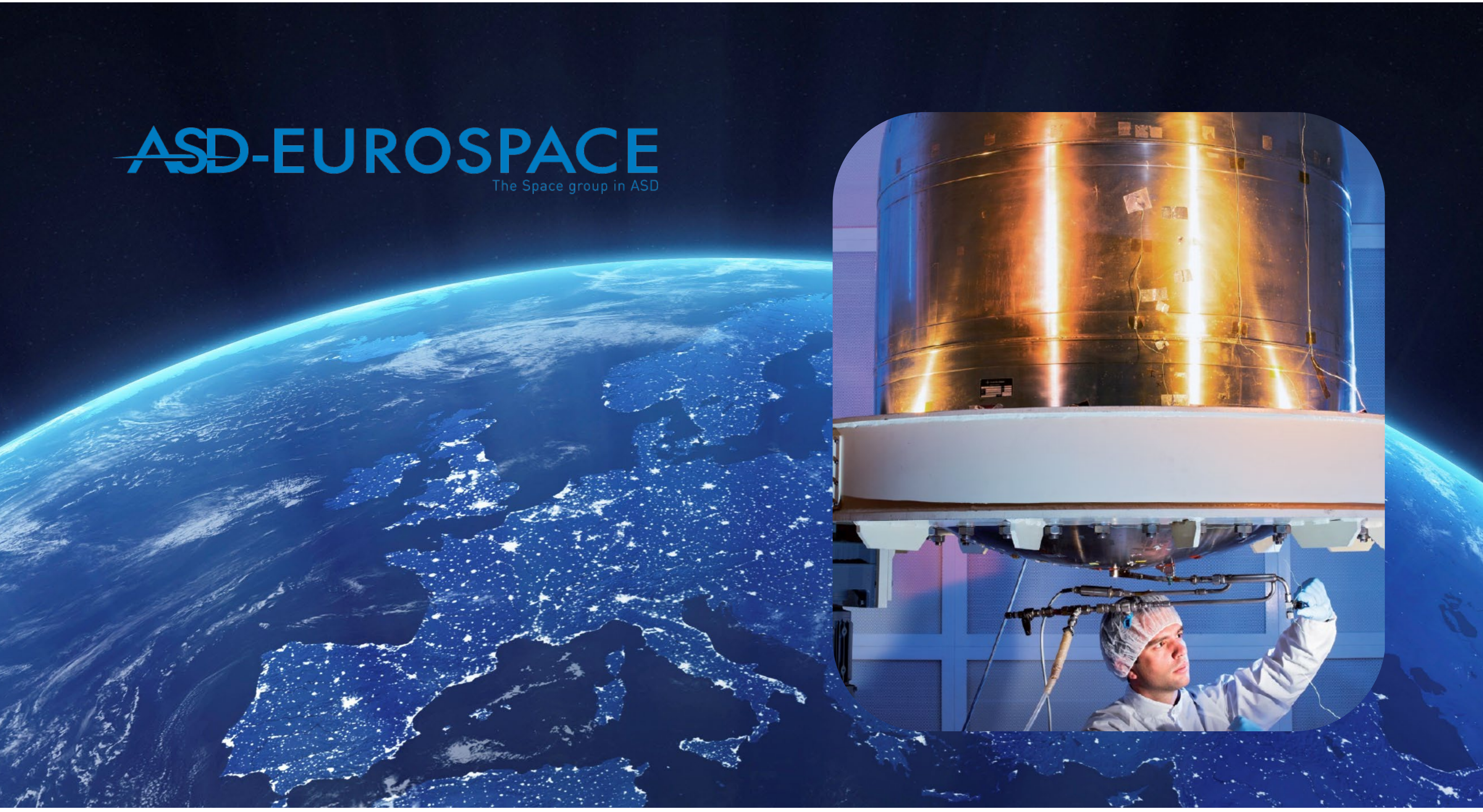

Paris, 22 September 2023

EUROPEAN SPACE SECTOR COMMENTS ON THE ANNEX XV RESTRICTION REPORT FOR PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

ECHA Public Consultation of 22 March 2023 on the proposed restriction on the manufacture, placing on the market and use of PFASs



PREFACE

This is the joint contribution of the European Space Industry, represented by ASD-EUROSPACE – with the support of European Space Agency (ESA), national space agencies and the European Defence Agency (EDA)[1] – to the ECHA Public Consultation on the Annex XV restriction report of 22 March 2023 for PFASs.

The contribution has been prepared by the participants of the Space Restrictions Task Force (RTF) under the Materials and Processes Technology Board of the European Space Components Coordination (ESCC MPTB). The RTF was kicked off on 10 February 2023. The contribution is based on dedicated surveys, including a survey to the RTF participants to address the questions in this consultation. It reflects the best knowledge available from experts in their field, thanks in particular to the support of **ASD-EUROSPACE,**

the following corporations:

AIRBUS DEFENCE AND SPACE
ARIANEGROUP
AVIO
BEYOND GRAVITY
ESR TECHNOLOGY (ESTL)
LEONARDO COMPANY
MAXON
OHB
THALES ALENIA SPACE
W. L. GORE & ASSOCIATES

the EUROPEAN SPACE AGENCY (ESA) and the following national space agencies:

AGENZIA SPAZIALE ITALIANA (ASI)
CENTRE NATIONAL D'ETUDES SPATIALES (CNES)
GERMAN AEROSPACE CENTER (DLR)

the EUROPEAN DEFENCE AGENCY as an observer;

as well as the MAX PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS and TNO, as independent research organisations. REACHLaw Ltd. supports the group as a consultant.

Further information about the RTF is available on the ASD-EUROSPACE website: https://eurospace.org/new-space-sector-task-force-on-large-scope-reach-restriction-initiatives-on-pfas-and-bisphenols.

[1] As an observer.

The proposed restriction aims to address the risks to human health and the environment posed by the manufacture and use of per- and polyfluoroalkyl substances (PFASs) due to their very high persistence. The substances in the scope of the proposed restriction are aligned with the OECD definition[2] *of PFAS which encompasses more than 10 000 substances. This includes polymeric PFASs such as fluoropolymers (FPs) and perfluoropolyethers (PFPEs), and non-polymeric PFASs such as F-gases. Two restriction options (ROs) are presented: (i) a full ban with an 18-month transition period after entry into force (RO1); and (ii) a ban with use-specific (mainly) time-limited derogations for several sectors (RO2). The proposed restriction option corresponds to RO2 and would ban the manufacture, placing on the market and use of PFAS as such, as well as the placing on the market as a constituent in another substances, in mixtures, and in articles above set concentration limits. The derogations and their duration (either 5 or 12 years from the end of the general transition period of 18 months) are based on the availability of alternatives and socio-economic considerations. In addition, five time-unlimited derogations are currently proposed. The restriction could enter into force as early as in 2025.*

[2] Any substance that contains at least one fully fluorinated methyl (CF3-) or methylene (-CF2-) carbon atom (without any H/Cl/Br/I attached to it).

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LIST OF KEY ACRONYMS

AoA	Analysis of Alternatives
ASD	Aerospace, Security and Defence Industries Association of Europe
ATHENA	Advanced Telescope for High ENergy Astrophysics
ATOX	Atomic Oxygen
CAS	Chemical Abstracts Service
ECSS	European Cooperation for Space Standardization
EEE	Electrical, Electronic and Electro-mechanical components
EN	European Standard
EPA	Environmental Protection Agency (US)
ePTFE	Expanded PTFE
ESA	European Space Agency
ESCC	European Space Components Coordination
ESTEC	European Space Research and Technology Centre (part of ESA)
ETFE	Ethylene tetrafluoroethylene
FEP	Fluorinated ethylene propylene
FEPM	Tetrafluoroethylene propylene
FFKM	Perfluorelastomers
F-Gas	Fluorinated Gas
FKM	Family of Fluorocarbon-based Fluoroelastomer Materials
FMQ, FVMQ	Fluorosilicone rubber
FP	Fluoropolymer
FPG	Fluoropolymers Product Group
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether
HSE	Health and Safety Executive, the Agency for UK REACH
IEC	International Electrotechnical Commission
IPC	The Global Association for Electronics Manufacturing (https://www.ipc.org)
IRIS²	Infrastructure for Resilience, Interconnectivity and Security by Satellite
ISO	International Organization for Standardization

ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
LEO	Low Earth Orbit
MIL	US Military Standards
MLI	Multi-Layer Insulation
MPTB	Materials and Processes Technology Board
NASA	National Aeronautics and Space Administration (US)
NiPTFE	Nickel PTFE
PCB	Printed Circuit Board
PE	Polyethylene
PFA	Perfluoroalkoxy alkane
PFAE	Perfluoroalkylether
PFAS	Per- and Polyfluoroalkyl Substance
PFCL	Perfluorocarbon Liquid
PFPE	Perfluoropolyether
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene fluoride
PVF	Polyvinyl fluoride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation (EC) No 1907/2006)
RF	Radio Frequency
RO	Restriction Option
RTF	Space Restrictions Task Force (see Eurospace news alert on Task Force kick-off: Link)
SEA	Socio-Economic Analysis
SDS	Safety Data Sheet
SVHC	Substance of very high concern (see REACH Article 57)
TT&C	Telemetry, Tracking and Command
TRL	Technology Readiness Level
UK	United Kingdom
uPFAS	Universal PFAS (the Annex XV restriction report subject to the ECHA public consultation)
U.S.	United States

1. GENERAL COMMENTS

This is the **initial** technical contribution to the universal PFAS restriction initiative of ASD-Eurospace. It has been prepared with the support of the Space Restrictions Task Force (RTF) of European space companies, key suppliers, the European Space Agency (ESA) and national space agencies as well as independent research organisations and REACHLaw Ltd. as a consultant.

Note on comment structure: The contribution paper MPTB-ES-PO-0131 together with the confidential Appendix 1 (Excel Table of PFAS uses in the European Space Sector), uploaded in 'SECTION IV. Non-confidential attachment' (MPTB-ES-PO-0131) and 'SECTION V. Confidential Attachment' (Appendix 1) of the ECHA webform contain our single consolidated input to this ECHA public consultation. Our answers in the ECHA webform in 'Section III. Non-confidential comments' are mere summaries and other extracts from the contribution paper. For clarity, these extracts are marked in **Grey** in the contribution paper, leaving all additional input unmarked. References to Chapter/Section numbers, Appendices, Case Studies and Tables/Info boxes/Figures are those in the two documents uploaded in the ECHA webform. This shall enable most efficient processing by the competent authorities in this restriction process.

The European Space industry is a **niche sector** characterised by **very small volumes** and with **products sent to space**. It is embedded in the wider European aerospace and defence industrial complex. The European Space Sector is **strategic for the EU** and its technological non-dependence (see COM(2022) 142 final, recital (16)), essential for the implementation of many public policies and supporting all economic sectors, and for Europe's independent access to space (see also Appendix 2, Case Study #1 concerning the Ariane 6 launcher and Case Study #4, Use case 1 concerning PTFE in seals).

Our companies produce equipment, which must operate in extreme space environmental conditions requiring a high level of reliability, resilience and materials performance. The stakes of space activities are high, also considering especially for launchers the catastrophic impact of a failure, while for satellites no repair is possible after launch and on the International Space Station (ISS) there is very limited potential for servicing.

Given its small market size and position at the end of the manufacturing supply chain, the European Space Sector is **highly dependent** on its upstream suppliers and market opportunities offered to them by bigger sectors. Please see Chapter 2 for more details on European Space Sector specificities.

The detailed investigations launched in response to the PFAS restriction proposal (see Appendix 3 for more information) have clearly shown that this wide-scope proposal as it stands would be **disproportionate and not manageable** for our sector, threaten its competitiveness and strategic programmes benefitting EU citizens, as well as the on-going and future collaboration with our non-EU partners (such as NASA, JAXA). A non-use without suitable derogations could be extremely impactful, given the widespread reliance on PFAS as detailed in this contribution. With satellites being a key component in the **European Defence strategy**, the restriction proposal as it currently stands would also significantly hamper Europe's vital interest to have autonomous defence capabilities.

This conclusion is evident despite the many unknowns given our complex supply chains and the non-reporting on those PFAS substances which are not classified, not to be disclosed in Safety Data Sheets and REACH Article 33 declarations (i.e. REACH Candidate List SVHCs).

We have identified a **myriad of space applications** reliant on PFAS, many of which concern fluoropolymers (see Appendices 1 and 2). Examples include lubricants, coatings, creep barriers, functionalised polymer surfaces, coolant fluids, fluoro-elastomeric sealants, cable insulation, shrink sleeves, Printed Circuit Boards (PCBs), processes for electronic assembly and many others. PFAS use is mandated in dozens of long-established standards and specifications applicable to space (such as ECSS, ESCC, MIL, IEC), including many approved by ESA, NASA and other national space agencies and without any known alternative.

Research on **alternatives** has already shown in some important cases that PFAS chemistry is the only viable solution also for space applications (see more information in Section 3.3.5.1.). It should also be noted that the Space Sector is not involved at all in the manufacturing of PFAS substances and mixtures and the design of many PFAS-containing components. For that we depend completely on our suppliers.

To ensure the continued uninterrupted functioning of the European and global space industry supply chain, the restriction should not prevent (either directly or indirectly) the availability of PFAS reliant mixtures and articles, before viable alternatives have been developed, tested and qualified for use in all affected space parts, products and processes.

The examples of other sectorial derogations already proposed, such as for fluoropolymer applications in petroleum and mining industry (par. 6.f.) show that this is the only viable approach where the number of individual products/components affected is very high and the substitution potential low, as is the case for our products.

However, transitional periods and duration limits to derogations have no basis at a time when not yet even an idea of a suitable alternative exists for the bulk of uses identified.

Consequently, ASD-Eurospace strongly requests the following:

1) Further to existing use-specific derogation proposals, **fluoropolymers** including fluoroelastomers should be entirely excluded from the scope of the universal PFAS restriction, at least for industrial applications. These applications account for the large majority of identified uses, as also shown in our use mapping (see Appendix 1). Also, the risk is mainly constrained to the manufacture and end of life, which is even not relevant for products sent into space! Such risks can be more adequately targeted through other regulatory measures.
2) **We request a derogation for all remaining PFAS uses in equipment designed to be sent into space, as long as no successful transition to space qualified alternatives can be achieved**. This is in line with several pieces of existing EU legislation, which do not

apply to 'equipment designed to be sent into space' for similar reasons: Article 2(4)(b) of Directive 2011/65 EU (RoHS); Article 2(4)(a) of Waste EEE Directive 2012/19/EU; Article 8(1)(b) of Mercury Regulation (EU) 2017/852); and most recently Article 1(5)(b) of the new EU Regulation (EU) 2023/1542 of 12 July 2023 concerning batteries and waste batteries. This also takes into account that different PFAS-based use and derogation cases **should not be seen in mere isolation**, as shown in this contribution.

3) Even with such a specific derogation covering space applications, the EU's vital interest to have an independent space capability may be significantly eroded by the proposed universal PFAS ban. As an example, we have already been informed by a key supplier that the space activity for coaxial connectors and components is not viable without the other markets, so the derogations also have to be obtained for use in the different applications of these products, not only for space. Therefore, we **equally request to enable our chemicals and component suppliers to maintain a business** viable market in the EU for aerospace and defence, electronics and related sectors by means of further derogations, as further detailed in Sections 3.2.2., 3.4. and 3.5.

Without prejudice to our dedicated requests above, we also support contributions from other related industries to this consultation, including in particular from the *Aerospace, Security and Defence Industries Association of Europe (ASD)* and further organisations listed in Info box 1.

Info box 1 Other supported industry contributions to the ECHA Public Consultation on universal PFAS

Aerospace, Security and Defence Industries Association of Europe (ASD); *ArianeGroup* with *Air Liquide Advanced Technologies (ALAT)* (ECHA submission number: e33a424f-7a32-42ea-b69a-a75e585d7935, see also Case Study #1 in Appendix 2 of this contribution); the *European Sealing Association e.V.* (ECHA RCOM part 20, ref. #4472); the *Fluoropolymers Product Group (FPG)* (ECHA RCOM part 31, ref. #6148); *RECHARGE* (ECHA RCOM part 2, ref. #3925); *ROGERS CORPORATION* (ECHA RCOM part 27, ref. #6006); *W. L. Gore & Associates* (ECHA RCOM part 35, ref. #6301).

Recent assessments published for the group of PFAS in non-EU jurisdictions (UK, U.S.) suggest targeted and science-based approaches to address identified risks which, if the current uPFAS restriction approach is implemented, would further increase the regulatory divergence between the EU and key partner nations.

A **UK HSE** *Analysis of the most appropriate regulatory management options* (published in April 2023, available on the HSE website) considers specific restrictions of PFAS to address only identified *wide dispersive uses* as well as the manufacture and placing on the market of certain *consumer articles* with likely emission and exposure potential.

In the **U.S.**, a recent report for Congress of March 2023 (available on the website of The White House) provides a high-level overview of research on PFAS as a chemical class by addressing four key strategic areas that, when addressed, will generate actionable information to address PFAS. The report also identifies data gaps that serve as a roadmap to advance science in those specific areas. The stated long-term goal is to eliminate PFAS in all sectors to the maximum extent possible by applying sustainable chemistry principles and embracing an essential use concept, where essential use is defined as a use of PFAS for which use of a replacement substance is impossible or impractical.

With regard to the proposed **requirements in paragraph 7 (annual reporting to ECHA) and 8 (site-specific management plan)** of the suggested restriction text we believe that they are excessive for space applications given our very small quantities, as well as the in-space/in-orbit end of life location for the majority of our products and the evident justification for the use. Further details on our related proposal can be found in Section 3.6.

Against this backdrop, we urge the Dossier Submitters to implement the needed changes and create a **proportionate and fit-for-purpose restriction proposal**, which targets emission hotspots and consumer protection following the risk-based approach according to REACH Article 68(1). This will also enable the avoidance of additional unnecessary costs and efforts for our industry and authorities during the further restriction process.

2. SPECIFICITIES OF THE EUROPEAN SPACE SECTOR

The requirement for space applications to be covered by a dedicated sectorial derogation is to be seen against the backdrop of our sector's specificities:

- There are **no PFAS emissions on Earth / the EU territory** for products sent into space!
- For the associated on-ground manufacturing, assembly and equipment designed to be sent into space (e.g. qualification models), the PFAS volumes and emissions (residues) are extremely low, basically negligible when compared to other industries.
- We have **very small production runs**, are highly specialized and capital intensive, with supply exclusively in business-to-business and business-to-government relationships. In 2022, the European Space Sector delivered 96 spacecraft (worth 50 tons at launch), of which 13 large satellites and 83 small satellites; it also delivered 5 launchers for operations in Kourou (launching 28,5 tons to orbit).
- The **high-performance and reliability requirements,** as well as the need for **heritage,** are due to the fact that the space environment is extremely harsh and no repair is possible after launch. Performance needs to be guaranteed during the use phase of space products, which may extend to several years or even decades.
- To guarantee high and life-time performance and reliability, a broad range of **dedicated space customers standards** (such as ESA ECSS standards and ESCC specifications) to be complied with and **specifically requiring the use of PFAS**, as further detailed in this contribution, have been established; long, extensive and extremely expensive verification paths had and have to be completed.
- Space is a **strategic sector** for the EU (cf. Union Space Programme Regulation (EU) 2021/696), European public institutions are key customers (ESA +40%, EU Commission, long investments from EU governments). Therefore, the European Space Industry must be sustained, in order to deliver products for this strategic

sector. Comprehensive restrictions like in the case of PFAS are extremely detrimental to the competitiveness of the European space industry.

- Space is **essential for the functioning of our society**.
- Small manufacturing companies including SMEs (**'New Space'**) are becoming increasingly important. They are even more vulnerable to respond to material changes and to legal compliance complexities associated with REACH restrictions and other regulatory constraints.

In addition, the Space Sector shares a number of specificities with Aerospace and Defence (A&D) products at large, such as

- **High complexity** in terms of assemblies and supply chains, which are global;
- **Very long lifecycles** from development to production and use phase; ESA missions can take up to 20 years to develop, with a 15+ year operational life, costing billions of euros per project. Examples of long-term and strategic programmes include Europe's own global navigation satellite system Galileo[3], the European Union's Earth observation programme Copernicus[4], Telecom constellations, ISS[5], Artemis and Lunar Gateway led by NASA[6]. Equally launcher vehicles such as Ariane 6 can have a service life of over 30 years.
- **Dependency on a plethora of substances** – in a multitude of systems and processes; our sector does not produce PFAS, our member companies are downstream/end users or integrators of the most complex assemblies of articles.

Hence, a single regulatory change typically has numerous impacts on space materials and processes. In the case of uPFAS, this single change concerns more than 10,000 substances!

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[3] More information at https://defence-industry-space.ec.europa.eu/eu-space-policy/galileo_en and https://www.esa.int/Applications/Navigation/Galileo.

[4] https://www.copernicus.eu/en and https://www.esa.int/Applications/Observing_the_Earth/Copernicus.

[5] https://www.nasa.gov/mission_pages/station/main/index.html and https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station.

[6] https://www.nasa.gov/specials/artemis and https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/Gateway.

3. USES AND DEROGATIONS

3.1. SECTORS AND (SUB-)USES (QUESTION #1)

Based on our PFAS use mapping exercise we have identified a limited number of cases that are generally addressed in the Annex XV restriction report under existing 'proposed derogations', 'potential derogations' or 'other identified uses'. However, the **bulk of the uses** for space applications we have collected are **not addressed in the report**. Overall, we consider our uses for space applications as **'missing uses' ('niche applications')**, which should be covered by a dedicated sectorial derogation. Nevertheless, the broader use/derogation cases discussed in the restriction report and identified below are also valid as far as they are also required by other end user sectors.

Below we provide comments on the following sectors and (sub-)uses identified in the Annex XV restriction report (Table 9):

- Applications of fluorinated gases (Annex E.2.8.)
  - Refrigeration
  - Solvents
  - Fire suppressants
- Transport (Annex E.2.10.)
  - Use of PFASs in applications affecting the proper functioning related to the safety of vehicles, and affecting the safety of operators, passengers or goods, to the extent not addressed under other parts of this proposed restriction (e.g. under lubricants, electronic equipment and TULAC)
  - Hydraulic fluids
  - Transport refrigeration
- Electronics and semiconductor (Annex E.2.11.)
  - Electronics
  - Semiconductors
- Lubricants (Annex E.2.14.)
  - Sector as a whole

In addition, we provide comments on 'missing uses' (niche applications).

3.2. PROPOSED DEROGATIONS (QUESTION #5)

3.2.1. TONNAGE AND EMISSIONS

Information on PFAS volumes is broadly not yet known. For lubricants for products sent into space (general derogation in par. 5.s.) a rough calculation provided suggests just above 20kg per year in the entire European Space Sector. Regarding emissions (see also Section 4.1. regarding ECHA question #2), it has to be noted that space products are sent to space.

3.2.2. COMMENTS ON THE SCOPE OF PROPOSED DEROGATIONS

As a general comment, we would like to reiterate the need for those general derogations that our activities depend upon in order to enable our chemicals and component suppliers to maintain a business viable market in the EU for aerospace and defence, electronics and related sectors, not limited to space only. This applies in particular, but is not limited to:

- **Refrigerants in laboratory test and measurement equipment (par. 5.g.) and in transport refrigeration (par. 5.q.)**
- **Industrial precision cleaning fluids (par. 5.k.)**
- **Clean fire suppressing agents (par. 5.m.)**
- **Additives to hydraulic fluids in aircraft and aerospace industry (par. 5.o.)**
- **Lubricants where the use takes place under harsh conditions or the use is needed for safe functioning and safety of equipment (par. 5.s.)**
- **Calibration of measurement instruments and as analytical reference materials (par. 5.t.)**

The proposed derogation for **lubricants** (par. 5.s.) has been flagged unanimously as being of critical importance. The non-exhaustive list of PFASs used in lubricants in Table A.59 of Annex A to the Annex XV Restriction Report already includes various spacecraft examples. In addition for this contribution, we have identified a number of space use cases in Appendix 1 (rows #29-37) which are generally addressed by this proposed derogation and in Appendix 2 elaborated a Case Study #7 on lubricants for space mechanisms. In relation to the proposed duration of 12 years, it was stressed that the Space Sector needs flight-proven materials, using flight demonstrators and long-term testing. In the example of greases and other lubricants for mechanisms real-life time testing of 10-12 years is required in order to establish the suitability of an alternative. This does not include the subsequent qualification and implementation of the alternative, if found suitable. The timelines in our sector are thus not even compatible with derogation periods of 13.5 years.

Furthermore, with regard to lubricants (par. 5.s.) it has been reported that PFAS-based **solvents** may be required for their use. Therefore, if access to the specific solvents is restricted (as is already happening within our supply chain), the lubricants also become unusable. This shows, that different PFAS-based use and derogation cases **should not be seen in mere isolation**.

With regard to **industrial precision cleaning fluids** (par. 5.k.) it has been suggested that the scope of this clause is clarified by explicitly including the term “solvents” as one example case.

Hydraulic fluids (par. 5.o.) are discussed in the Annex XV restriction report under the ‘transport’ sector. Space products (such as satellites, launchers and probes) are not part of the transport sub-sectors addressed by the Dossier Submitters (as also clarified in #11.1 of the Q&A published on 28.6.2023 on the ECHA website). Space applications of PFAS for hydraulic fluids are rather niche applications and hence to be addressed as ‘missing uses’ (see below Section 3.3 and Appendix 1).

3.3. MISSING USES (QUESTION #6)

The information presented in this section is mainly based on data collected from RTF participants and a number of suppliers who provided data. It can only be seen as a snapshot of the current status of the use mapping work, which is impossible to complete within a 6-month public consultation window. At the same time, it is deemed sufficient to justify our request for exemption, as detailed in our General Comments.

3.3.1. OVERVIEW OF PFAS USES IN THE SPACE SECTOR

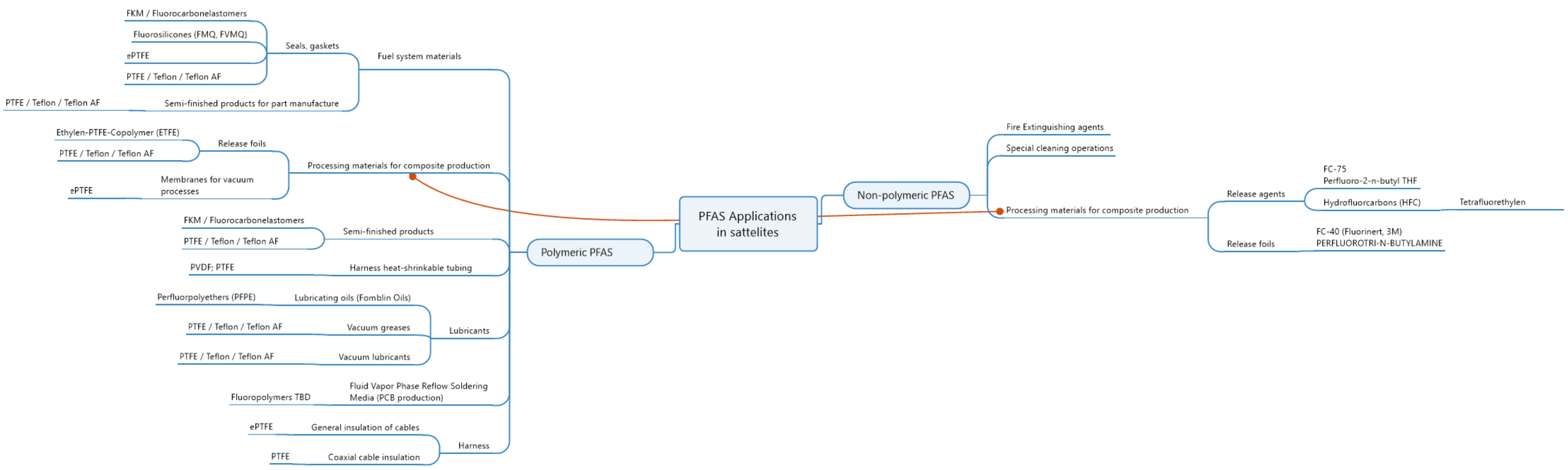
PFAS are a very heterogeneous group of substances and are used in an extremely wide variety of applications in many materials and multiple manufacturing processes for the production of space launchers and satellites. Space verification is reliant on it, such as lubricants, coatings, creep barriers, functionalised polymer surfaces, coolant fluids, fluoro-elastomeric sealants, cable insulation, shrink sleeves, PCBs, processes for electronic assembly and many others. Some of these materials were even initially developed specifically for space use and cannot be easily replaced due to their high performance in harsh space environments.

The table in Appendix 1 to this contribution provides a non-exhaustive consolidated overview of space applications of PFAS informed across different entities in the frame of the RTF. They are grouped by category, types of PFAS (fluoropolymers, perfluoropolyethers, non-polymeric) and possible derogation clause, where included in the Annex XV restriction dossier. The table shows that no derogation clause is currently even potentially available for the large majority of the space applications.

In addition, we have collected a number of case studies and examples in Appendix 2 to illustrate and provide more detail on the vast dependence on PFAS chemistry in the European Space Sector today. Column L in the table in Appendix 1 provides the reference to applicable case studies for a given space application (sub-use).

The example below (Figure 1) of a large system integrator illustrates the diversity of different PFAS uses identified in very different applications part of extremely complex space systems.

Figure 1 PFAS use mapping for a large space system integrator (Source : Airbus Defence and Space)



Ground stations and ground control centres, i.e. the ground infrastructure required to operate space systems (launchers during launch, and spacecraft during operational lifetime) are also part of the European space infrastructure and may rely on PFAS applications for components supplied which may require suitable derogations as well. Examples include the Spaceport in French Guiana (also known as the Guiana Space Center), control rooms and telecom installations such as antennas to communicate with satellites. We understand that related use cases have not been assessed in the restriction proposal either and are therefore missing. Detailed data on PFAS use for components supplied in this segment could not be obtained during the consultation period, but see an example in Appendix 2, Case Study #4, Use case on PTFE as dielectric material.

3.3.2. ANNUAL TONNAGE AND EMISSIONS (POINT A.)

The **type of PFAS** associated with the relevant use is indicated in Appendix 1 (Table). Hence, the large majority of uses are those of fluoropolymers and perfluoropolyethers. But there are also many different space applications of fluorinated gases and other non-polymeric PFAS.

According to the survey responses received, information on PFAS **volumes** for the uses identified (content in products and processes) is **broadly not known**. In some cases more detailed assessments are still running. The analysis is limited because of complex and multi-layered supply chains, with activities carried out by external suppliers. Space companies are only users of materials containing PFAS, they do not manufacture PFAS substances and PFAS-containing mixtures. Furthermore, it is difficult to provide precise estimates of the content of PFAS because in most cases an SDS does not provide this information and even direct suppliers may not be aware.

As a trend however, it was reported that **volumes** from space system integrators and subsystem producers would be even smaller compared to lower-level product manufacturers. In any case, volumes in the Space Sector are negligible compared to other industries such as automotive, construction or consumer products.

Regarding **emissions** (see also Section 4.1. regarding ECHA question #2), it has to be noted that space products are sent to space. Hence, the end-of-life issues in other industrial sectors do not apply to space products. The majority of PFAS is used in the form of solids, which are precious materials embedded in satellites, probes or in launchers, and they do not interact with their environment, until the deorbit burning and disintegration in upper levels of the atmosphere, thus eliminating all potential PFAS present in the re-entering item.

In case of use of PTFE as a contact material, e.g. at production sites of contractors responsible for composite structures, curing, moulding etc., PTFE is very resistant to any degradation, and is therefore essentially reused indefinitely for the purpose, and does not contribute to any pollution externally.

Regarding PFPE/HFE fluids, further information from ESA can be found in Appendix 2, Case Study #5.

3.3.3. KEY FUNCTIONALITIES AND SPACE CUSTOMER STANDARDS (POINT B.)

Within the Space Sector, PFAS substances are used due to their unique combination of well-known functions already reflected in the Annex XV restriction report, such as:

- ✓ High temperature resistance
- ✓ High abrasion resistance
- ✓ Chemical resistance, chemical compatibility
- ✓ Pyrotechnic compatibility
- ✓ Corrosion resistance
- ✓ Inertness
- ✓ Non-adhesive/low friction
- ✓ Low permeation
- ✓ Flexibility/malleability
- ✓ Lightweight
- ✓ Non-flammable
- ✓ Other physical properties such as dielectric constant

PFAS materials are often the only means to meet such complex requirements, and this is also the rationale as to why they were developed and used for over 50 years in the space industry globally, and they have been demonstrated, and therefore qualified to be used for space missions. As a consequence, space materials and components are relying heavily on **heritage** with PFAS (see more details for launchers in Appendix 2, Case Study #1, use case on pyrotechnic composition).

Specifically for Space, these functions have three additional aspects:

- ➢ They have to meet **enhanced performance requirements** due to the spatial conditions (vacuum/low temperature/radiation) and the associated environmental conditions.
- ➢ They have to meet **compatibility requirements**, e.g. in contact with liquid propellants, in particular liquid oxidizers used for space propulsion, which are highly reactive substances. For long term applications in combination with severe performance requirements, such as leak tightness requirements for propellant valve seats, PFAS containing materials are without any alternative!
- ➢ They are embedded in numerous **customer requirements** such as ECSS standards and ESCC specifications, which are calling for the use of PFAS, mainly fluoropolymers.

The various case studies in Appendix 2 provide illustrative examples of the unique properties provided by PFAS that have to be met for various components to ensure the efficiency, reliability and safety for multi-decade launcher, satellite and scientific programmes respectively.

In relation to customer requirements (the third additional aspect mentioned above), there would be a significant impact from the proposed universal PFAS restriction on ECSS quality/technical standards, as well as specifications of qualified components and electrical parts, where specifically the presence of fluoropolymers and fluorocarbon fluids is requested by the standard in the form of a firm requirement (mainly due to safety, reliability and highest possible performance needed). Other properties, such as flexibility, resistance to space radiation[7], outgassing in vacuum (see also Case Study #7 and #8 in Appendix 2), low surface energy, wear resistance, and all in combination, can only be achieved by certain PFAS materials, hence why their use has been standardised since the Apollo program (MIL, NASA standards) in the 1960s and later in European ECSS standards and ESCC qualified parts. All the ESA missions, including launchers, rely on ECSS and, if not available, MIL standards. Many ESCC qualified parts are calling for the presence of PFAS.

On top of standards that the European Space Sector controls or can affect (ESCC, ECSS, some ISO, EN), there are important MIL standards or IPC standards governed by committees from the U.S. These could be relevant to the industry (specifically where there is no equivalent European standard), calling for PFAS usage in the component, test method or material.

Info box 2 provides a non-exhaustive list of standards and specifications for space use that call for the use of fluoropolymers.

Info box 2 List of Space Sector requirements that contain PFAS (Source : ESA)

ECSS standards (ECSS-Q-ST-70-18, ECSS-Q-ST-70-61, ECSS-E-ST-20-08, ECSS-Q-ST-70-02, ECSS-Q-ST-70-05, ECSS-Q-ST-70-30), with multiple individual requirements on PFAS presence

EEE parts with ESCC specifications (3401/004, 3401/008, 3401/066, 3401/079, 3401/079, 3401/089, 3401/090, 3401/091, 3401/093, 3401/095, 3402/001, 3402/002, 3402/003, 3402/004, 3402/005, 3402/006, 3402/008, 3402/009, 3402/010, 3402/024, 3402/025, 3402/026, 3402/027, 3402/028, 3408/002, 3409/001, 3409/002, 3901/001, 3901/002, 3901/009, 3901/012, 3901/013, 3901/017, 3901/018, 3901/019, 3901/020, 3901/021, 3901/022, 3901/024, 3901/026, 3902/001, 3902/002, 3902/003, 3902/004, 4006/014, 3601/007, 3702/002, 3602/001, 3602/009, 4009/002, 4009/003 (this represents the use of PTFE, ETFE, FEP, PFA in space qualified passive electronics, such as radio frequency cables, LF cables, coaxial cables, connectors), qualified film heaters, all being very critical for ESA missions.[8]

MIL standards and/or specifications (MIL−STD−750−1B, MIL-STD-883-1), and many others

Specific test standards (ESCC21100, ESCC24500), utilising PFPE fluids as an inert environment.

[7] Space radiation may include, protons, electrons, UV, heavy ions, gamma, etc.

[8] See also Case Study #8 in Appendix 2, which highlights that all 19 cable product groups that are qualified according to ESCC specifications for low and high frequency wires and cables include PFAS (basically fluoropolymers like PTFE, ETFE, FEP and PFA).

For better illustration Info box 3 provides some textual examples of ECSS standards potentially impacted by the proposed restriction, that are calling explicitly for PFAS (fluoropolymers).

Info box 3 Examples of ECSS standards explicitly mentioning PFAS (PTFE)

> Full text search focused on the example of fluoropolymers: PTFE (21 hits):
>
> **ECSS-E-ST-50-12** 5.2.2.3a Requirement ECSS-E-ST-50-12_0910009 *Each signal shall be insulated using expanded, microporous PTFE with only those additives for processing and pigmentation.*
>
> **ECSS-Q-ST-70-18C** 5.2.4c Requirement ECSS-Q-ST-70-18_0620051 *The supplier shall procure semi-rigid cable with dielectric material composed of polytetrafluoroethylene (PTFE) or fluorinated ethylene propylene (FEP).*
>
> **ECSS-Q-ST-70-02C** 5.2.2.1.2a RequirementECSS-Q-ST-70-02_0510010 *Three test specimens of each material shall be prepared as follows:*
>
> *NOTE The material cuttings are in general made by the test house concerned.*
> *1. For potting materials and bulky adhesives do the following:*
> *(a) Cast them on a PTFE sheet so that a sample of a few millimetres thick (preferably 2 mm) can be separated from the PTFE after curing; …*

3.3.4. SIZE/SCOPE OF THE CHALLENGE, INCL. # OF COMPANIES AFFECTED (POINT C.)

The Eurospace economic model considers 428 space units in Europe for the year 2022; 192 companies are formally qualified as SMEs (representing 7667 employees), out of a total of 369 small space businesses.

PFAS chemicals are used throughout the supply chain – a product may have thousands of PFAS containing components and/or have components where PFAS chemicals were used in their production (e.g. microelectronics – this covers all electronic systems).

PFAS may be present in satellites, probes, launchers and ground segment equipment, but they are not exhaustively reported down the supply chain. Therefore, the PFAS content cannot be easily or exhaustively identified.

Nevertheless, based on ESA's internal survey, it can be said with high certainty that there is not a final product in frame of ESA programmes which is being currently developed without the use of PFAS. Info box 4 below provides an account of the many PFAS uses collected for the example of a satellite.

Info box 4 PFAS use – Unspecified satellite from the Earth observation fleet (Source : ESA)

> MLI (outermost layer, repair tapes, studs and clips), secondary surface mirrors for thermal control for radiators, thin films on PCBs, radiator materials, static charge control materials, (high voltage) cables, adhesive repair tapes, e.g. for MLI, PTFE oil for potentiometer bearing lubrication, micro-strip cover laminate, wire protection and insulation, seals, optical fibre protection, electrical insulator, tubing, washers, insulators of connectors, sensor wires, filters, dielectric bushing, satellite harness and wiring

As producers of very complex assemblies of articles, space companies use PFAS as chemicals to a lesser extent. They mainly buy components, sub-systems and systems, integrating them into finished products that they sell to their customers. Many products have very long service lives requiring operational functionality throughout their use life in space (see already Chapter 2 above). Space supply chains are multi-tiered and complex. There are very strict qualification requirements for parts/components used in the products. These may relate to space standards, MIL standards and/or specifications, and similar (see Info box 2 above). This means that the parts cannot be changed easily.

A rough order of magnitude has also been estimated by ESA, see Info box 5 below.

Info box 5 PFAS impact according to ESA declared material lists (Source : ESA)

From the overall record of 22,000 items in aggregated material lists, which represents 15 % of all declared material lists to ESA, the PFAS impact is in the range of 5-10%, depending on the project. In practice this would be **1000-2000 individual PFAS uses per available record**, making it virtually impossible to replace, even if PFAS alternatives were available (which is commonly not the case, see below Section 3.3.5.). Extrapolating for the uses, R&D activities and missions, which are not reflected in digital databases and tools available to ESA, it can be assumed that there are **at least 10,000 or more individual PFAS material entries**, and this is only in ESA missions. The impact on manufacturing processes was not assessed, but the number of processes relying on PFAS containing material entries may be in a similar order of magnitude.

3.3.5. ANALYSIS OF ALTERNATIVES (POINTS D.-F.)

3.3.5.1. POINT D. INFORMATION ON ALTERNATIVES

Respondents stated that there are **in general no PFAS-free alternatives** for the uses identified, and information about alternative candidates is not yet known from suppliers. Space system manufacturers **depend on their suppliers** to first propose alternative solutions. Based on the suppliers' answers from supply chain enquiries, which have just started, space companies may be able to check the viability of candidates for substitution and plan their development work.

Even where there is an existing candidate alternative, the replacement can only be realised after **rigorous testing and space qualifications**, which (if successful) demonstrate that the stringent performance and project requirements continue to be met. The outcome of these steps will be uncertain and in some cases replacement would be impossible. It was also noted that the price of the PFAS material used in space relevant equipment, or ground segment equipment may be negligible, but the PFAS presence is critical to its success, with extremely costly consequences should a failure occur.

In the event of alternative candidates existing, the process must be qualified to proceed further with its integration, on a so-called **Technology Readiness Level (TRL)** scale. Each of these steps on the way from TRL1 until TRL9 (space heritage) increases the value (price paid) exponentially and goes hand in hand with the level of integration and confidence in the technical solution, ending with successful flight (maiden flight, protoflight model, inauguration launch, etc.). Each mission phase may require different levels of approval for funding, depending on funding schemes. In the worst case, project delays or even cancellations may occur as a result of unforeseen events, including substantial cost increases.

Taking the example of an electronic assembly, potentially every component replaced should be evaluated and/or retested within the context of the system to achieve requalification. This process should be repeated where replacement components are found to be unsuitable. Even if technically possible, the replacement of the PTFE would imply the redesign of thousands of products, because the Radio Frequency (RF) design of connectors and components is dependent on the dielectric constant of the material. The redevelopment would trigger the requirement to recertify the platform containing the assembly.

In some cases where alternatives were / are investigated, the following was reported:

- In the case of **sealants for space launcher applications**, PTFE or fluoropolymers-based solutions in general are the only viable options (see also Appendix 2, Case Study #4, Use Case 1 on PTFE in seals). This has been proven by multiple studies and demonstrated experimentally in recent investigations. The evidence on the performance of PFAS-free alternatives contains proprietary information and can be shown if requested by the authorities (Dossier Submitters, ECHA, COM), but cannot be part of this contribution.
- **Wire and cable insulation** for space applications continues to rely on the properties of fluoropolymers like PTFE, which have been found to provide the highest dielectric strength and be the lowest outgassing insulating materials as compared to Polyethylene (PE) and silicon rubber based materials (see Appendix 2, Case Study #8 on signal and power wire and cables).
- For **PTFE lubricants** there are some PFAS-free alternatives. However these are extremely uncommon or not technically equivalent.
- For the **vapor phase soldering process** PFAS-free alternatives are already marketed, but manufacturers of the soldering chambers themselves are not endorsed to use these alternative fluids in their equipment, and do not guarantee the correct performance or functionality when using a PFAS-free alternative. The substitution challenge for PFAS is further increased with regard to the on-going transition effort to lead-free soldering, where a higher temperature is needed (see Case Study #6 in Appendix 2); thus, concurrent replacement activities for these substances also aggravate the risk of regrettable substitution with technically inferior alternatives.
- A few **suppliers** presented their involvement in substitution efforts but this is not necessarily compliant with space application requirements. Also, some space companies have started checking possible alternatives depending on application and mission scenarios (load cases). A detailed analysis is necessary.

Therefore, it can be generally concluded that there is **no proven evidence for the existence of available and suitable PFAS-free alternatives** for the uses identified in Appendix 1.

3.3.5.2. POINT E. INFORMATION ON THE STATUS OF R&D PROCESSES

Replacement is a very **time-consuming process** in our complex industry. In addition, replacement R&D cannot be launched without our suppliers, which further adds to the duration. For the example of F-Gas it was reported that replacement programmes would exceed 15 years and require the prior future emergence of viable and available alternatives for each application.

According to the survey responses most products and items are considered critical as they do not have a replacement and **no systematic replacement campaign has been started**; this is not typically done on substances not classified or shortlisted for regulatory measures (e.g. through candidate listing). In case a legal compliance requirement would come into force, funding would need to be agreed in order for R&D activity to be conducted. This is a long-term process in the European Space Sector typically exceeding even the longest derogation timelines, with success not guaranteed, as it is extremely difficult to substitute one of the best performing materials in the space environment.

The future simultaneous launch of replacement programmes investigating the qualification of alternatives is **not expected to be manageable**:

- There will not be enough time to perform all qualification activities and to introduce the replacement solutions on extremely complex space hardware such as launchers as one important principle is to introduce modifications (i.e. qualified technologies or substitutes) step by step and not simultaneously with no prioritisation. The objective is to avoid or at least to limit as far as possible any unexpected events (such as a side effect from one product on other parts).
- There will not be enough qualified people to manage said research programmes and to carry out simultaneous tests.

Furthermore, the **development of new ECSS standards or ESCC specifications** based on a suitable alternative, including the granting of the ESCC certification status for the part manufacturer requires lot of time (several years), manpower and funding, mostly to be covered by taxpayers' contributions via ESA member states funds. It must be recognised that when discussing alternatives for PFAS, the impact on the qualification processes cannot be ignored, and upheaval that would be required to the very foundations of the standards that the industry is reliant upon. This would also be applicable to all ECSS standards that state the use of PFAS as a hard requirement (see above Section 3.3.3).

Additional complexities would arise in relation to **specifications and standards from outside Europe (such as MIL and IPC standards**, see above Section 3.3.3.). Even if PFAS-free alternatives were available, the entire process of re-configuring and reviewing all standards and specifications currently used would require reciprocal European alternatives to MIL specifications, resulting in non-quantifiable workloads for standardisation working groups. In addition, all customer requirements that rely upon impacted standards would need to be reevaluated. This would present an enormous administrative burden to ESA programmes, resulting in hundreds of contract change notices (CCN), Request for Waivers (RFW), and Request for Deviations (RFD) in the projects currently being developed. Among those are projects strategic to the European Commission, such as Galileo, Copernicus, Telecommunication satellites etc.

The overall PFAS substitution cost to industry and space agencies could be in the order of hundreds of millions of Euros for current ongoing and future programmes, to mitigate against the risks to the most critical applications.

3.3.5.3. POINT F. INFORMATION WHERE SUBSTITUTION IS FEASIBLE

We have not been able to identify such cases in the context of needed derogations. Please see the sections above regarding the absence of suitable alternatives and R&D status.

3.3.6. SOCIO-ECONOMIC ANALYSIS (NON-USE SCENARIOS) (POINT G.)

3.3.6.1. ANNUAL VALUE OF EU SALES AND PROFITS AND EMPLOYMENT NUMBERS

In 2022, the European space industry posted **sales** of 8.25 billion €, thereof 67% of total sales to ESA and other European public institutions (see Info box 6). This is a drop in sales worth 400 million € comparing to 2021; the European space manufacturing sector has recovered partly from the Covid-19 downturn, but some market segments are still affected by structural slowdown (commercial satellite and launcher segments).

Info box 6 Sales breakdown by segments (Source : ASD-Eurospace facts & figures 2023)

Sales by macro segment and by customer (M€)

M€	Launcher systems	Satellite applications	Scientific programmes	Ground systems & services	Other / Unknown systems	Total
Sales to ESA (incl. delegated EC programmes - GMES & Galileo)	445	1225	1085	807	41	3602
Sales to other European institutions (public)	62	1035	117	640	99	1954
Sales to Public institutions RoW	3	255	38	58	10	363
Other/unknown European customers	9	18	11	41	25	104
Sales to European private operators	1	367	7	63	14	452
Sales to Arianespace	589	3	1	28	0	621
Sales Private satellite operators RoW	2	362	41	43	8	455
Sales of equipment and parts RoW	103	387	102	56	28	677
Other/unknown RoW customers	1	6	1	14	7	28
Total	1214	3657	1403	1750	232	8257

Beyond the contribution to European space programmes, the Space Sector is also a positive contributor to the European trade balance with an average net surplus worth 900 million € every year in the past decade, thanks to exports of both satellite systems and launch services.

Furthermore, while the European public space infrastructure provides unmeasurable, but significant, social, scientific and strategic benefits via the provision of free services (weather, climate and environmental data, timing and position information, tactical and strategic intelligence, television broadcast, etc.), it also creates more than 200B€ of revenues through its value chain, thanks to the induced markets for applications and terminals (source EUSAP EO and GNSS Market report 2022). Space applications permeate through all areas of the global digital economy, and it is projected that the sector will further accelerate its economic development in the next decade.

Regarding **profits**, currently there is no consolidated data for the space segment alone. However, profits in the sector are very low in general. The few European space companies with published financials (OHB, Beyond Gravity, Arianegroup, e.g.) registered losses in recent years or very low profit margins (below 3-4%).

In 2022, the European space industry **employed** a total of 57510 workers (FTE: Full Time Equivalents), according to the ASD-Eurospace facts & figures 2023. The 6 major ESA member states (France, Germany, Italy, United Kingdom, Spain and Belgium) provide roughly 90 % of European space industry employment, and the 30 largest space companies in Europe account for almost 80% of total employment in the sector. The remaining smaller players, of which there are hundreds, represent barely 20% of the total employment, with the proportion of SMEs between 13% and 15%. The smaller players work predominantly as subcontractors, except when they are involved in development activities and directly contracted by space agencies, mostly ESA.

3.3.6.2. SOCIO-ECONOMIC IMPACTS WHERE SUBSTITUTION IS NOT FEASIBLE

The implementation of **RO1** (full ban in ca. 2026-27) would result in a complete grounding of our entire sector, including delays and cost overruns to everything the European Space Sector currently intends to build, and including but not limited to all strategic missions to the European Commission.

In the assumed worst-case scenario of a restriction with **major derogation gaps** (case of the current restriction proposal, **RO2**) there could in the best case still be a partial success of those projects which could stockpile, and place on the market before derogations expire (as also clarified in #2.3 of the Q&A published on 28.6.2023 on the ECHA website). However, most of the projects would have uses / activities in conflict with the restriction where substitution is not technically or economically feasible. The following possible direct and wider socio-economic impacts were reported:

Direct impacts:

- **Supply chain disruptions** for mixtures and articles would occur due to market withdrawal or bankruptcy of suppliers not covered by derogations (this was reported for example for coaxial connectors and RF coaxial components). There is already a threat of losing PFAS materials which are going to be obsolete as early as 2025, which **could bring certain project to an end** if suitable alternatives are not found in time.

- Multiple spacecraft applications and missions would be severely impacted. The **production and delivery of space products may need to cease**, including a potentially severe rescope of missions and hardware requirements. Missions may need to be delayed or cancelled. As an example, without the capabilities of fluoropolymers like PTFE, all European satellites, including Galileo 2nd Generation, Copernicus or the future Telecom Satellites Secure Connectivity Program IRIS² cannot be realised, as there is no known replacement material today providing the properties for cable insulation to survive the harsh space environment (see Case Study #8 in Appendix 2).
- In the absence of suitable alternatives that provide the same performance, the safety and functionality of the systems could be compromised with the **possibility of malfunctioning commercial, military and scientific satellites or instruments**.
- Space products / equipment (due also to ground station support difficulties) may need to **retire prematurely from service.**
- On **human spaceflight missions** regrettable substitution with less performing alternatives could even cause unacceptable risks to the lives and safety of the crew (see e.g. Case Study #2 and Case Study #6 in Appendix 2).
- The **economic impact** will in any case be substantial. Considerable extra costs would be needed for identifying a substitute product and for the subsequent qualification activity, including for space programmes already in progress or in the design phase. These will add further pressure on the already very low profits in the sector. Available funding schemes (*currently none are available*), EU-wide co-ordination of efforts and cross-sectorial activities will play a major role.
- Given the widespread inclusion of PFAS in ECSS standards, ESCC specifications, MIL specification as well as test methods, a restriction would also have a **broader impact on ESA's standardisation effort**, budgets (which are based on taxpayers' money from ESA's member states), qualification status of parts and test activities across test sites in Europe.

Wider socio-economic impacts:

- A missing derogation without available alternatives would lead to a **clear competitive disadvantage** to the EU space industry (direct impact on design and performance).
- There is a potential opening of a **new strategic dependency on non-EU/EEA countries** (at least for article manufacturing using PFAS in processes, where PFAS are no longer present above applicable thresholds in imported products).
- With regard to the **collaboration with non-EU partners**, a PFAS restriction without sufficient derogations could thwart any ESA participation in American or Japanese space programmes. Uses of PFAS in ESA's instruments, interfaces, etc., would still be required on the non-European side but would be restricted for placing on the EU/EEA market (noting that there may be a multi-tier supply chain also in the EU/EEA prior to

export, with only this last step excluded from the restriction scope!). For the EU space industry, as there are many MIL U.S. specifications and requirements still requiring PFAS, then European manufacturers would need to **move from EEA territory** to keep the business running outside Europe.

- This will impact the **overall added value in the EU** and lead to **loss of jobs**. Not only would space companies be affected, so would their supply chains and institutional customers (including ESA, national agencies, the European Commission) as well as commercial partners (those who rely on the products and services provided by the sector). This will include impact on industries reliant upon the technology development of the space industry, e.g. other high-tech industries or consumer industry.
- Given the strategic and security aspects of European space activities, an inability to build high-performing and reliable space launchers and satellites would also jeopardize Europe's **independent access to space** and significantly hamper Europe's vital interest to have **autonomous defence capabilities** (see already Chapter 1).

Finally, even if sufficient derogations for our own products were available in the final restriction, there is a serious **commercial obsolescence risk**. This means that materials and components qualified for space applications may become unavailable without alternatives, even if derogations for our sector were in place, because the continuation of the space market alone is not business-viable for the supplier. In the survey it was mentioned that suppliers of PFAS solvents are already advising companies in the space mechanisms industry to move away from such solvents; obviously however this is difficult if there are no existing and qualified alternatives.

3.3.7. SUMMARY FOR ECHA WEBFORM (QUESTION #6)

The PFAS use mapping for this contribution (see Appendix 1) has shown that no derogation clause is currently even potentially available for the large majority of the space applications identified that rely on PFAS. In addition, we have collected a number of case studies and examples in Appendix 2 to illustrate and provide more detail on the vast dependence on PFAS chemistry in the European Space Sector today.

Here below we provide a brief summary of points a.-g. of the ECHA Specific Information Request. For further details and illustrative examples please see Section 3.3 – 3.3.6., Appendix 1 and 2 to our contribution paper (MPTB-ES-PO-0131).

Point a. Annual tonnage and emissions: According to the survey responses received, information on PFAS volumes for the uses identified is broadly not known for a number of reasons detailed in our contribution paper. However, volumes are estimated to be very small, and in any case negligible compared to other industries such as automotive, construction or consumer products. Regarding emissions it must be considered that space products are sent to space.

Point b. Key functionalities: Within the Space Sector, PFAS substances are used due to their unique combination of well-known functions already reflected in the Annex XV restriction report. PFAS materials are often the only means to meet such complex requirements (see e.g. illustrative Case Study #2 on orbital propulsion systems for satellites and Case Study #3 for a scientific mission for ESA (the Athena Wide Field Imager), in Appendix 2 of the contribution paper), and this is also the rationale as to why they were developed and used for over 50+ years in the space industry globally, and they have been demonstrated, i.e. qualified to be used for space missions. As a consequence, space materials and components are relying heavily on heritage with PFAS (see more details for launchers in Appendix 2, Case Study #1, use case on pyrotechnic composition). Importantly, the use of PFAS (predominantly fluoropolymers) is embedded in numerous customer requirements, such as ECSS standards and ESCC specifications, especially for EEE parts. On top of standards that the European Space Sector controls or can affect, there are important MIL standards or IPC standards governed by committees from the U.S.

Point c. The number of companies in the sector estimated to be affected by the restriction: The Eurospace economic model considers 428 space units in Europe. PFAS chemicals are used throughout the supply chain; a product may have thousands of PFAS containing components and/or have components where PFAS chemicals were used in their production (e.g. microelectronics – this covers all electronic systems). Our contribution paper provides further statistical detail and estimates, which shows the vast reliance on PFAS for space programmes.

Point d. Information on alternatives: Respondents stated that there are in general no suitable PFAS-free alternatives for the uses identified, and information about alternative candidates is not yet known from suppliers. Space system manufacturers depend on their suppliers to first propose alternative solutions. Even where there is an existing candidate alternative, the replacement can only be realised after rigorous testing and space qualification, which (if successful) demonstrate that the stringent performance and project requirements continue to be met. The process must be qualified on a so-called Technology Readiness Level (TRL) scale. Therefore, it can be generally concluded that there is no proven evidence for the existence of available and suitable PFAS-free alternatives for the uses identified in Appendix 1. The substitution challenge for PFAS is further increased with regard to the on-going transition effort to lead-free soldering, where a higher temperature is needed (see Case Study #6 in Appendix 2), thus also aggravating the risk of regrettable substitution.

Point e. Information on the status of R&D processes: Replacement is a very time-consuming process in our complex industry. In addition, replacement R&D cannot be launched without our suppliers, which further adds to the duration. According to the survey responses, most products and items are considered critical as they do not have a replacement and no systematic replacement campaign has been started; this is not typically done on substances not classified or shortlisted for regulatory measures (e.g. through candidate listing). The future simultaneous launch of replacement programmes investigating the qualification of alternatives, with subsequent revision of standards, is not expected to be manageable and is prone to unexpected events. Additional complexities would arise in relation to specifications and standards from outside Europe (such as MIL and IPC standards). The overall PFAS substitution cost to industry and space agencies could be in the order of hundreds of millions of Euros for current ongoing and future programmes, to mitigate against the risks to the most critical applications.

Point f. Information where substitution is feasible: We have not been able to identify such cases in the context of needed derogations.

Point g. Socio-Economic Analysis (non-use scenarios): In 2022, the European space industry posted sales worth 8.25 billion € (a drop of 400 million € compared to 2021) and employed a total of 57510 workers (FTE: Full Time Equivalents). Profits in the sector are very low in general. In the assumed worst-case scenario of a restriction with major derogation gaps (case of the current restriction proposal, RO2) most of the projects would have uses / activities in conflict with the restriction where substitution is not technically or economically feasible. Possible direct socio-economic impacts reported include supply chain disruptions, ceasing of production and delivery of space products, the possibility of malfunctioning commercial, military and scientific satellites, premature retirement from service. As an example, without the capabilities of fluoropolymers like PTFE, all European satellites, including Galileo 2nd Generation, Copernicus or the future Telecom Satellites Secure Connectivity Program IRIS^2 cannot be realized, as there is no known replacement material today providing the properties for cable insulation to survive the harsh space environment (see Case Study #8 in Appendix 2). On human spaceflight missions regrettable substitution with less performing alternatives could even cause unacceptable risks to the lives and safety of the crew. The economic impact will in any case be substantial, including for space programmes already in progress or in the design phase, thus adding further pressure on the already very low profits in the sector. As a result, a missing derogation without available alternatives would lead to a clear competitive disadvantage to the EU space industry, the potential opening of a new strategic dependency on non-EU/EEA countries as well as complications in collaborating with our non-EU partners. This will impact the overall added value in the EU and lead to the loss of jobs. Given the strategic and security aspects of European space activities, an inability to build high-performing and reliable space launchers and satellites would also jeopardize Europe's independent access to space and significantly hamper Europe's vital interest to have autonomous defence capabilities. Finally, even if sufficient derogations for our own products were available in the final restriction, there is a serious commercial obsolescence risk, if business continuity is not ensured for related supplier markets.

Ground stations and ground control centres, i.e. the ground infrastructure required to operate space systems (launchers during launch, and spacecraft during operational lifetime) are also part of the European space infrastructure and may rely on PFAS applications for components supplied which may require suitable derogations as well. Examples include the

Spaceport in French Guiana (also known as the Guiana Space Center), control rooms and telecom installations such as antennas to communicate with satellites. We understand that related use cases have not been assessed in the restriction proposal either and are therefore missing. Detailed data on PFAS use for components supplied in this segment could not be obtained during the consultation period, but see an example in Appendix 2, Case Study #4, Use case on PTFE as dielectric material.

3.4. POTENTIAL DEROGATIONS (QUESTION #7)

As for the *proposed* derogations, the need for *potential* derogations from the European Space Sector perspective is primarily driven by our niche sector's critical dependence on its upstream suppliers of chemicals and components to maintain a business viable market in the EU for aerospace and defence, electronics and related sectors, not limited to space only.

According to the surveys conducted for this contribution at least the following derogations 'for re-consideration' need to be activated to this end:

- **the use cases in relation to 3D printing applications (par. 5.x. and y.)**
- **the semiconductor manufacturing process (par. 5.ee.)**
- **applications affecting the proper functioning related to the safety of transport vehicles, and affecting the safety of operators, passengers or goods (par. 6.o.)**

With regard to **semiconductors** it was reported in the response to the survey that the use of many PFAS are essential in semiconductor manufacturing and finished semiconductors. There are so far no alternatives known for many PFAS applications.

More specifically PFAS (PFCL) is required for ESA qualified radiation hardened devices in hermetic packages for space / satellite applications (see entry row #23 in Appendix 1). The final hermeticity test is based on PFAS-containing liquids. The volume is ca. 30kg per year. The company uses PFAS because they are required by ESCC specifications (e.g. ESCC 5010 requires Seal. Gross Leak test according to MIL-STD-750, Test Method 1071, condition C or K ; MIL-STD-750, Method 1071, cond. C "liquid fluorocarbon gross leak" explicitly requires two perfluorocarbon fluids with low and high boiling points). However, we believe that such a use case driven by space requirements should be covered by the requested space-specific derogation (niche application).

With regard to **'transport vehicles'** (par. 6.o.) it was already recalled for hydraulic fluids (par. 5.o.) that space products (such as satellites, launchers and probes) are not part of this domain according to the Annex XV restriction report. Indeed, space applications of PFAS are niche applications which are by no means comparable in terms of their absent (in space) or minimal (on ground) environmental impact with transport vehicles operated in the EU; hence they are suitably addressed as 'missing uses'.

3.5. OTHER IDENTIFIED USES (QUESTION #8)

We were surprised to find not even a *potential* derogation for the broad group of **electronics** in the Annex XV restriction report. Only for the Space Sector, our survey has informed a variety of applications containing PFAS – mainly fluoropolymers – for which there are no existing or qualified alternatives and where PFAS are often even required in space specifications and standards. These include (see Table in Appendix 1, rows #16-28) wires, cables, cable assemblies, capacitors, connectors, flex leads; shrink sleeves for protection or insulation, shrinking tubes; PCBs (e.g. substrates, high speed prepregs and laminates for PCBs, reinforced glass fibre PTFE for high frequency PCBs); heaters; EEE parts; batteries. Those space uses should be covered as niche applications (see section on 'missing uses' with further details on the information elements a.-g.).

Just like for the *proposed* and *potential* derogations, the need for broader derogations for electronics from the European Space Sector perspective is primarily driven by our niche sector's critical dependence on its upstream suppliers of chemicals and components to maintain a business viable market in the EU for aerospace and defence, electronics (see e.g. https://www.fpp4eu.eu/library/value-chain-factsheet-electronics) and related sectors, not limited to Space only. Sufficiently broad derogations for electronics are therefore mandatory.

3.6. REPORTING REQUIREMENTS AND CHALLENGES TO IDENTIFY ALL PFAS USES

Collecting information on the use of such a large number of substances in our complex articles and supply chains is a tremendous challenge, even more given the absence of legal supply chain reporting requirements for non-classified substances/mixtures (in Safety Data Sheets) and non-SVHCs (only Candidate List substances are in scope of REACH Article 33(1) reporting). In response to the publication of the Annex XV restriction report, numerous surveys have been launched in the Space Sector, both internally within businesses, agencies and research institutes and externally with suppliers (see Appendix 3 for further information).

The proposed detailed **annual reporting requirement to ECHA** in paragraph 7 of the suggested restriction text for *'i. the derogation that the intended use belongs to'* and *'ii. The identity and quantity of the substances placed on the market in the previous year'* would also apply *'manufacturers and importers of PFAS containing articles'*, without any minimum volume threshold. Given the limited information available about substance identity and volumes today (see also above Section 3.3.2.) we believe that it will not be manageable to fulfil such requirement for the entities in our sector that are manufacturing very complex assemblies, even less should there be multiple specific derogation clauses. We also find it inconsistent that 'downstream users' other than formulators are excluded from the reporting duty for practical reasons (p12 of the Annex XV restriction report), but manufacturers and importers of PFAS containing articles (which are even further downstream of downstream users) are not. We therefore require that **no reporting duty** shall apply to manufacturers and importers of articles as such an as part of assemblies either. Should the reporting duty be maintained, we require the **space-specific derogation clause to be referred to** for our uses (see Chapter 1, General Comments) as well as a **minimum volume threshold** to trigger the reporting duty. Also, any such requirement should be **limited to 'available' information.**

Equally, paragraph 8 proposes the additional requirement of a **'site-specific management plan'** to be reviewed annually for manufacturers, importers **and downstream users** of **fluoropolymers and perfluoropolyethers** making use of any derogation, including *'i. information on the identity of the substances and the products they are used in'*, *'ii. A justification for the use'* and *'iii. Details on the conditions of use and safe disposal'*. We believe that this requirement is **excessive for space applications** given our very small quantities, as well as the in-space/in-orbit end of life location for the majority of our products and the evident justification for the use. Therefore, it **should not apply** to equipment designed to be sent into space.

4. INFO ON OTHER ECHA QUESTIONS

In this Chapter we provide some comments on other ECHA Specific Information Requests, even though data are very limited given our sector's specificities.

4.1. EMISSIONS IN THE END-OF-LIFE PHASE (QUESTION #2)

We wish to recall that there are no PFAS emissions on Earth / the EU territory for products sent into space. Spacecraft lift off from the Earth on the launcher and either burn on their way back from low Earth orbit after conducting experiments, or live a long service life, orbiting Earth and staying operational before deorbiting (meteorological satellites, telecommunication), or remain permanently as Earth's satellites in a 'graveyard orbit' (Navigation satellites in geostationary orbits). In some cases, ESA develops rovers, probes, landers, which are destined for use on or around other planets of our solar system (Rosetta, Venus Express, BepiColombo, Solar Orbiter, Juice and many others) and are not ending their life cycle in Earth's atmosphere nor near to Earth's orbits.

For the associated on-ground activities PFAS are not broadly used and the volumes are very small, essentially negligible when compared to other industries.

Therefore, there is only very little positive potential benefit of a PFAS restriction on the environment or a positive impact on society at large which could be linked to PFAS-free alternatives in the European Space Sector, especially considering that the majority of our products are not ending in ecosystems on Earth, and therefore do not contribute to the issues this restriction is primarily targeting.

4.2. WASTE MANAGEMENT OPTIONS (QUESTION #3)

Our survey has not yielded detailed information to answer this question. We wish to stress that the issue of waste management only concerns very small cases as far as on-ground activities in the European Space Sector are concerned. All waste is handled and disposed as per national legislation (see also Case Study #5 in Appendix 2 regarding PFPE fluids).

4.3. IMPACTS ON THE RECYCLING INDUSTRY (QUESTION #4)

This question is rather addressed to the recycling industry. We do not have information on this topic. Also, equipment sent into space is not being recycled after its end of life.

4.4. DEGRADATION POTENTIAL OF SPECIFIC PFAS SUB-GROUPS (QUESTION #9)

We do not have information on this question. However, we would like to recall that PFAS substances in equipment sent into space are destroyed in space at their end of life, when they burn at re-entry into the atmosphere.

4.5. ANALYTICAL METHODS (QUESTION #10)

We do not have information on this question. However, we wish to stress that for PFAS embedded in closed sealed articles (i.e. complex assemblies of articles), e.g. scientific instruments imported from non-EU partners to be integrated into platforms on the EU territory, there is no non-destructive analytical method available to prove or disprove the content of PFAS inside the article.

APPENDICES

APPENDIX 1: TABLE OF PFAS USES IN THE EUROPEAN SPACE SECTOR (CONFIDENTIAL)

We refer to the Table titled "Appendix 1 to MPTB-ES-PO-0131_uPFAS Mapping_CONFIDENTIAL" (.xlsx), which is enclosed to this contribution as a **confidential attachment**. It should be noted that this table is by its nature **non-exhaustive**, as it only reflects the current status of the PFAS use mapping for space applications and supply chain visibility is limited. At the same time, we consider it as a representative reflection of PFAS uses in space applications for the purpose of the present restriction process and our request for exemption.

We have the following reasons enumerated in Article 4(1) or 4(2) of Regulation (EC) No 1049/2001 regarding public access to documents why the information submitted as confidential cannot be disclosed to persons requesting access to documents:

As recalled in our contribution, the European Space Sector is strategic for the EU and its technological non-dependence. The attachment contains an extensive structured, consolidated list of PFAS uses in the European Space Sector, which we consider to expose strategic sectorial dependencies on this substance group. Therefore, it is submitted in support of our request for exemption for the exclusive evaluation by the competent authorities in the present restriction process. Given the level of detail provided in the attachment, the strategic dependencies shown and the links of space applications to public security, defence and military matters, we believe that disclosure would undermine the public interest as regards these aspects according to Article 4(1)(a) of Regulation (EC) No 1049/2001.

APPENDIX 2: ILLUSTRATIVE CASE STUDIES / EXAMPLES

This Appendix provides a number of case studies and examples to illustrate the vast dependence on PFAS chemistry in the European Space Sector today.

CASE STUDY 1: PFAS APPLICATIONS ON THE ARIANE 6 LAUNCHER

Ariane 6 is currently being developed in Europe on behalf of ESA. The final qualifications are currently taking place, and its maiden flight is planned for early 2024. It will replace Ariane 5 as part of the Ariane launch vehicle family, making an important contribution to Europe's independent access to space.

The use of PFAS substances plays an essential role in the context of European Ariane launchers. Despite growing concerns about PFAS in the environment, it is also crucial to recognise their unique attributes that render them irreplaceable in ensuring the reliability, safety and finally the success of Ariane launcher missions.

Ariane 6 is a very complex launch system that must fulfil a high level of requirements. As with other complex assemblies, Ariane 6 uses many PFAS substances (predominantly fluoropolymers) including in the following range of applications (non-exhaustive list):

- Lubricants
- Coatings
- Creep barriers
- Functionalised polymer surfaces
- Cleaning agents
- Coolant fluids
- Fluoro-elastomeric sealants
- Pyrotechnic compositions
- Blowing agents for thermal insulation
- Adhesives
- Fire suppressants
- Cable insulation
- Shrink sleeves
- PCBs
- Processes for electronic assembly

In addition, some applications are very specific to the needs of Ariane 6. Three use cases are detailed hereunder to illustrate why the continued use of PFAS substances is critical for the Ariane 6 launcher.

Fluorinated gas-based blowing agents for cryogenic thermal insulation

Most structural parts of cryogenic space launchers must be protected with thermal insulation due to the very high thermal constraints on ground and / or during flight. Cryogenic tanks and cryogenic lines, especially, are covered by external Cryogenic Thermal Insulation.

Cryogenic Thermal Insulations used to protect Ariane 6 are made of polyurethane closed cell foams. Those foams are applied directly to parts through the use of fluorinated gas-based blowing agents, which would now fall under the PFAS restriction.

Such foams have a low thermal conductivity which is necessary to reach the optimized insulation properties required for cryogenic tanks and can also withstand relatively high temperatures during flight.

Such foams also feature required mechanical properties for ensuring:

- the necessary adhesion on substrate throughout the lifetime of the launcher
- the resistance to thermo-mechanical loads during flight
- the required flexibility throughout the lifetime of the launcher

Regarding the process application, the fluorinated gas used has a very low flammability and can be sprayed at room temperature.

At this time, only fluorinated gases are able to create such closed cell foam to ensure insulation, while preserving the high thermo-mechanical performance of the insulation material. Fundamental research is ongoing but currently there are no alternatives qualified to meet the high performance cryogenic insulation requirements of the launcher.

Without this thermal protection on cryogenic stages, the safe operation of the launcher cannot be ensured, thus French Space Law [9] safety requirements cannot be met and consequently no launch services could be provided anymore.

Please note that this particular case has been addressed in the response to the public consultation on PFAS made by ArianeGroup and Air Liquide Advanced Technologies (reference number: e33a424f-7a32-42ea-b69a-a75e585d7935).

[9] Loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales and its 3 decrees : Décret no 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales; Arrêté du 31 mars 2011 relatif à la réglementation technique en application du décret n° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales ; Arrêté CNES/ P N° 2010-1 du 9 décembre 2010 portant réglementation de l'exploitation des installations du Centre Spatial Guyanais.

Pyrotechnic composition

Certain fluoropolymers are included in energetic compositions because they provide key safety functionalities to the materials.

For instance, for Ariane 6 the new pyrotechnic system requires an energetic composition which includes Viton®.

The use of Viton makes this energetic composition insensitive to friction and to electrostatic energy that is absolutely necessary for safety measures.

In the launcher industry, the concerns about the heritage of systems, components and materials in launchers are extremely important. After the development stage, the system configuration is fixed with every system in one launcher being identical to the next, meaning that the configuration for the operational systems is rather rigid with little flexibility provided in change situations.

This is why, once validated, material or technology is produced with the aim of not implementing changes to protect the validity of the qualification status.

This Viton technology has been developed more than 30 years ago and meets our requirements. That's why this product is still used in production. Developing and qualifying a replacement solution would require long term development studies and qualification. This duration is difficult to estimate because of the lack experience.

Surface treatment for propellant tank fill-in tools

The majority of the initial thrust of the launcher is provided by solid propellant boosters. These are mainly composed of an envelope containing the propellant, an igniter and a nozzle. The powder block is pierced by a longitudinal channel which serves as a combustion chamber. When the booster is ignited, the surface of the channel-side powder block starts to burn, producing high-pressure flue gases that are expelled through the nozzle. By giving a particular geometry to the channel, we control the pressure-flow rate curve.

The use of fluoropolymers in the manufacturing of solid propellant boosters is essential. Indeed they are contained in the coating of moulding tools that will facilitate the transfer of this very specific geometry to the combustion channel.

They have a lubrication function allowing the propellant to flow and the safe extraction of the tools. Fluoropolymers are the only materials that can prevent friction and adhesion between the propellant and the tools. Moreover they prevent contamination and are compatible with launcher propellant.

At this time, no alternative for this lubricant exists on the market which would meet our requirements regarding these major functionalities. Without fluoropolymers, it will no longer be possible to manufacture solid propellants boosters. Those solid boosters are produced by Europropulsion and are integrated either in Ariane 6 or in the Vega launcher.

CASE STUDY 2: VALVE SEATS, GASKETS AND MOULDED PRODUCTS FOR ORBITAL PROPULSION SYSTEMS AS SATELLITE SUBSYSTEM

Fluoropolymers – especially Teflon/PTFE - play a crucial role in ensuring the effectiveness of high-performance gaskets such as valve seats or interconnection seals for propellant lines, as well as for moulded products including bladders and diaphragms for satellite propellant tanks. Whilst acknowledging general concerns surrounding PFAS compounds, it is imperative to highlight their unique properties that make them irreplaceable, through ensuring the efficiency, reliability and safety over multi-decade orbital propulsion missions. Especially for manned missions, a PFAS restriction without suitable derogations would present an unacceptable risk to the safety of the crew.

For orbital propulsion systems, the following properties are key:

Unparalleled Chemical Stability:

The demanding conditions of orbital propulsion systems, including extreme temperatures and exposure to highly reactive propellants, require materials with exceptional chemical stability. PFAS substances possess this characteristic, allowing them to maintain their structural integrity and functional properties in the presence of corrosive and highly reactive chemicals.

Sealing and Leak Prevention:

Orbital propulsion systems include a complex system of fluid-carrying components, where even minor leaks can lead to catastrophic failures and mission losses. PFAS-based materials offer unmatched sealing capabilities that prevent leakage and safeguard the integrity of these critical systems over multi-decade missions. This feature is crucial to avoid mission failures and ensuring the safety of both spacecraft and crew.

Longevity and Durability:

Orbital propulsion systems are designed to operate efficiently over extended periods, enduring extreme temperature variations and exposure to harsh conditions. PFAS substances exhibit exceptional resistance to degradation, ensuring the longevity and durability of critical components within propulsion systems.

Compatibility with Varied Materials:

PFAS materials are renowned for their compatibility with almost all highly reactive propellants used for orbital propulsion systems. This compatibility in combination with elasticity, which ensures leak tightness over the entire mission, is paramount for their application in valve seats, gaskets, bladders or diaphragms in propellant tanks. Furthermore, they can form strong bonds and protective coatings on various surfaces, contributing to the structural integrity and reliability of propulsion system components.

Adaptability to Space Environment:

The space environment, with its unique combination of vacuum, radiation and microgravity requires materials that can maintain performance under these extreme conditions. The exceptional stability of PFAS substances makes them perfect for such environmental conditions and ensures a consistent level of performance, which is crucial for orbital propulsion missions. Considering these factors, it is evident that the advantages offered by PFAS substances remain unrivalled within the realm of orbital propulsion systems.

Absence of alternatives:

For the time being, there are no direct replacements available for most of the mentioned applications. In view of the exceptional properties of PFAS materials and the stringent safety, performance and reliability requirements for space applications, it is even doubtful whether suitable alternatives with equal or sufficient performance properties can be developed in the coming decades.

Illustrations:

The pictures below serve to pinpoint the aforementioned uses of PFAS in key areas (components) of orbital propulsion systems for satellites, taking different examples (thruster technologies, propellant tank, Monopropellant Propulsion System for an Earth Observation Satellite).

Figure 2 Schematic of a Bi-propellant Propulsion System for Telecommunication Satellites

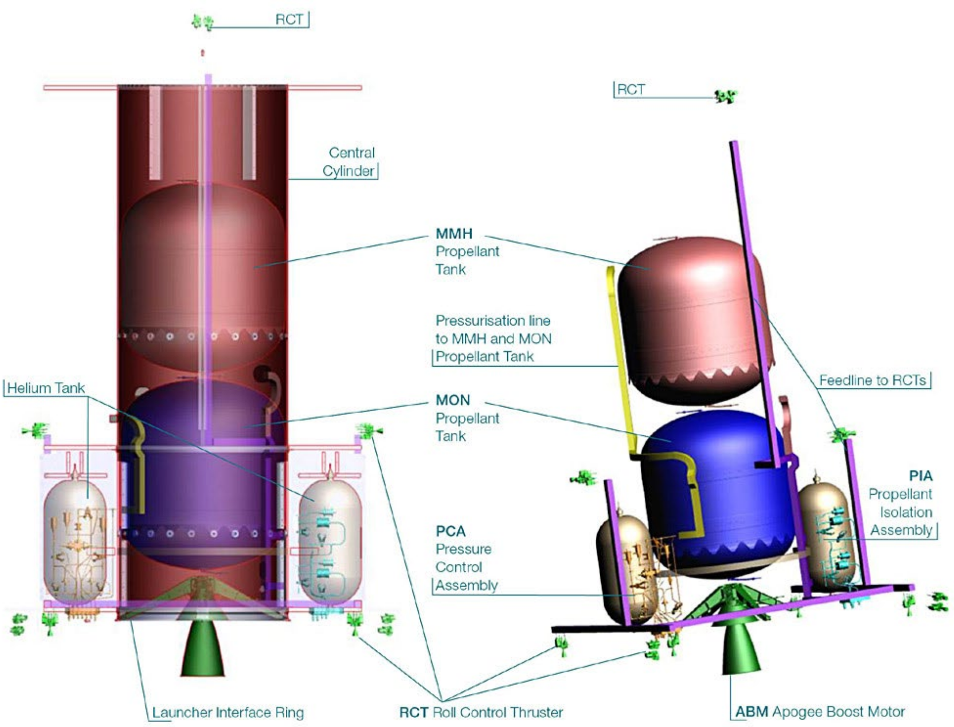


Figure 3 Example of 200 N Thruster Cluster for Orbital Propulsion

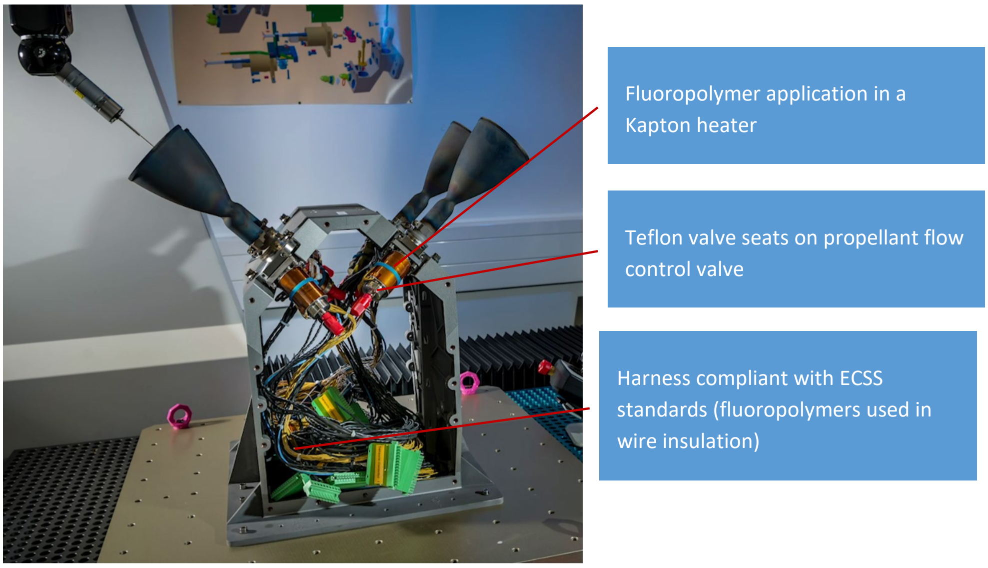


Figure 4 Example of 1N Hydrazine Thruster for Satellite Propulsion

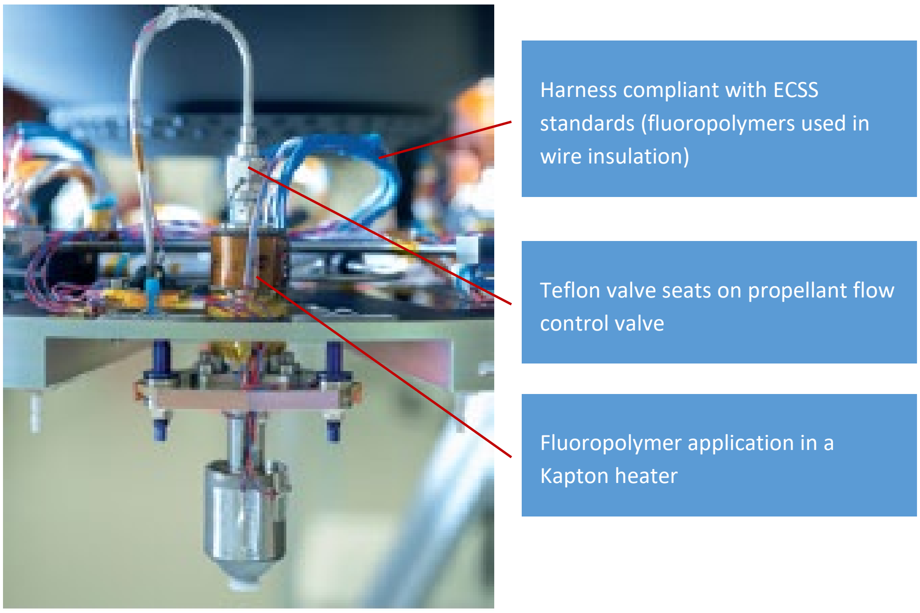


Figure 5 Example of Propellant Tank for a Satellite Propulsion System

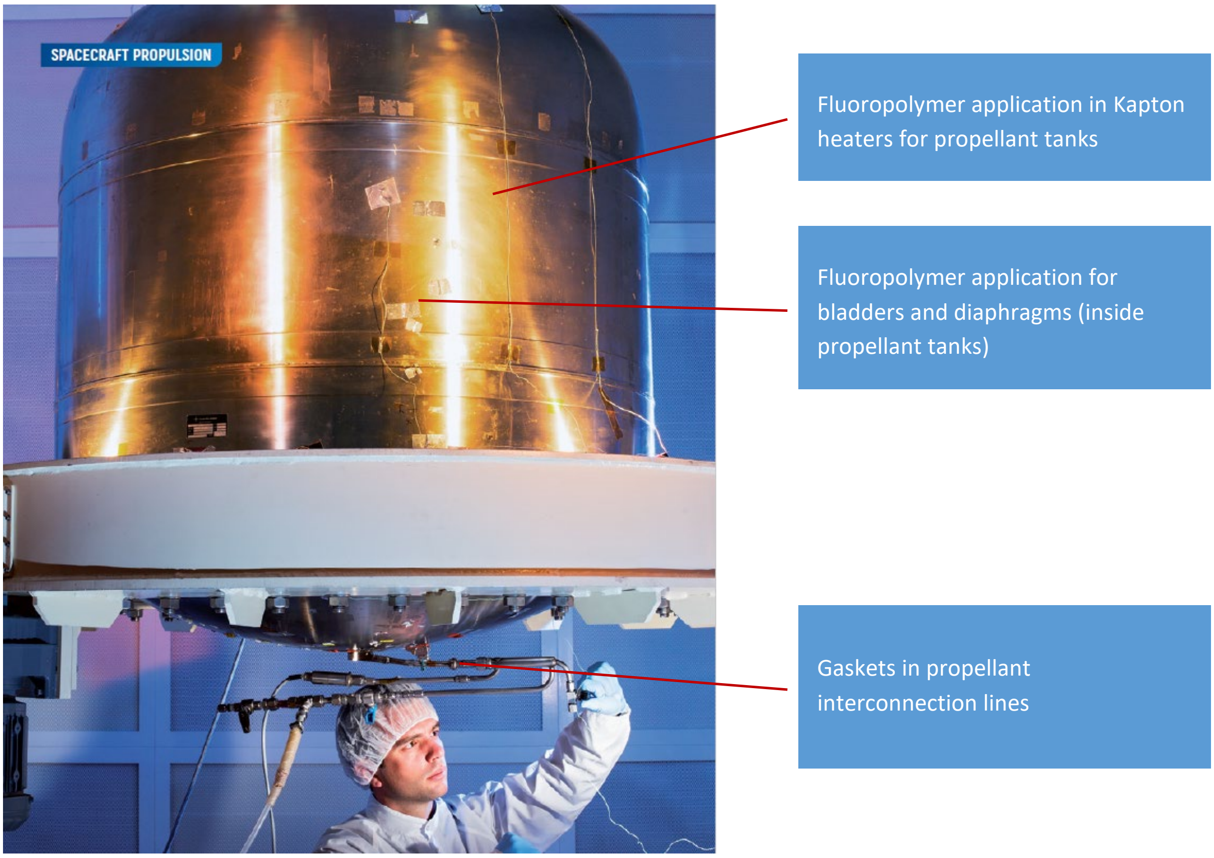
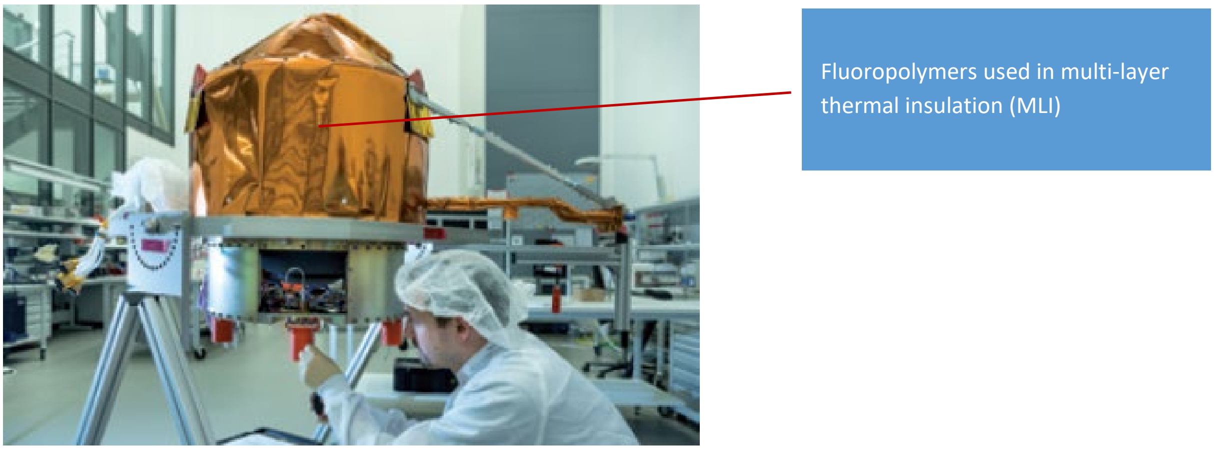


Figure 6 Example of Monopropellant Propulsion System for an Earth Observation Satellite



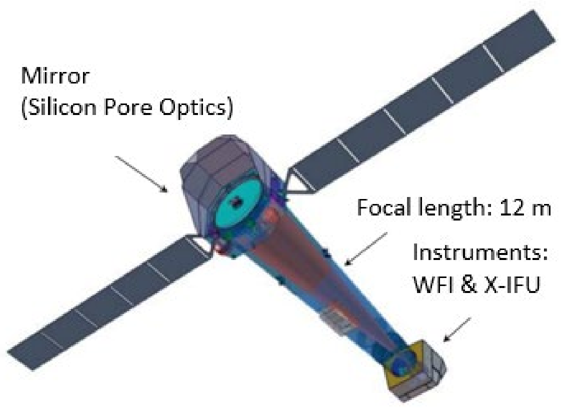
CASE STUDY 3: SCIENTIFIC MISSION FOR ESA: THE ATHENA WIDE FIELD IMAGER

The Wide Field Imager (WFI) constitutes one of the two focal plane scientific instruments situated on the Athena (**A**dvanced **T**elescope for **H**igh **EN**ergy **A**strophysics) X-ray Observatory (depicted in Figure 7, Picture 1 below), the second major mission within the European Space Agency's (ESA) Cosmic Vision program.[10] The primary purpose of the WFI involves both imaging and spectroscopy across an expansive field of view, facilitating observations of high count rates extending to and surpassing 1 Crab source intensity.

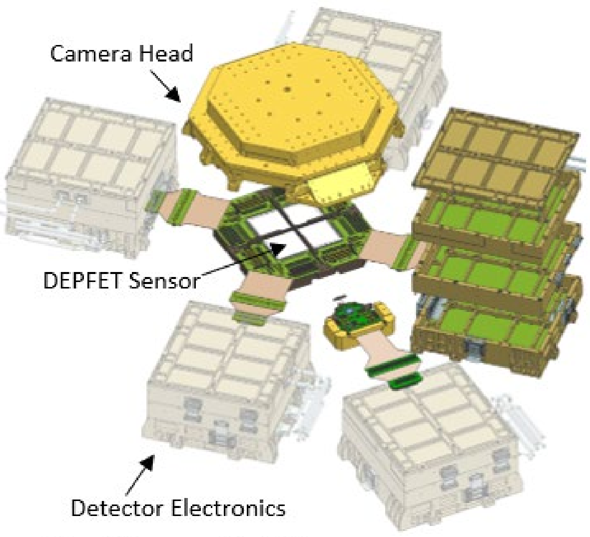
Employing specially designed DEPFET (DEPleted Field Effect Transistor) active pixel sensors, the WFI attains notable quantum efficiency and cutting-edge energy resolution spanning the energy range of 0.2 to 15 keV (kilo electron volt). These sensors also enable remarkably swift readout speeds. The WFI camera is shown in Figure 7, Picture 2 below. Concurrently, the other focal plane instrument in the Athena telescope, known as the cryogenic X-IFU (X-ray Integrational Field Unit) camera, complements the WFI by offering exact spectral resolution imaging, achieving a resolution of 2.5 eV (electron volt) at 7 keV.

Both cameras utilise a movable mirror system, strategically directing X-ray photons towards either side. Projections for Athena involve a launch timeframe anticipated in the latter half of the 2030s, with operational presence envisaged in orbit around the first Lagrange point, L1, about 1.5 million kilometres from Earth. Notably, Athena will be a unique instrument, slated for an in-space operational span of 4 years, extendable potentially up to a decade.

Figure 7 Wide Field Imager for Athena X-ray Observatory



Picture 1 [image credits: ESA]



Picture 2 [image credits: MPE]

[10] For more information about Athena, please see at https://www.mpe.mpg.de/Athena.

Development efforts for the WFI are being steered by an international consortium, primarily composed of European countries, along with contributions from the United States of America. The Max Planck Institute for Extraterrestrial Physics (MPE) in Garching, Germany, spearheads this consortium's collaborative endeavours.[11]

Constructing a highly intricate and sensitive instrument like the one described poses exceptional demands and challenges due to the harsh conditions it will encounter, including vacuum environments, extreme temperature fluctuations, and cosmic particle radiation. These conditions underscore the need for meticulously chosen materials to guarantee the functionality and durability of the telescopes. Among the critical materials, temperature resistance and minimal outgassing are paramount. Only PFAS can fulfil all these rigorous prerequisites. Up to this point, several vital project components have been recognised as containing PFAS. These encompass cables, shrink tubes, cleaners, and electronic printed circuit boards (PCBs). We are sure this is not an exhaustive list, indicating that additional PFAS components may have yet to be identified. Over the past decades, space agencies such as ESA and NASA have established comprehensive regulations based on research findings, outlining acceptable components and procedures. Consequently, manufacturers intending to offer products for space applications, like components or assemblies, must undergo an arduous and costly testing process sanctioned by the authorities. As users and manufacturers of X-ray telescopes, we are doubly bound by the stipulations of space agencies like DLR, ESA, and NASA and the unique conditions prevailing in the space environment.

In the progression of the WFI project, a pivotal milestone was reached in spring 2022 with the System Requirements Review (SRR). The SRR is a formal evaluation to ensure the complete and accurate identification of system requirements, fostering a shared understanding between ESA and the instrument developers. Afterwards, the general conditions are established. In parallel, the critical technology developments and necessary breadboarding activities leading to the Preliminary Design Review (PDR) are already complete.

Indeed, the comprehensive identification of all the affected components remains challenging due to our reliance on collaboration with the manufacturers and adherence to ESA regulations coordinated by the European Space Components Coordination (ESCC). The complexity of our project and the strict standards imposed by ESA necessitate careful evaluation and verification of each component's suitability and compliance with established guidelines.

Regrettably, there are no alternatives for these crucial elements in the present technological landscape. Given the stringent ESA regulations and the intricate nature of the development stages of our space project, seeking exceptions or approvals for alternative components is not feasible.

[11] For more information about the MPE, please see at https://www.mpe.mpg.de/main.

CASE STUDY 4: EXAMPLES OF USE CASES OF PFAS SPECIFIC FOR ESA PROJECTS

Below are three examples of PFAS use cases specific to ESA missions, projects or general space technologies which are part of spacecrafts, launchers or infrastructure. These are only amongst the most obvious cases and are by no means an exhaustive list of all PFAS uses impacting ESA projects.

The main purpose is to highlight critical uses where no PFAS-free replacement is known, or by research and development activity proven that the PFAS-based alternative is the only technically/chemically feasible solution.

Use case 1: PTFE in seals

Sector: *Launcher*

Project: *Specific project under ESAs Launcher technology programme*

Essential PFAS substance: *PTFE*

Essential application where this substance is used: *4 in final application, sealing purposes*

Reason/function of PFAS in the item: *Multiple: mechanical, thermal, chemical properties at cryogenic temperatures*

Availability of PFAS free alternatives: *Unknown or unavailable in near term horizon*

Is PFAS substitution possible/desired option?: *No. This project tried to work with other types of seals, including metallic seals, but PTFE is proven to be the only one fulfilling project needs.*

Note: *Leak-tightness specifications are derived from operational safety requirements.*

First and last model to be built: *Demonstrator estimated in 2027, first flight prototype 2030, further commercial use in next decade, 2030-2050 minimum*

Derogation needed? *Yes, at least for period 2030-2050 for commercially evolved launcher (more than 13.5 years from coming of PFAS restriction into force), hence incompatible with the proposed maximum derogation time*

Financial/schedule consequences of PFAS unavailability: *15 years of development time would be needed to develop a new sealing solution, starting with alternatives that have a very low technology readiness level (TRL) of 1. The total financial loss of the entire project is currently difficult to estimate (upper tens of millions EUR). Such PTFE sealings are also currently in use in cryogenic valves, including in launcher engines. A restriction of PTFE would result in the grounding of the Ariane 6 launcher, resulting in an inherent incapability of the European Space Sector to launch scientific, national, international or commercial satellites for the next 30 years should the PFAS restriction go through as it is proposed.*

Use case 2: PTFE as dielectric material

Sector/segment: *Space, Ground-stations, electronic ground segment equipment*

Project/use: *Navigation project-specific use and general use on ground*

Sub-system/unit of PFAS used within: *Radio frequency (RF) platform (TT&C), RF payload (any), ground station harness and RF modules*

Essential PFAS substance: *PTFE*

Reason/function of PFAS in the item: *Dielectric properties, in particular tg(delta) in case of PTFE, dielectric properties combined with mechanical properties*

Availability of PFAS free alternatives: *Unknown or unavailable in near term horizon*

PFAS Substitution possible/desired option?: *In most cases no, as it compromises flight safety, performance, and quality*

First and last model built/placed on the market: *2023 - 203x?, depends on European Commission's commitments and needs in global navigation applications*

Specific derogation needed?: *Yes*

Derogation duration needed until: *>> 2035 minimum or longer, assuming heritage based on PFAS is used to further reduce costs of space navigation systems*

Financial/schedule consequences of PFAS unavailability: *Entire navigation spacecraft fleet, entire space application heritage including infrastructure would need to be rebuild. Potential impact would go to multibillion Euro contracts to be interrupted and PFAS-free alternatives to be searched for which are currently not known.*

Use case 3: HFE based hermeticity test fluids
Sector: *Space segment / ground test methods for ESCC qualified parts*
Project(s): *Multiple, all relying on space qualified EEE parts with hermetic packaging*
Essential PFAS substance: *HFE (Hydrofluoroether-based solvents, C5-C18), CAS: 86508-42-1, CAS 69991-67-9*
Essential application where this substance is used: *Laboratory use on ESCC and MIL specification tests on EEE hermeticity, which cannot be altered*
Reason/function of PFAS in the item: *Inert behaviour towards electronics, specific behaviour of fluids, boiling points, PFAS HFE formula's tuned based on hermeticity test needs*
Availability of PFAS-free alternatives: *No known alternatives*
PFAS Substitution possible/desired option?: *No, as it must follow ESCC or MIL specification on fluorocarbon fluids as inert test fluids.*
Specific derogation needed?: *Yes*
Derogation duration needed until: *>> 2035 minimum or longer, justification: Assuming test heritage based on PFAS, long ECSS and ESCC specification modification in case PFAS free alternative must be found*
Financial/schedule consequences of PFAS unavailability: *Currently the entire sector struggles with a shortage of HFE test fluids, as there are no alternatives, reliability of components which are not tested against hermeticity could fail specifically in vacuum conditions of space missions, which could have dramatic consequences, in some cases leading to degradation or loss of the entire satellite/mission objectives.*

CASE STUDY 5: PFPE/HFE FLUIDS: USE, EMISSIONS AND EMISSION CONTROL (FROM ESA)

PFPE/HFE fluids which are used in human spaceflight, must fulfil multiple requirements, linked to their durability/performance as the heat exchange medium over extremely long service lifetimes. The future success of our missions will rely on these and similar applications of PFAS fluids, and on proven space heritage of HFE fluids, which dates back to the Space shuttle programme. In this case, substitution by PFAS-free alternatives (not available today) would have no benefits, but on the contrary constitute a serious risk, including to lives of the crew on these space missions.

There is no emission associated with that use, as these systems operate in closed loops of heat exchangers.

PFPE fluids which are specifically used for gross leak test (hermeticity tests), are used in a laboratory environment which is fully controlled. The advantage of PFAS is that it does not mix, therefore it is not consumed in such tests, as it is inert to the environment, tested parts etc. and it is confined in the test chamber and drained back to the reservoir. At ESTEC the impact of PFAS fluids on the environment is therefore considered to be negligible. Once these fluids have expired, there is a dedicated procedure for disposal of hazardous waste at ESTEC, and a specialist contractor company is responsible for destruction of such chemical waste. In the case of PFAS fluids it may be recommended to use supercritical water oxidiser reactors, incineration, etc. Methods for the destruction of PFAS exist which would eliminate the perception that once PFAS is manufactured and used, then it automatically ends up in environment, ecosystem or food chain. In case of closed loops and closed life cycle, there cannot be a valid justification for such a broad restriction.

CASE STUDY 6: VAPOR PHASE SOLDERING FOR ELECTRONIC ASSEMBLIES

1) Application as heat transfer medium for soldering electronic assemblies:

In the soldering of electronic assemblies, so-called vapour phase soldering with the application of Galden® PFPE occurs. Vapour phase soldering has the following advantages compared to other processes:

- Soldering of massive assemblies (e.g. power electronics especially for electromobility, radar technology, etc.).
- Maximum temperature limited by the boiling point of Galden® PFPE. This means that the critical components cannot overheat under any circumstances.
- The inert property of Galden® PFPE additionally prevents oxidation during soldering and improves wetting. This reduces the likelihood of various soldering defects occurring.

2) Alternatives

Alternative methods: Currently, the properties of vapour phase soldering described above cannot be replaced by other processes.

Alternative heat transfer medium: There is no medium that has the same properties as Galden® PFPE. The substitution challenge for PFAS is further increased with regard to the on-going transition effort to lead-free soldering, where a higher temperature is needed (see Info box 7).

Info box 7 Impact of lead-free transition on PFAS substitution

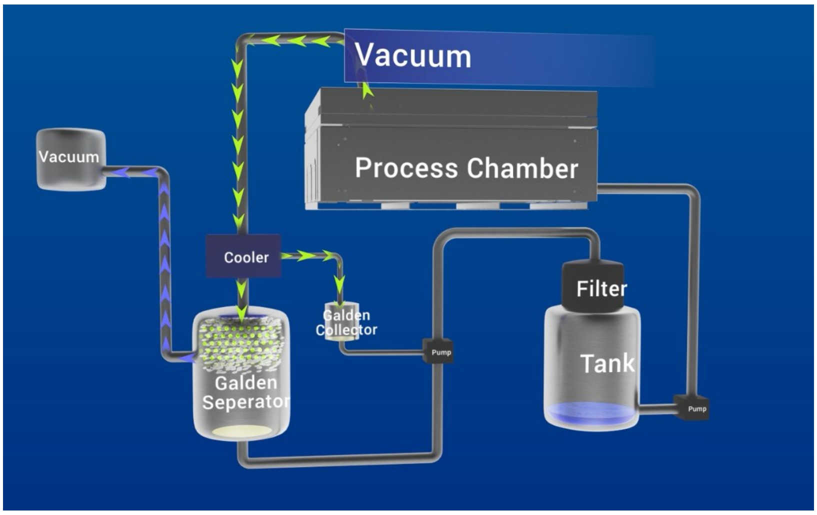
Lead metal (CAS 7439-92-1) was included in the EU REACH Candidate List in June 2018. On 12 April 2023 ECHA further recommended lead for inclusion in the REACH Authorisation List, with the support of the ECHA Member State Committee. Lead is an essential element in a broad range of high reliability industrial applications requiring longevity in the European Space Industry, including in lead-based soldering of space electronics.

In response to the increasing commercial and REACH regulatory pressure a joint Lead-free Transition Working Group (LFTWG) of the European Space Sector is looking into alternatives. In July 2023 a consortium has been selected for an R&D contract of 2.7 M€ by the European Commission in the frame of Horizon 2020 (signature expected in Q4/2023). The research funded will help the European Space Industry transition to lead-free electronics.

In the context of lead-free transition, a higher temperature is needed for lead-free soldering. To find a PFAS-free medium for this higher temperature is even more difficult. Hence, the on-going lead-free transition effort promoted by Member States, ECHA and the European Commission further increases the substitution challenge for PFAS in this case.

3) System technology according to the injection principle (closed-loop system)

Since 1999, Rehm has been developing vapour phase soldering systems according to the injection principle. This principle allows the amount of Galden® PFPE to be precisely dosed, almost completely removed from the chamber and the assemblies, cleaned by a multi-stage system and reused. This closed-loop system significantly reduces the consumption and thus also the loss of Galden® PFPE. Depending on the process design and assembly size, the loss is a maximum of 1 g per soldering cycle. Depending on the solder system size that means a loss of less than 67ppm per cycle for the corresponding Galden® PFPE total mass of 15-20kg.

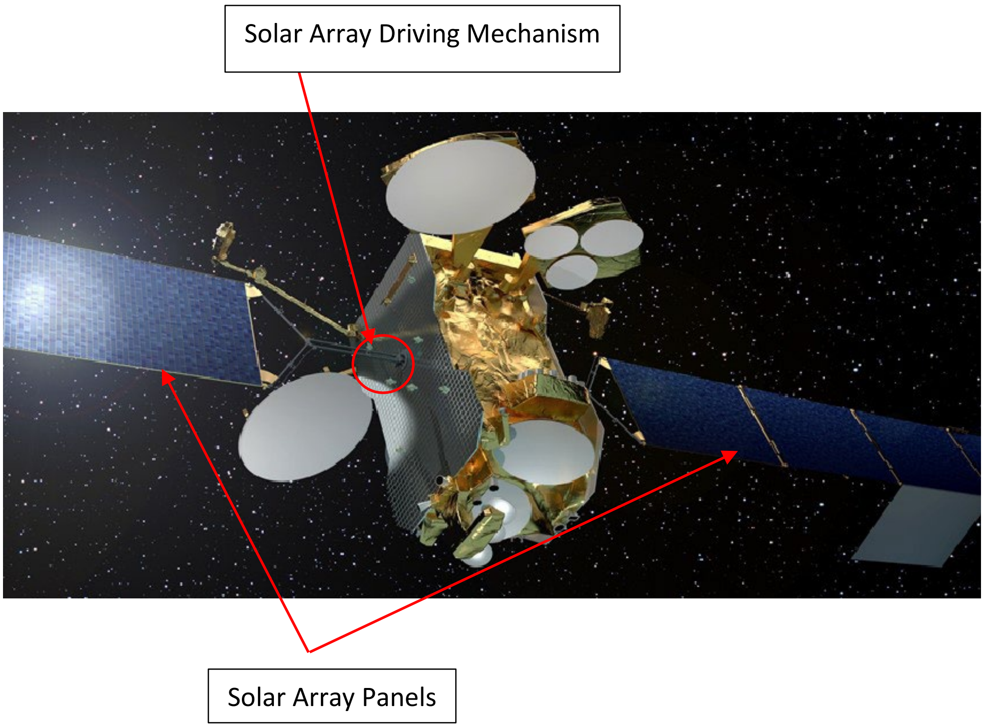


Rehm - CondensoXP Principle - YouTube

Rehm Ensures Sustainable Condensation Soldering with the Closed-loop Principle and Active Galden Filtering (iconnect007.com)

CASE STUDY 7: LUBRICANTS FOR SPACE MECHANISMS

Figure 8 Illustration of solar arrays and solar panels for space applications



Mechanisms are used in all satellites at least at solar array panel level, that provides the necessary electrical energy through solar energy transformation. The mechanism is necessary so that the solar array panels have always the right orientation towards the sun.

Depending on its mission, the satellite may have other mechanisms for example for mobile antennas or for deployment of units stowed in the launch phase.

Lubricants containing PFAS are extensively used in space mechanisms in the form of:

- PFPE oils
- Greases obtained by thickening of oils with PTFE particles
- PTFE bulk composite material with special adds-on for bearing cages

In addition to their lubricant properties, PFPE oils and PTFE have one key asset: it is their compatibility with space vacuum, evaluated for vapour pressure for PFPE Oils and for outgassing for PTFE.

PFPE oils have an extremely low vapour pressure that ensures the evaporated material will be low enough not to create contamination problems and that the oil will not run out through evaporation before the mission end of life.

PTFE has very low outgassing properties which ensures a very low contamination contribution. Outgassing is related to the amount of molecules evolved from a material subjected to vacuum. All space materials are screened by an outgassing testing.

Presently there is only one oil without PFAS used in space applications. Currently, no grease without PFAS is used. The non-PFAS oil cannot replace PFPE oils completely due to a narrower thermal range. On the other hand, the replacement of a grease by an oil may be theoretically possible but needs redesign and long-life duration testing (lasting several years).

A non-PFAS wet lubricant alternative that can fully replace present space products is still to be found.

The time necessary to find alternatives, to make the necessary mechanism redesign and to perform extensive testing to have a flight worthy mechanism is evaluated to be greater than 10 years.

This duration is so long because of the criticality of mechanisms. A failure usually has a major or even a catastrophic impact on the satellite mission, i.e., failure of the solar array driving mechanism.

CASE STUDY 8: NEXT GENERATION SATELLITE AND LAUNCH VEHICLE SIGNAL AND POWER WIRE AND CABLES

Without the capabilities of fluoropolymers like PTFE, all European satellites, including Galileo 2nd Generation, Copernicus or the future Telecom Satellites Secure Connectivity Program IRIS² cannot be realized, as there is no known replacement material today providing the properties for cable insulation to survive the harsh space environment.

All 19 cable product groups that are qualified according to the European Space Components Coordination (ESCC) specifications for low and high frequency wires and cables include PFAS (basically fluoropolymers like PTFE, ETFE, FEP and PFA).[12]

Space applications require a large operating temperature range, high electrical insulation resistance and low outgassing in order to operate in vacuum, flexibility for harness routing and finally the lowest weight and smallest dimensions due to limited launcher capacities. Moreover, Low Earth Orbit (LEO) applications require Atomic Oxygen (ATOX) resistant materials and launchers require non arc tracking insulation material. A material used in space applications must perform its function in harsh conditions. Not only mechanical robustness regarding shock and vibration during launch, but also chemical resistance to propellants and other chemical substances are key to mission assurance.

To date there is no known wire insulation material or cable dielectric material able to provide all these properties at the same time other than PTFE, ETFE, FEP and PFA.

It is desirable to provide small cables to realize tight bend radii and lowest weight to minimize mass in space. Power and data cables can account for up to 30% of a satellite's dry mass.[13] This means having the smallest possible harness dimensions and weights are key to maximize the number of instruments, crew and/or cargo that can be launched to space.

PTFE is the insulation material providing the highest normalized dielectric strength (>50kV/mm insulation wall thickness on wire)[14] which is essential for weight and high voltage/power applications in space (e.g., signal amplifiers). Power cables in satellite applications typically operate in the range of -55°C to +270°C. In Orbit, thermal balance can only take place by direct material contact. Electronic components used in space applications heat up much more without an atmosphere present, compared to ambient ground applications. Therefore, any maximum current limit must consider this heating effect in order

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[12] ESA. (various). *ESCC Published Specifications Wires and cables.* Retrieved from European Space Components Information Exchange System: https://escies.org/specification/listpubspecs?pubcode=25&family=6.

[13] Xavier Cadiot, L. S. (2022, September). *Dynamic Base Excitation of a Satellite Cable Harness: Modeling and Experiments.* Journal of Spacecraft and Rockets.

[14] Juster, H. (2020, October 08). *Find about plastics, Polymer Engineering and Leadership.* Retrieved from https://www.findoutaboutplastics.com/2020/10/design-properties-for-engineers.html.

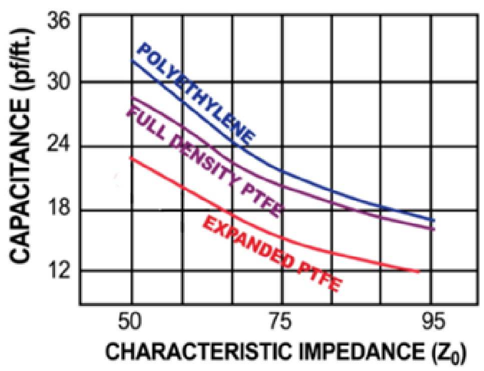
to not exceed the maximum operating temperature of a material. Lower thermal buffers for wire insulation will require larger conductor diameters to transfer the same power adding weight to spaceflight harnesses.

PTFE provides the highest resistance to residual ATOX for LEO applications. Any other potential insulation material used in LEO will have higher mass loss due to ATOX erosion over its lifetime. Non-PTFE based materials are expected to reduce spacecrafts' lifespan due to ATOX degeneration of the cable insulations. There are ~10 km of power wires used on solar power generator panels on a mid-size satellite. About 80% of all satellites are linked to communication and earth observation, nearly all of those operating in LEO would have their affected lifetime impacted due to the lowered ATOX resistance.

PTFE is the best material to prevent arc tracking accidents.[15] Fires due to ignition with flash over when using non-PTFE insulations have caused serious aviation accidents in the 1980s. The same hazard could occur during rocket launch. Launch vehicles require wires using non arcing insulation material when powered with voltages of 230V or higher in a certain altitude range to avoid flash over fires.

In radiofrequency (RF) signal cable applications a low capacitance over distance is key for signal performance, because it reduces signal distortion. Expanded PTFE provides the lowest capacitance for any impedance (see Figure 9).

Figure 9 Capacitance per distance over characteristic impedance for expanded PTFE vs next best alternative PE



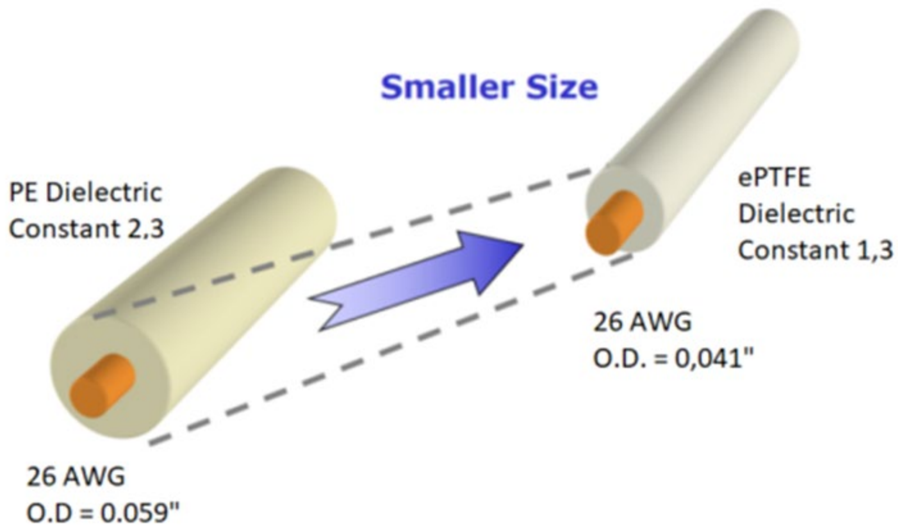
In signal cables, the lowest dielectric constant (ε_r) expanded-PTFE material enables higher data rates, because electromagnetic waves are slowed down by a factor of $\sqrt{\varepsilon_r}$. Moreover, low εr provides a thin wall thickness at a given characteristic impedance. Even in cases where the operating temperature is below 80°C, so that e.g., Polyethylene (PE) as a next best alternative could be used, a 50 Ohm RG 174 PE Coax cable with AWG 26 conductor will end up in 1,5 mm

[15] Ted Steinberg. (1991). *Validation of NHB 8060.1C, Test 18 (TR-651-001).* Las Cruces, NM, US: National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center.

(0,059”) outer diameter.[16] The same characteristics will be achieved with 1,04 mm (0.041”) final diameter when using expanded PTFE like in ESCC390200204B coax cable.[17] This means 30% savings in diameter and 35% in weight and operating temperature up to 180°C by using an expanded PTFE dielectric (see Figure 10).

This is also valid for all digital signal cable harnesses used in the latest generations of configurable satellites. They cannot be realized without using expanded PTFE, due to temperature, high speed data protocols and numbers of channels in a limited budget for weight and volume.

Figure 10 Dimensions PE versus expanded PTFE 50 Ohm AWG 26 Coaxial Cable



Any material used in space must show low outgassing under vacuum conditions in orbit to ensure minimal contamination to the surrounding instruments (which would result in cloudy optics) and/or prevent toxic off gassing in human spaceflight applications. Fluoropolymers are the lowest outgassing insulating materials that ensure gas loads below 4^{-7} mbar L/s cm².[18] Alternative materials like Polyethylene (PE) produce twice as much and silicon rubber based materials up to 100 times higher gas load compared to PTFE. High gas loads also increase the risk of a “blow up” insulation damage, caused by residuals evaporating during launch.

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[16] MIL-C-17G. (1990). MILITARY SPECIFICATION: CABLES, RADIO FREQUENCY, FLEXIBLE AND SEMIRIGID, GENERATION SPECIFICATION FOR [S/S BY MIL-DTL-17H].

[17] *ESCC Detail Specification No. 3901/002.* (2012). European Space components Coordination.

[18] K. Diels; R. Jaeckel. (1962). *Ausgasraten verschiedener Materialien im Vakuum.* Vakuum-Taschenbuch, 2. Auflage, Graphik. Berlin.

APPENDIX 3: INFORMATION ON METHODOLOGY TO DETERMINE IMPACT

For the purpose of determining the impact on the European Space Sector in response to the uPFAS restriction initiative and the ECHA public consultation launched on 22 March 2023, a number of extensive information collection activities have been launched. Key activities are summarised below. It should be noted that at the beginning of these campaigns, no detailed or structured overview of PFAS uses in space applications was available.

Space Restriction Task Force (RTF) survey, including third party responses: Based on the preliminary assessment of the final Annex XV restriction report published on 22 March 2023 and the ECHA uPFAS webinar on 5 April, an information collection survey was prepared and distributed to the RTF participants on 2 May 2023. The survey covered questions on general views and expected impacts, supply chain enquiries, PFAS uses and functionalities, volumes and emissions, alternatives, substitution plan, derogations assessment and socio-economic consequences of a PFAS ban. To date, survey responses and related input have been received from ca. 20 entities, including RTF participants, component suppliers and a research institute. Within their own organisations these entities have often formed working groups, launched supply chain enquiries (see details below) and internal surveys to collect relevant information, such as the ESA Internal PFAS Survey (see details below).

Supply chain enquiries: Many components that could contain PFAS are produced in global supply chains and are therefore very complex to investigate. As producers of complex assemblies, space companies critically depend on supply chain input regarding the use of PFAS in the products supplied, given the common absence of PFAS-related info in REACH Article 33 declarations and SDSs. This is even more challenging regarding the supply of articles and assemblies. Shortly after the start of the ECHA public consultation several surveyed companies have launched dedicated enquiries with their suppliers (including subcontractors) to determine the impact of the restriction proposal on products supplied. This also included the request to verify the use of PFAS throughout the supply chain. To date, qualified responses have been received only to a very limited extent (a few percentage of the total contacted). In some cases, additional exchanges are already conducted to deepen the impact assessment. In other cases, there has only been time thus far to review the internal databases in order to perform the mapping of PFAS in products. Clearly, exhaustive responses from the supply chain cannot be received within the ECHA 6-month consultation window!

ESA Internal PFAS Survey: In May 2023 ESA launched an extensive internal survey. Over 260 personnel across all ESA directorates have been contacted, equally representing the ground segment, space segment as well as the launcher segment, with a technical and quality/product assurance background. 13 questions included those relating to PFAS, covering the identification of PFAS substances relevant to space (not exhaustive!), their purpose in space applications and nominal function in different types of space products (satellite sub-system, launcher, etc.), as well as the existence of PFAS-free alternatives. Assessed areas covered

Declared Materials Lists (DMLs) of selected projects, ESCC specifications and parts, ECSS standards, test methods and laboratories.

ESA REACH Tool Analysis and integration of EPA Master List: The ESA REACH Tool is a materials obsolescence risk assessment tool developed for the European Space Sector, which can identify REACH impacted substances in space-relevant materials. Whilst only representing a limited sample of all materials used in the European Space Sector, the analysis of the tool may help identify affected materials. To this end the clear identification of the substance by its numerical identifiers (CAS and EC numbers) is essential. Given the absence of such an identifier list for the PFAS restriction proposal the EPA PFAS Master List has been used. The REACH Tool has been updated at the beginning of July 2023 today to include all PFAS CAS numbers from that Master List. It should be noted that even this Master List can be no more than a starting point, as it lacks CAS numbers for certain PFAS substances such as PVDF.

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