaign completed, results documented in a report to be shared
- Future testing will focus on validating alternative fluids performance to ensure continuity of hermeticity testing post PFPE phase-out

03
Next steps

- Further validation of testing solutions and alternatives
- Support adaptation to PFAS regulatory constraints

Thank you for your attention

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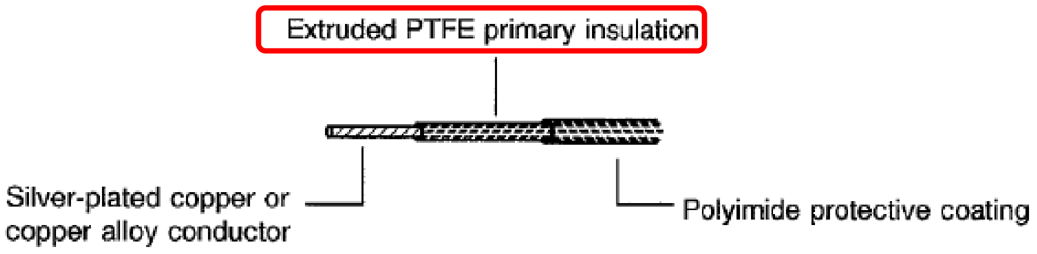
BACKUPSLIDES

1. Credits
2. PFAS impact on space sector - ESCC
3. PFPE fluids – hermeticity testing

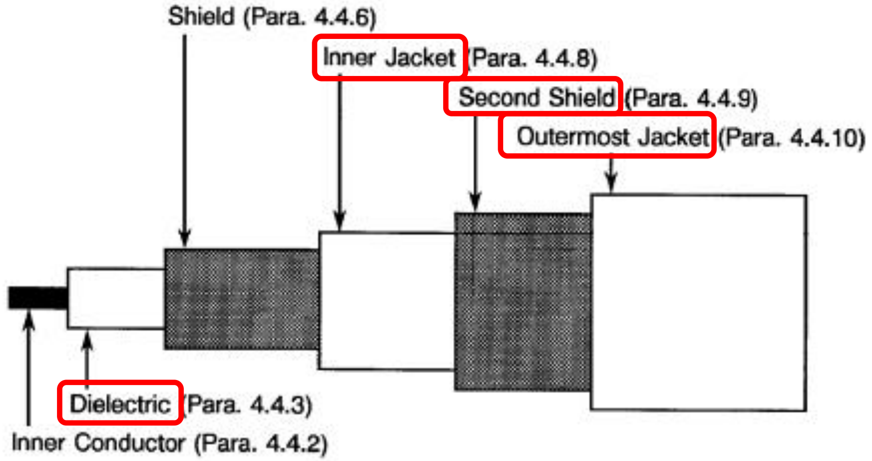
BACKUPSLIDES, Credit photos

- p.3: Westerlund 2 — Hubble's 25th anniversary image | ESA/Hubble - Credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA), A. Nota (ESA/STScI), and the Westerlund 2 Science Team
- p.5: ESA - Images - A European powerhouse, HI-RES, Credit: NASA
- p.12: ESA - Earth - Earth, HI-RES, Credit: Pixabay
- p.14: LEFT: Credit ESA/NASA/ Thomas Pesquet – RIGHT: Credit ESA - ESA Strategy 2040
- p.20: ESA Brand Center: Digital Backgrounds – ESA Brand Centre ; Columbus module, cupola and Mars_BG
- p.23: ESA - Space Station over Earth ; HI-RES, Credit: NASA

PFAS impact on Space sector – ESCC



PTFE insulated wires and cables – ESCC 3901/013 Figure 2(a): Finished wires



Triaxial Cable – ESCC 3902/002 (Wires and Cables) Figure 2(a)

- Primary insulation made of PTFE

- Dielectric made of PTFE
- Inner Jacket made of PTFE
- Second shield made of PTFE
- Outermost Jacket made of PTFE copolymer PFA

PFAS impact on Space sector – ESCC

Coaxial cable:

For outer diameter: ~1.8mm
Length: 1m
Density: ~4 g/cm^3

Volume: ~2.5 cm^3/m
Mass: **~9-10 g/m**

PFAS represent roughly: 10-20% of volume, with PTFE density (2.1-2.3 g/cm3)

→ Estimation of 1.5-2g

Order-of-magnitude estimation based on typical cable geometry and fluoropolymer content: **1.5-2g of PFAS /m of cable (15-20% of total mass)**

Triaxial cable 3902/002:

For outer diameter: ~5-8mm
Length: 1m
Density: ~3-4 g/cm^3

Volume: ~28 cm^3 /m
Mass: **~80-150g/m**

PFAS represent roughly: 30-50% of volume, with PTFE density (2.1-2.3 g/cm3)

→ Estimation of 28g

Order-of-magnitude estimation based on typical cable geometry and fluoropolymer content: **20-40g of PFAS /m of triaxial cable (30-50% of total mass)**

PFAS impact on Space sector – ESCC

Material identification:	Chemical nature:	Mass:
3901/002 insulated wire and cable	Polyimide insulated Cu alloy and Cu /Ag core **without shield**	W3

FIGURE 2(a) – FINISHED WIRE / CORE

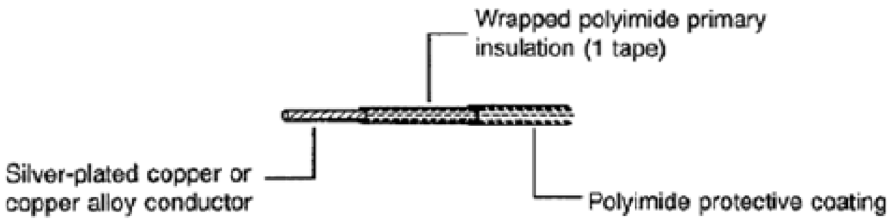
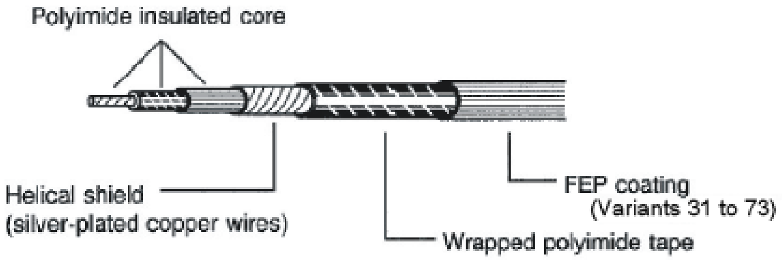


FIGURE 2(b) - SHIELDED AND JACKETED CABLES



ESCC 3901/002 Figure 2(a) and 2(b)

PFAS impact on Space sector – ESCC

Why not focus on cables & wires only?

1. On one case study: 64% of PFAS-containing materials were **not** cables or wires, or [2,1 – 21,8] kg on [6,7-67,8] kg

2. If conservative* and take all cables & wires (even not mentions of PFAS) :

- **196 items** (+102), **+3,5% impacted**
- **Between 5,6 and 56kg of cables & wires impacted in total**
- **[1 – 10] kg more than found with macro [4,6 – 46,0] kg**

3. If you remove alloys and materials were insulation materials, jackets, shielding are written:

- **60 items** (on 2907 items total in DML), **+2%**
- **0,9 and 9,3 kg**

*Solder wires, welding wire, brazing wire, wire flux and spring wire were not considered

PFPE fluids

Hermeticity testing

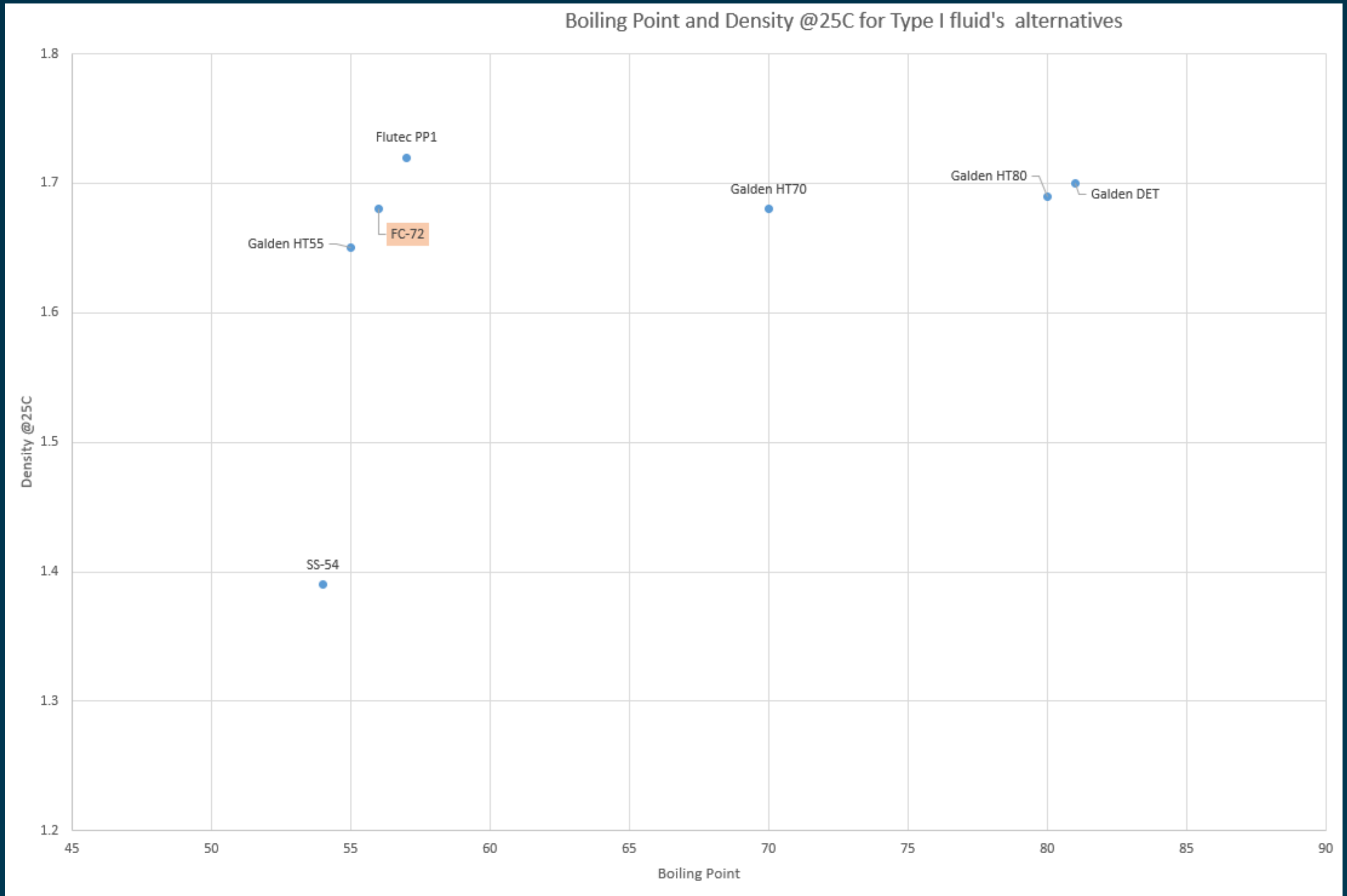
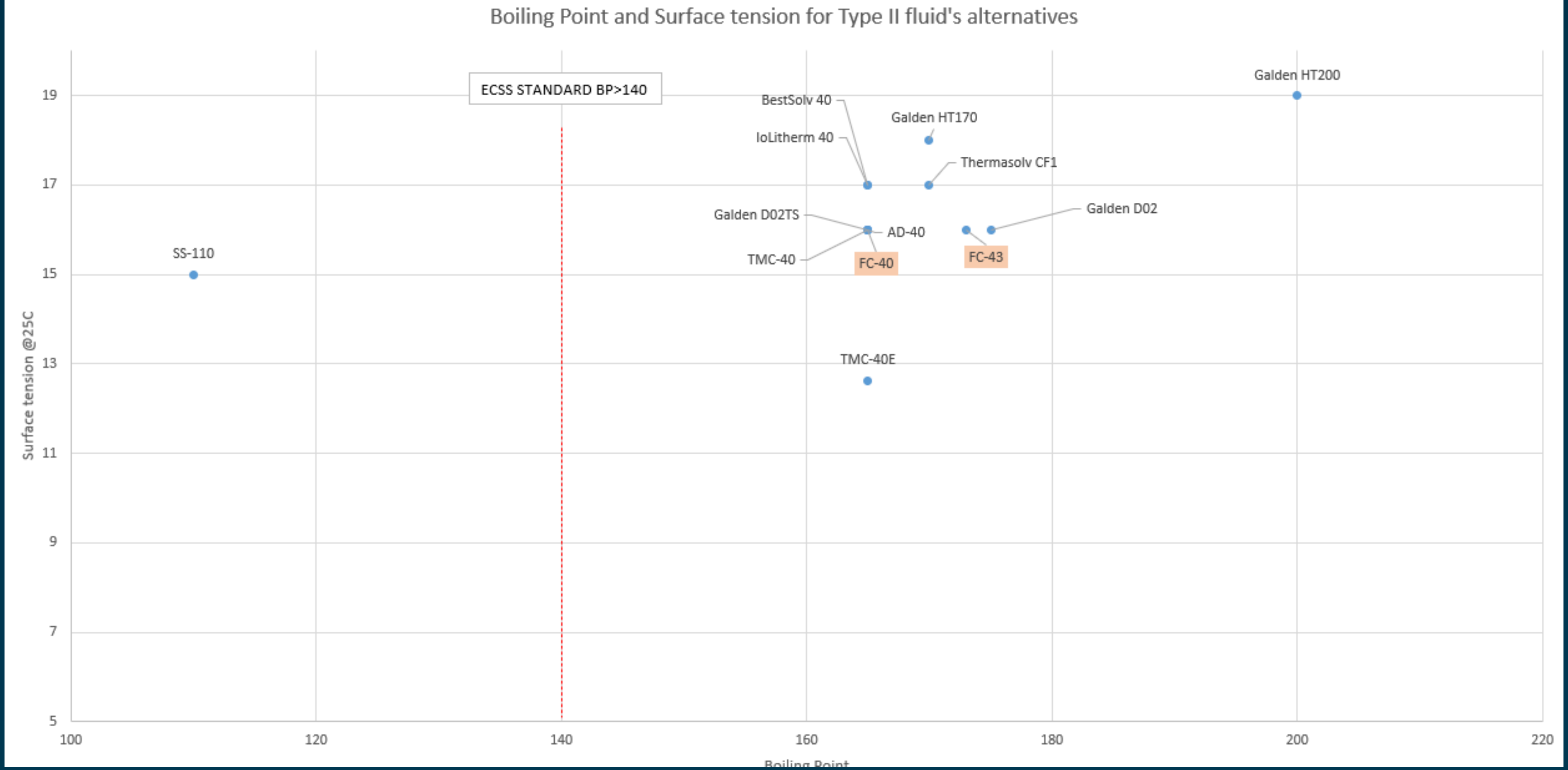


Fig.2 : Alternative Type I fluid – Boiling Point VS Density @25ºC

Type I detector fluid : 3M FC-72
Boiling Point : 50 < X < 100 ºC
Low Viscosity

PFPE fluids

Hermeticity testing



Type II detector fluid: 3M FC-40 or FC-43
Boiling Point : 50<x<95 ºC
Low Viscosity

Fig.3 : Alternative Type II fluid – Boiling Point VS Surface tension

PFPE fluids

Hermeticity testing

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Which manufacturers offer alternatives for 3M Fluorinert:

Brand name	Manufacturer	HQ country
FC	3M	USA
AD	A.D Dawning	China
XP	A.D Dawning	China
Nanoproof	Aculon, Inc.	USA
BestSolv	Best Technology, Inc.	USA
Opteon	Chemours	USA
SS Daisave*	Daikin Chemical	Japan
Fluo-oil	Emulseo	France
Prosolv	Enviro Tech Europe, Ltd	UK
Promosolv	Inventec Performance Chemicals	France
Thermasol	Inventec Performance Chemicals	France
QUICKSOLV	Inventec Performance Chemicals	France
Thermasolv	Inventec Performance Chemicals	France
IoLitherm	Io.Li.Tec Ionic Liquids Technologies GmbH	Germany
Galden	Syensqo	Belgium
TMC	TMC Industries, Inc.	USA
Flutec	TMC Industries, Inc.	USA

Which products seem to be good alternatives (according to TDS):

Product name	Manufacturer	HQ country	Type fluid
SS-54*	Daikin Chemical	Japan	Type I
Galden HT55	Syensqo	Belgium	Type I
FC-72	3M	USA	Type I
Flutec PP1	TMC Industries, Inc.	USA	Type I
Galden HT70	Syensqo	Belgium	Type I
Galden HT80	Syensqo	Belgium	Type I
Galden DET	Syensqo	Belgium	Type I
SS-110*	Daikin	Japan	Type II
AD-40	A.D Dawning	China	Type II
BestSolv 40	Best Technology, Inc.	USA	Type II
FC-40	3M	USA	Type II
Galden D02TS	Syensqo	Belgium	Type II
IoLitherm 40	Io.Li.Tec Ionic Liquids Technologies GmbH	Germany	Type II
TMC-40	TMC Industries, Inc.	USA	Type II
TMC-40E	TMC Industries, Inc.	USA	Type II
Galden HT170	Syensqo	Belgium	Type II
Thermasolv CF1	Inventec Performance Chemicals	France	Type II
FC-43	3M	USA	Type II
Galden D02	Syensqo	Belgium	Type II
Galden HT200	Syensqo	Belgium	Type II

Non-exhaustive lists