Reference:

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# Impact of PFAS-Related Regulations on the Global Space Material Supply Chain

7th ESA REACH Workshop
2 June 2026

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CHEMICAL AND MATERIAL RISK MANAGEMENT PROGRAM
AND
REGULATORY RISK ANALYSIS & COMMUNICATION TEAM

# Agenda

- NASA Chemical and Material Risk Management Program
- PFAS uses in the space sector
- PFAS regulations
- Supply chain challenges

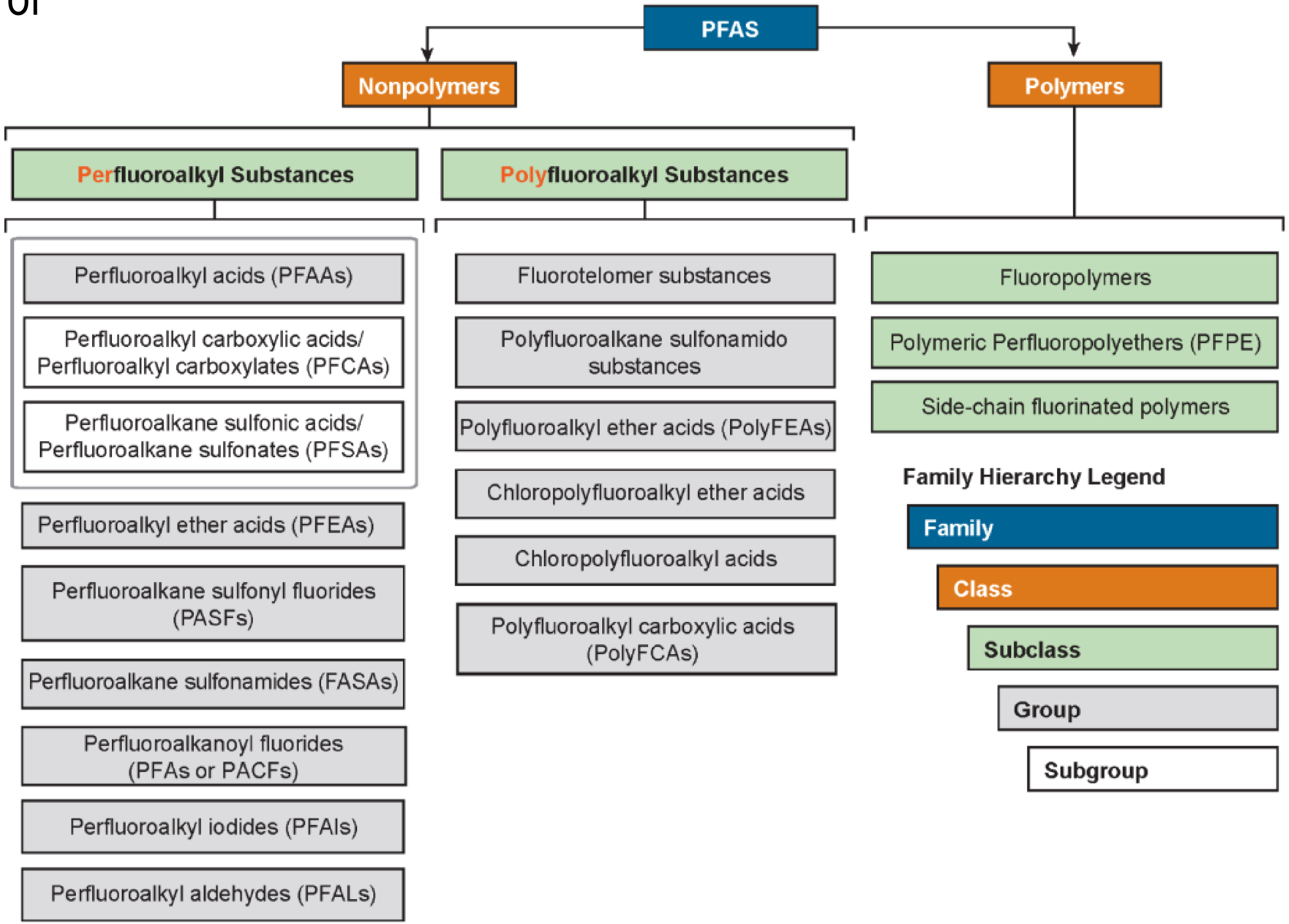
# NASA CMRM Program

| | |
|---|---|
| Emerging Requirements | Toxic Substance Control Act (TSCA)<br>Per- and Polyfluoroalkyl Substances (PFAS)<br>American Innovation and Manufacturing (AIM) Act<br>Regulatory driven chemical and material risk mitigation |
| Regulatory Compliance | TSCA Section 6 Risk Management Rules |
| Information Management | Hazardous Materials Management System (HMMS)<br>NASA Uses and Mission-Critical Applications of Regulated Substances (NUMARS) |
| External Collaboration | Environmental Protection Agency<br>Other Federal Agencies – Department of Energy and Department of War<br>International Partners – European Space Agency and Japan Aerospace Exploration Agency<br>Industry associations |

*CMRM = Chemical and Material Risk Management*

# PFAS Overview

- Large family of thousands of fluorinated chemicals
- Key properties:
  - Thermal resistance
  - Chemical resistance
  - Water/oil repellency
  - Durability
- Widely used in:
  - Aerospace
  - Electronics
  - Semiconductors
  - Firefighting foams
  - Textiles
  - Medical devices
  - And much more




*Graphic from the Interstate Technology Regulatory Council (ITRC) https://pfas-1.itrcweb.org/2-2-chemistry-terminology-and-acronyms/*

# PFAS Uses in the Space Sector

Artemis II launching from NASA's Kennedy Space Center/NASA

| | | | |
|---|---|---|---|
| Semiconductors | Lubricants | Seals | Coatings |
| Electrical systems | Hydraulic fluids | Corrosion inhibitors | Heat transfer fluids |
| Lifesaving equipment | Fire suppressing agents | Wire and cable insulation | Fluorinated gases |
| Foam blowing agents | Solvents | Textiles | High performance membranes |
| | Metal plating and manufacturing | And much more | |

# Why PFAS Matter in Space

- Spacecraft operate in environments where failure can be catastrophic
- PFAS provide unique performance not replicated by any other material class, such as:
  - ➢ Extreme thermal and chemical resistance
  - ➢ Very low friction and wear properties
  - ➢ Electrical insulation and dielectric stability
  - ➢ Dimensional stability
  - ➢ Flammability properties
  - ➢ Reliability in harsh environments


*Orion spacecraft being prepared for integration with the Space Launch System for Artemis II/NASA*

# Critical PFAS Uses in Space Systems

- Seals & Elastomers
  - PTFE, FKM, and other fluoropolymers used in fuel systems, hydraulic systems, engines, valves, O-rings, and gaskets
  - No substitutes meet chemical, thermal, and durability requirements
- Lubricants & Greases
  - PFAS required in engines, actuators, gearboxes, bearings
  - Provide unmatched high-temperature resistance and low friction.
- Coatings & Surface Treatments
  - PFAS used as a solvent in coatings as wetting, leveling, and dispersing agents
  - Provide high temperature resistance, reduce friction, abrasion/corrosion resistance
- Batteries
  - Used at electrode level as binders and at the cell/battery level as separator coatings, additives in the electrolyte, gaskets/seals, pipes, valves and sealings
  - Required for thermal stability and dielectric performance
- Wires & Cables Insulation
  - PFAS used in insulation applications
  - Critical for thermal and chemical resistance, mechanical strength, and dielectric constant
- Composite Materials Manufacturing
  - Release films for removal of composite parts from other media used in the curing process
  - Critical in the ability to manufacture complex shapes with extremely tight tolerances

# Growing Public and Regulatory Concern

- Persistence in the environment
  - Carbon-fluorine bond is extremely stable
  - Many PFAS:
    - do not readily degrade
    - accumulate in water and soil,
    - can travel long distances
  - Widespread detections globally

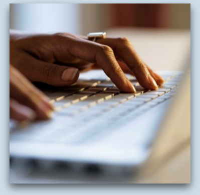
- Emerging toxicology evidence
  - Studies have linked certain PFAS exposure to:
    - elevated cholesterol
    - immune system effects
    - liver impacts
    - developmental effects
    - reduced vaccine response
    - some cancers

- Increasing recognition for the need to address the risks to human health and the environment posed by PFAS
- Regulatory agencies are taking differing approaches to addressing PFAS
- No global consensus on how to regulate PFAS

# US Federal Regulatory Activities

The U.S. Environmental Protection Agency (EPA) established maximum contaminant levels for PFOA and PFOS at 4 ppt under the Safe Drinking Water Act

EPA designated PFOA and PFOS as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)



Toxic Substances Control Act (TSCA) Section 8(a)(7) Reporting and Recordkeeping Requirements for PFAS

# US State Regulatory Activities

US states have moved aggressively with regulating PFAS in some form with a patchwork of state laws

Establishing stricter drinking water limits

Developing cleanup standards

Regulating PFAS in consumer products

Requiring PFAS disclosures on package label

# EU Universal PFAS Restrictions

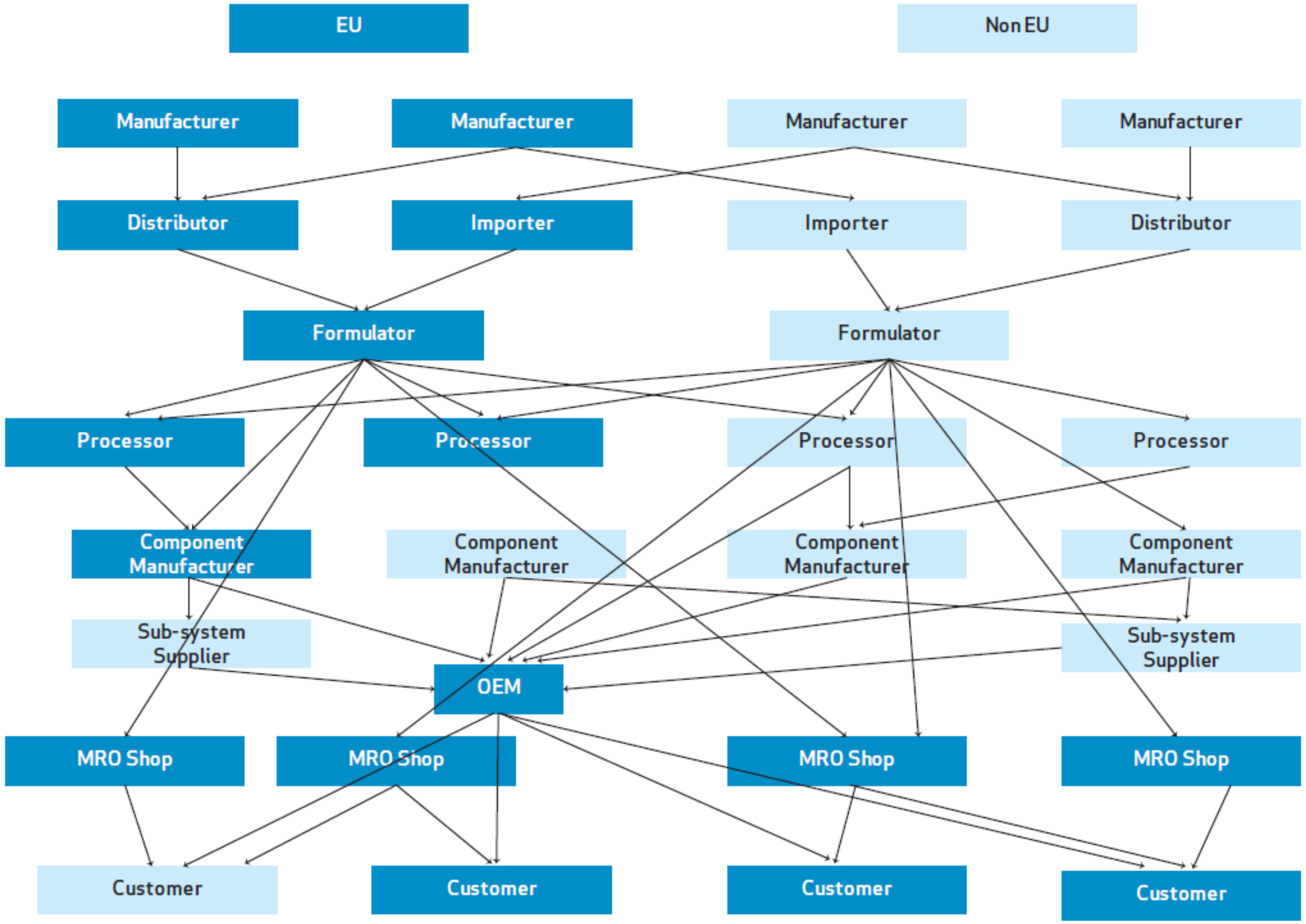
- The proposed universal PFAS regulation would apply to over 10,000 PFAS substances
  - Prohibit the manufacture, use, and placing on the market as substances on their own
  - Prohibit placing on the market in another substance as a constituent, a mixture, and an article above certain concentration limits
- Apply 18 months from entry into force (EIF) of the restriction.
- The proposal includes time-limited derogations (typically 5 or 12 years after EIF) for uses where alternatives are not yet technically or economically feasible
  - The 5-year derogation period is granted when substitution potential exists but requires additional development, testing, or partial redesign
  - The 12-year derogation period is granted where alternatives are currently not technically or economically feasible, and premature phase-out would cause disproportionate socio-economic or safety impacts

# Regulatory Impacts to the Space Sector

- The proposed universal PFAS restriction would impact all life cycle stages of critical PFAS uses – from the manufacture of PFAS to formulation of PFAS-based materials, and the use, maintenance, and disposal of PFAS materials and articles
- The space sector relies on PFAS materials across many interconnected components and sectors including:
  - Electronics and semiconductors
  - Energy
  - Fluorinated gases
  - Lubricants
  - Metal plating and manufacturing
  - Textiles
  - Transport


*James Webb Space Telescope being prepared for launch on Ariane 5/NASA*

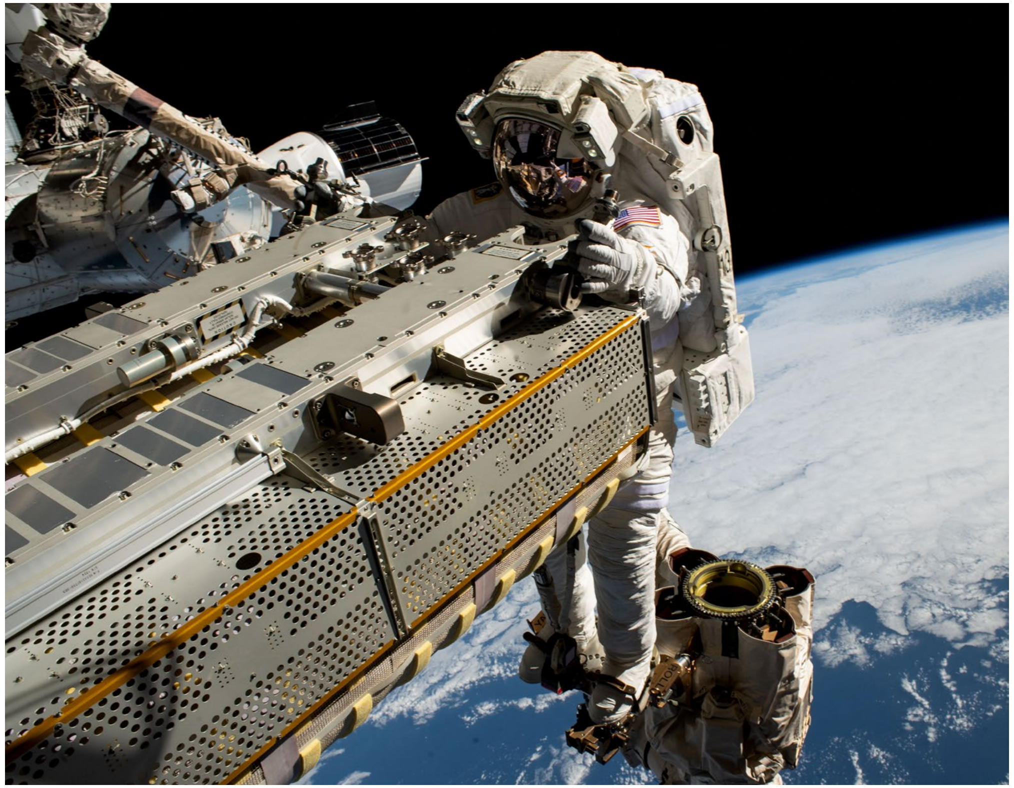
# Complex Supply Chain




The space sector has complex, multi-tiered supply chains involving thousands of global companies including suppliers and downstream users before ultimately reaching the end user

*Illustration from ECHA/EASA(2014) An elaboration of key aspects of the authorisation process in the context of aviation industry*

# Challenges with Identifying PFAS in the Supply Chain



NASA astronaut Woody Hoburg conducting a spacewalk at the International Space Station/NASA

## Multi-layered, global, and opaque supply chains

- PFAS may be used several steps upstream, and manufacturers frequently lack visibility into proprietary formulations or specialty chemicals used by sub-tier suppliers

## Over 10,000 PFAS substances

- Varying structures and diverse functional uses makes identifying PFAS challenging

## PFAS are not always disclosed in Safety Data Sheets

- Considered proprietary, present at low concentrations, or not hazardous

## Proprietary, confidential, or undisclosed chemistries

- Aerospace materials frequently rely on specialty chemicals and materials that involve PFAS whose chemical identities are protected as confidential business information

# Challenges With Identifying PFAS-Free Substitutes

## PFAS deliver performance that alternatives cannot match

- PFAS provide unique combinations of chemical resistance, thermal stability, low flammability, durability, lubricity, dielectric strength, and low friction.
- Space applications often require all of these properties simultaneously—something no current substitute can achieve

## Substitutions could require 10+ years of qualification and certification

- Aerospace substitution is not a simple material switch.
- Every new material must go through a process of development, qualification, validation, certification and production

## Substitutes may require redesign of entire systems

- Spacecraft are complex systems with many interconnected components
- Substitution challenges compound when viable alternatives for individual parts may not work collectively

*Visualization of Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer (OSIRIS-REX) collecting a sample of rocks and dust from Bennu's surface/NASA*

# Pre-Mature Obsolescence Concerns

Regulatory complexity, uncertainty, and inconsistency may impact all levels of the PFAS supply chain

PFAS uses in the space sector represent a small fraction of total PFAS uses

Downstream impacts on aerospace customers may not be fully considered by manufacturers and suppliers exiting the market

Exempted or derogated PFAS uses may become unavailable

# Overall Supply Chain Impacts

- The convergence of regulatory actions from multiple jurisdictions aimed at managing PFAS human health and environmental risks, often by restricting or eliminating PFAS from the market, pose significant risks to the space sector due to product obsolescence and reformulations unable to meet space sector performance requirements
- Substitutions could require 10+ years of qualification and certification, and may require redesign of entire systems
- Impacts on the space sector will be exacerbated due to space uses representing a small share of the total PFAS demand as manufactures and suppliers exit the market
- Broad supply chain impacts may occur due to banning most commercial market uses and it may not be economically feasible to continue making or supplying PFAS materials and articles to a niche space sector market
- Increase reliance on sole sources and/or adversarial countries