Update on Critical Per- and Polyfluoroalkyl Substance Uses

Pursuant to House Report 118-121, page 257, accompanying H.R.4365, the DoD Appropriations Bill, 2024.

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Acronyms

AFFF	Aqueous film forming foam
AIM Act	American Innovation with Manufacturing Act of 2020
ASSIST	Acquisition Streamlining and Standardization Information System
C	Centigrade
CASRN	Chemical Abstracts Services Registry Number
CBRN	Chemical, Biological, Radiological, and Nuclear
CMRMP	Chemical and Material Risk Management Program
CT	Computed tomography
DIB	Defense industrial base
DLA	Defense Logistics Agency
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DoD	Department of Defense
DOE	Department of Energy
DSP	Defense Standardization Program
ECGC	Emerging Chemicals Governance Council
ECTFE	Ethylenechlorotrifluoroethylene
EPA	U.S. Environmental Protection Agency
EPTFE	Expanded polytetrafluoroethylene
ETFE	Ethylene tetrafluoroethylene
F3	Fluorine-Free Foams
FEP	Fluorinated ethylene propylene
FFKM	Perfluoroelastomer
FKM	Fluoroelastomer
FSC	Federal Supply Classification
H.R.	House of Representatives
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether
HFO	Hydrofluoroolefin
HMX	High Melting Explosive
IV	Intravenous
Li	Lithium
Li-ion	Lithium-ion
LiBETI	Lithium bis(pentafluoroethylsulfonyl)imide
LiTFSI	Lithium bis(trifluoromethane)sulfonimide
MCMEU	Mission-critical military end use
MILSPEC	Military Specification

MILSTD	Military Standard
MRI	Magnetic resonance imaging
NASA	National Aeronautics and Space Administration
NAVSEA	Naval Sea Systems Command
OASD(EI&E)	Office of the Assistant Secretary of Defense for Energy, Installations, and Environment
OECD	Organisation for Economic Co-operation and Development
PBX	Polymer-bonded explosive
PCB	Printed circuit board
PFA	Perfluoroalkoxy alkanes
PFAS	Per- and polyfluoroalkyl substances
polyFAA	Polyfluoroalkyl acid
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene fluoride
R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
RF	Radiofrequency
sPEEK	Sulfonated polyether ether ketone
U.S.	United States
UL	Underwriters Laboratory
UV	Ultraviolet

I. Introduction

House Report 118-121, page 257, accompanying H.R. 4365 Department of Defense Appropriations Bill, 2024 requests the Secretary of Defense to submit a report to the congressional defense committees to coordinate with relevant agencies, industries, and academia to research alternatives to defense critical uses of per- and polyfluoroalkyl substances (PFAS). This request directs that the plan include a scientific evaluation and review of key technical standards for PFAS critical materials to ensure the standards are effective, accurately represent desired performance outcomes, and ensure that viable PFAS-free alternatives are not artificially excluded and encourages the Department to commission a study from the National Academies on PFAS essential uses and alternatives.

As requested by the House of Representatives Appropriations Committee, this report, prepared by the Chemical and Material Risk Management Program (CMRMP) of the Office of the Assistant Secretary of Defense for Energy, Installations, and Environment (OASD(EI&E)), describes the Department's plan for a phased approach to (1) prioritize investment into research and development (R&D) of alternatives for mission critical uses of PFAS and (2) evaluate and review the key technical standards for PFAS critical materials to ensure that viable PFAS-free alternatives are not artificially excluded. Specifically, this report presents the DoD's plan to: (1) coordinate with relevant agencies, industry, and academia to research alternatives to mission critical PFAS uses, and (2) scientifically evaluate and review key technical standards for PFAS critical materials to ensure that the standards are effective, accurately represent the required performance, and ensure that viable PFAS-free alternatives are not artificially excluded.

This report also provides information on mission critical PFAS uses identified in the DoD supply chain since the drafting of the 2023 DoD *Report on Critical Per- and Polyfluoroalkyl Substance Uses* ("2023 DoD PFAS Critical Use Report").[1] The information contained in this report is limited to what is currently known. Due to a lack of knowledge of the complete chemical composition in products and articles (e.g. end items)[2] and the significant uncertainty regarding the presence of PFAS in products (and in the manufacturing process) that make up a complex supply chain, the information presented is not a comprehensive representation of the mission critical PFAS uses. Additionally, where information is available, the military specifications (MILSPECs) and standards (MILSTDs) associated with the identified mission critical PFAS uses are presented.

II. Definitions

For purposes of this report, the terms "per- and polyfluoroalkyl substances" and "critical to the national security" are defined as in the 2023 DoD PFAS Critical Use Report:[3]

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[1] Department of Defense, Report on Critical Per- and Polyfluoroalkyl Substance Uses Pursuant to Section 347 of the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023 (Public Law 117-263). August 2023. https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/reports/Report-on-Critical-PFAS-Substance-Uses.pdf. ("2023 DoD PFAS Critical Use Report.")

[2] An end item is the "final combination of end products, component parts, or materials that is ready for its intended use, e.g., ship, tank, mobile machine shop, or aircraft." DoD Supply Chain Terms and Definitions (January 9, 2024). https://www.acq.osd.mil/asds/log/docs/DoD_Supply_Chain_Terms_and_Definitions.pdf.

[3] 2023 DoD PFAS Critical Use Report, sections II.1 and II.2.

- DoD is using the broad, structural-based definition for PFAS put forward by the Organisation for Economic Co-operation and Development (OECD) in its 2021 report, *Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance*.[4] "PFAS" is defined as fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e., with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS.
- "Critical to national security" is defined as "[t]hose uses of regulated substances by an agency of the Federal Government responsible for national defense that have a direct impact on mission capability, as determined by the U.S. Department of Defense, including, but not limited to uses necessary for development, testing, production, training, operation, and maintenance of Armed Forces vessels, aircraft, space systems, ground vehicles, amphibious vehicles, deployable/expeditionary support equipment, munitions, and command and control systems." This is the definition for "mission-critical military end use (MCMEU)" in regulations promulgated by the U.S. Environmental Protection Agency (EPA) under the American Innovation and Manufacturing Act of 2020 (AIM Act).[5] DoD is using the MCMEU definition with the recognition that both market forces and increased regulation can have a direct impact on mission capability.

The updated PFAS mission critical use information presented herein is organized by the same focus areas (e.g. use sectors) used in the 2023 DoD PFAS Critical Use Report:

- Kinetic capabilities
- Energy storage and batteries
- Microelectronics and semiconductors
- Castings and forgings
- Strategic and critical minerals

Mission critical PFAS uses that extend beyond the five focus areas above were also identified in the 2023 DoD PFAS Critical Use Report. The potential risk of supply chain disruption for mission critical uses would undercut not only mission readiness but also potentially other elements of critical infrastructure of the United States and the U.S. economy.

III. DoD Phased Approach to Prioritize Investment into R&D of Alternatives for Mission Critical Uses of PFAS

III.1 Background

PFAS needed for production, performance, and sustainment of DoD systems are critical to the national security of the United States. An increasing number of mission critical PFAS and

[4] Organisation for Economic Co-operation and Development (OECD), *Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance*, (Series on Risk Management No. 61), July 9, 2021, https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf.
[5] 40 Code of Federal Regulations § 84.3.

PFAS-enabled products[6] are at risk for obsolescence due to market phase outs; manufacturer liability; complex geopolitical escalation dynamics; and regulatory complexity, uncertainty, and inconsistency which impact all levels of the PFAS supply chain. Major shifts in PFAS manufacturing decisions result in the chronic loss of products before alternatives can be qualified and the increased likelihood of substitution regret[7]—factors that contribute to the growing and impending risks to mission readiness and national security. The diminishing manufacturing sources and material shortages (DMSMS) pose the most significant risks to access critical-use PFAS until viable alternatives are developed and qualified which can take anywhere from 5-20+ years. The rate of obsolescence of existing chemicals is outpacing the defense sectors and other private industries' abilities to research, develop, test, evaluate, and adopt new chemical technologies, resulting in disruption to existing capabilities and/or sourcing from foreign entities of concern.

To mitigate mission impact, the DoD must implement a dual strategy to safeguard the continued domestic availability of PFAS critical for defense over the next 10 years or longer through regulatory and industry engagement, while proactively seeking PFAS alternatives which meet performance specifications and applicable regulatory thresholds for new or existing chemicals. The DoD recognizes that development and transition to non-PFAS alternatives will, in many cases, require significant resources and decades-long investment. In the interest of minimizing obsolescence and supply chain risks associated with defense products and weapon systems or sourcing PFAS from China and other foreign entities of concern, the DoD will undertake an orderly transition to alternatives. This includes supporting the continued availability of domestic sources of PFAS that are associated with those defense uses requiring extended research, development, test, and evaluation timelines to find alternatives or in cases where no alternatives are available. A phased approach supports an orderly transition to alternatives for mission critical uses of PFAS that is less likely to negatively impact national security.

Implementation of the short- and long-term strategies will yield a prioritized list of mission critical uses requiring sustained availability for the shorter term while investing into PFAS alternatives R&D. DoD will take a phased approach to strategically budget for and invest R&D funds into PFAS alternatives development and testing based on use sectors while also investing in technologies to support domestic sourcing of current and on-going PFAS requirements.

III.2 Phased Approach to Inform the Prioritization of Investment into R&D of Alternatives for Mission Critical Uses of PFAS

The Department will develop and implement an enterprise-wide, phased approach to prioritize investment into R&D to include coordination with relevant agencies, industries, and

[6] A "PFAS-enabled product" is one that uses PFAS to provide a specific functionality or property (e.g., water or oil repellency, stain resistance, dielectric and heat transfer properties, temperature-, pressure-, wear-, and chemical-resistance).
[7] Substitution regret can occur when a user replaces a chemical with a substitute chemical that might later be found to present an unreasonable risk of injury to health or the environment or be subject to regulation (also referred to as "regrettable substitution"). 89 Fed. Reg. 103,586 (December 18, 2024).

academia to research alternatives for mission critical uses of PFAS—those uses for which PFAS has a direct impact on mission capability and for which no alternatives that meet performance standards are currently available.

In Phase I, DoD will develop a strategy to review known uses of PFAS and PFAS-based products and prioritize those mission critical uses that require investment into R&D of alternatives. The strategy may consider factors such as:

- The breadth of PFAS uses with functional similarities across focus areas (e.g. use sectors).
- The probability that industry will address a particular use case thereby providing solutions that the DoD can adopt or adapt towards particular DoD use cases.
- The mission criticality of the uses (e.g. the essentiality of an item to the production, operation, or sustainment of a particular weapon system or multiple weapon systems).
- The probability of risk to an affected weapon system(s) over its lifecycle.
- The complexity of the use (e.g. implementation of an alternative necessitating infrastructure or hardware changes).
- Magnitude of obsolescence vulnerability (risk of insufficient or no market availability of PFAS and PFAS-enabled products).
- The degree of obsolescence risk mitigated through the development and implementation of manufacturing abatement technologies[8], recycling technologies, or alternative intermediates/processing aids (to reduce emissions, exposure risk, and potential liability and ensure near term continued domestic availability of mission critical PFAS). In some instances, advancements in manufacturing technologies may negate the need to develop viable alternatives.
- The degree of obsolescence risk mitigated through development and implementation of viable alternatives.
- Anticipated resources (DoD, defense industrial base (DIB)) required to support the development of a viable alternative.
- Anticipated resources (DoD, DIB) needed to qualify an alternative. This includes the resources associated with the qualification processes, the MILSPEC revision process, and the time associated with the regulatory approval process if the replacement chemical is considered a new chemical under the Toxic Substances Control Act.

Phase II will address alternatives development for the mission critical PFAS uses within the use sectors posing the most pressing threats to national security—kinetic capabilities; energy storage and batteries; microelectronics and semiconductors; and castings and forgings and strategic and critical minerals—which were prioritized in Phase I.[9] OASD(EI&E) will coordinate R&D activities across the DoD enterprise and with the interagency, private industry, and academia.

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[8] An abatement technology will prevent or reduce PFAS emissions from manufacturing or formulator facilities. The technology can refer to modifications to the production process or to implementation of an abatement process.
[9] Securing Defense-Critical Supply Chains (February 2022). https://media.defense.gov/2022/Feb/24/2002944158/-1/-1/1/DOD-EO-14017-REPORT-SECURING-DEFENSE-CRITICAL-SUPPLY-CHAINS.PDF.

Using the prioritization strategy developed in Phase I, Phase III will address alternatives development for the mission critical PFAS uses not addressed in Phase II. For example, these may include uses in the sectors listed below which were discussed in the 2023 DoD PFAS Critical Use Report (Section IV.5). See also Appendix A herein. Phase II and Phase III are not strictly sequential. Depending on the results of Phase I, activities within Phase II and Phase III may be initiated and progress concurrently in consideration of the mission criticalities identified. OASD(EI&E) will coordinate R&D activities (to include ongoing and planned efforts) in Phase III across the DoD enterprise and with the interagency, private industry and academia to complete the research, development, test, and evaluation of alternatives. Phase III may include alternatives development in the following sectors:

- Refrigeration and Air Conditioning, Cooling, and Electronics Thermal Control
- Fire Suppression in DoD Vessels, Aircraft and Ground Combat Vehicles
- Aqueous Film Forming Foam
- Lines, Hoses, O-Rings, Seals and Gaskets, Tapes, and Cables and Connectors
- Electronic/Dielectric Fluids
- Advanced Oils, Greases, Fluids, and Lubricants
- Precision Cleaning Fluids
- Degreasing/Cleaning Fluids
- Adhesives
- Insulation and Foam Blowing
- Resins for Specialty Materials
- Specialty Filters and Membranes
- Fabrics, Fabric Liners, and Fabric Barriers
- Customized Applications
- Medical Applications

As part of Phase II and Phase III, DoD will review the MILSPECs and MILSTDs for the mission critical uses to ensure they are effective, accurately represent the desired performance outcomes and ensure that viable PFAS-free alternatives are not artificially excluded.

Collaboration across the Federal Government, the DoD enterprise, and the public and private sectors, and academia will be key to the successful implementation of this long-term approach to address the most critical and challenging PFAS uses requiring a decade or more to find viable replacements. The Department will coordinate with other departments and agencies, industry, non-governmental organizations, and academia during Phase II and Phase III to build upon past and ongoing R&D investments to identify and develop PFAS alternatives, ensure resource leveraging, and avoid overlap and duplication of efforts.

During Phase IV, given availability of resources, DoD will consider engaging with the National Academies to conduct a study of the performance tradeoffs associated with PFAS alternatives and how to balance competing needs.

OASD(EI&E) will provide annual updates on this phased approach to develop alternatives to mission critical PFAS uses to the DoD Emerging Chemicals Governance Council (ECGC). The ECGC, comprised of Assistant Secretary of Defense-level executives, oversees policy that addresses risks associated with mission critical chemicals and provides executive-level, enterprise-wide strategic direction to the DoD emerging chemicals program.[10] The ECGC is chaired by the Under Secretary of Defense for Acquisition and Sustainment and co-chaired by the Under Secretary of Defense for Research and Engineering.[11]

IV. Methodology Used to Update the 2023 DoD PFAS Report

The CMRMP held industry engagement sessions with entities throughout the PFAS supply chain—manufacturers and formulators of PFAS materials and companies that produce PFAS-enabled mission critical products—to update DoD's understanding of the direct and indirect mission critical uses of PFAS. Information, where known, on the MILSPECs/MILSTDs governing mission critical PFAS uses and the availability of PFAS alternatives was also gathered.

To begin to identify DoD requirements that rely on the use of PFAS, the Defense Logistics Agency (DLA) Acquisition Streamlining and Standardization Information System (ASSIST)[12] was queried. DLA ASSIST is the official DoD database for "defense and federal specifications and standards, military handbooks, commercial item descriptions, data item descriptions, and related technical documents prepared in accordance with the policies and procedures of the Defense Standardization Program (DSP)."[13]

V. Updated Information on Mission Critical Uses of PFAS

DoD's known critical uses of PFAS, availability of alternatives, and MILSPECs/MILSTDs are summarized in Appendix A, organized by use sector. Information on uses and MILSPECs/MILSTDs gathered since the 2023 DoD PFAS Report is shown in red font. A significant amount of new PFAS use information was identified within the fabrics, fabric liners, and fabric barriers use sector and for medical applications. These uses are discussed in detail in the following sections. New use information was also identified in the following use sectors: (1) energy storage and batteries, (2) microelectronics and semiconductors, (3) fire suppression in aircraft and ground combat vehicles, (4) electronic and dielectric fluids, and in (5) three customized applications (lubricant-migration-deterring barrier coating solution; copper free antifouling paint component, and in the quality control testing of plastic blasting media) (see Appendix A). The complexities in dissecting the DIB supply chain and supply chain dependencies, in addition to the lack of transparency in chemical and material content data for products and articles (e.g. end items), prevented the CMRMP from gathering comprehensive data on all critical PFAS uses. Efforts to improve the understanding of critical PFAS uses and the supply chain dependencies will

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[10] DoD Instruction 4715.18. Emerging Chemicals of Environmental Concern. February 9, 2024.
[11] USD(A&S) Memorandum, Enterprise Wide Chemicals and Material Risk Management for Capability Development and Resilient Supply Chains. January 15, 2025.
[12] https://assist.dla.mil/online/start/index.cfm.
[13] https://www.dau.edu/blogs/assist-quick-search-powerful-tool.

continue within the Department to inform the implementation of the phased approach to prioritize R&D investments for PFAS alternatives.

V.1 Fabrics, Fabric Liners, and Fabric Barriers[14,15]

DoD uses PFAS-based finishes to provide water, oil, and stain repellency on clothing and equipment items and uses laminated films with polytetrafluoroethylene (PTFE) to serve as barriers and membranes against wind, water, and chemicals. PFAS are used in many DoD textile items due to their unique thermal stability, low friction, and chemical resistance properties. These properties ensure DoD protective clothing and equipment items provide DoD personnel with the protection needed, particularly the Warfighter operating in extreme weather and Chemical, Biological, Radiological, and Nuclear (CBRN) environments. Repellency is a critical property which prevents exposure to toxic chemicals, chemical warfare agents, fuels, motor oils, and other contaminants into and/or through fabric layers.

The DoD is currently tracking over 100 fielded items that are or will be affected by PFAS regulations and/or voluntary PFAS manufacturer market exits. The objectives of this work are to determine the functionality PFAS provides, identify timelines and manufacturer alternatives, track regulatory waivers, evaluate non-PFAS alternatives and monitor the research, development, test, and evaluation (RDT&E) of PFAS alternatives – both repellent finishes and barriers for protection. See Appendix A for a list of military textile items which are reliant on PFAS.

Many of the military clothing and equipment performance requirements likely can only be met using PFAS. Currently, known non-PFAS water repellent finishes do not provide the same level of durability as their PFAS counterparts, or the required level of saltwater resistance necessitated for ballistic protection. No PFAS-free alternative has been developed which can provide any level of oil repellency which is critical for the robustness of load carriage items and clothing frequently exposed to gun cleaners and lubricants, as well as fuel handler's garments that must retain fire resistance after exposure to petroleums, hydraulic fluids, and other fuels. Non-PFAS finishes struggle to meet military requirements over the expected life cycle of a clothing or equipment item. Additionally, no alternatives have yet been identified to replace PTFE membranes.

Certain specifications, such as GL/PD 07-06C and PD 77AESG 06-01A, explicitly mandate the use of PTFE for waterproof barriers. Many other specifications such as (including but not limited to GL-PD-12-19, GL-PD-07-06, and others) do not explicitly call out the use of PFAS-based textile finishes but require achieving a minimum '4' rating on the oil repellency test, AATCC 118, which only PFAS-based finishes are capable of. The DLA Troop Support is tracking MILSPECs/MILSTDs that are either known or suspected to use PFAS to meet performance requirements.

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[14] Raushel J, Williams K, Strohmetz A. 2023. DLA D65 Transition (slide deck). November 16. https://www.dla.mil/Portals/104/Documents/TroopSupport/CloTex/2023%20JAPBI/D65%20Shade-PFAS.pdf?ver=ktbkkVCWDIlVhdceJD1h-w%3d%3d.

[15] Army Information Paper: Impacts of Per- and Polyfluoroalkyl Substances (PFAS) on DoD Clothing and Equipment. February 13, 2024. https://www.pia.com/wp-content/uploads/PFAS-INFO-PAPER.pdf.

V.2 Medical Applications

PFAS are critical to medical applications—devices, pharmaceuticals, and equipment—due to their unique thermal stability, chemical resistance, low friction, and biocompatibility properties. Medical devices account for a small share (~2%) of the total PFAS market. Based on what is currently known, PTFE, ethylene tetrafluoroethylene (ETFE), fluorinated ethylene propylene (FEP), and polyvinylidene fluoride (PVDF) account for 90% of the fluoropolymers used in medical devices. Expanded polytetrafluoroethylene (EPTFE) and hydrofluoroethers (HFEs) are also used. Currently, there are no functional alternatives for PFAS in medical devices and it is estimated that to go from conception to market for a viable PFAS alternative would take 10 to 15 years.

Some medical devices, equipment, and products reliant on PFAS include:

- Implantable devices (e.g., stents, grafts, hernia mesh, surgical mesh). Surgical mesh is sometimes used to treat substantial wounds from field trauma.
- Prosthetics.
- Circuit boards, leads, foil in large equipment such as magnetic resonance imaging (MRI), computed tomography (CT), and mammography machines.
- Instruments and equipment (shears, cutters, staplers) used in minimally invasive endoscopic surgical procedures.
- Blood collection bags, suction devices used in respiratory therapy and for anesthesia, and intravenous (IV) solution bags.
- Guidewires and delivery systems used in minimally invasive procedures to navigate through a patient's anatomy (e.g. blood vessels, ducts).
- Automated medication dispensing systems (not classified as medical devices). Various parts of the mechanisms in the dispensing portions of the products, where they need to be durable, easy to clean, and non-stick, contain PFAS.

Additionally, PFAS are present in batteries and in electro-mechanical equipment used in health care products and devices. Specifically, PFAS are present in semiconductors and other electronic components as well as in Underwriters Laboratory (UL) certified grades of polymers suitable for use in electronics (for fire resistance).

PFAS-containing medical devices, while not used exclusively by the military, represent a civil-military commonality that is critical to military readiness and national security. Examples of PFAS-containing medical devices procured by DoD last year alone include millions of safety hypodermic products, primary tubes, and safety needles (containing PFAS in their barrel ink and packaging) and approximately 2.5 million wingsets (with PFAS in their plug [connector] components) from one manufacturer. Wingsets are critical for blood draws and testing.

VI. DLA ASSIST Query Results

The DLA ASSIST was queried using five PFAS-related search terms—"fluoro", "fluoropolymer", "fluorochemical", "HFC", and "PFA"[16]—to identify DoD requirement documents that may necessitate, or favor, the use of PFAS. The query yielded a total of 256 active

[16] HFC—hydrofluorocarbon; PFA—perfluoroalkoxy or perfluoro alkanes which are fluoropolymers.

documents associated with a wide range of Federal Supply Classification (FSC) codes. Almost all (253) contained the general search term *fluoro*. The number of documents which contain *fluoropolymer*, *fluorochemical*, *HFC*, or *PFA* and their associated FSC codes are summarized in Table 1.

These results do not represent a complete list of requirements that may necessitate, or favor, the use of PFAS, but rather illustrate the scope and extent of requirement documents containing search terms representative of PFAS. The approach to search DoD requirements databases for key words representative of PFAS underestimates the number of requirements reliant on PFAS due to the shift from detail specifications (e.g. identifying the materials to be used) to performance specifications (e.g. identifying required results and compliance criteria) within the DoD. Specifications are likely to identify the required performance characteristics (water repellency, oil repellency, chemical resistance, thermal stability, etc.) rather than the required PFAS constituents in a material or end item.

Table 1. Number of DLA ASSIST Documents Containing Select PFAS Terms and their Associated FSC Codes (as of December 5, 2024)

FSC Code / Description	Number of ASSIST Documents (Identified as Active) Containing Search Term			
	Fluoropolymer	Fluorochemical	HFC	PFA
1376 – Propellants, Boosters, etc.	1			
4210 – Fire Fighting Equipment			2	
5970 – Electrical Insulators and Insulating Materials	4			
5975 – Electrical Hardware and Supplies				2
6145 – Wire and Cable, Electrical	38			
6830 – Gases: Compressed and Liquefied			1	
6850 – Miscellaneous Chemical Specialties	1	1		
8030 – Preservative and Sealing Compounds			1	
9330 – Plastics Fabricated Materials	2			1
Total	**46**	**1**	**4**	**3**

VII. Conclusions

As with the 2023 DoD PFAS Report, this report summarizes known PFAS uses identified in the DoD supply chain that are critical to the national security of the United States, but it is not comprehensive. There remains significant uncertainty regarding the presence of PFAS in products that make up a complex supply chain. The difficulties in dissecting the defense industrial base supply chain and supply chain dependencies, in addition to the lack of transparency in chemical and material content data, preclude gathering comprehensive data on all critical PFAS uses.

Collectively, international, federal, and state regulatory actions to manage PFAS' environmental impacts and identify and eliminate PFAS from the market, and the resulting market changes (responses), pose increasing risks to DoD operations due to possible product obsolescence and reformulations. Regulatory complexity, uncertainty, and inconsistency impact all levels of the PFAS supply chain, including the feedstock minerals (fluorspar and possibly others), fluorochemicals, processing aids, and intermediates used to formulate PFAS, especially for manufacturers and formulators operating across multiple jurisdictions. The variability in how PFAS is defined exacerbates these issues. A variety of broad molecular structure descriptors, without regard to the individual substance's toxicity profile and hazard characterization, are used to define the chemical class "PFAS." These structural definitions do not inform whether a substance is harmful but only communicate that the substances share common structural traits to varying degrees. Regulatory agencies, and even different programs within the same agency, use different definitions for what constitutes a PFAS chemical, leading to inconsistences in how and where an individual PFAS is or is not regulated. Regulatory inconsistency contributes to shifts in PFAS manufacturing decisions, resulting in DMSMS within the DIB supply chain. To overcome the challenges of using broad, structural-based definitions for PFAS, a risk-based approach to defining PFAS that considers the chemical/physical properties and exposure pathways should be considered. For example, the definition could consider PFAS' intrinsic properties (e.g., half-life, water solubility, mobility, boiling point/vapor pressure, molecular size) and their toxicological effects (e.g., pathways of exposure, modes and mechanisms of action, elimination kinetics).

PFAS are critical to the national security of the United States, not because they are used exclusively in military applications (although some are), but also because of the civil-military commonality and the potentially broad impact to the civilian marketplace. There is a need to ensure that the dwindling number of domestic PFAS manufacturers remain able to and capable of providing PFAS critical to national security, including those producing the feedstock minerals (fluorspar and possibly others) and chemicals and all the intermediate chemicals leading to the manufacture of fluoropolymers, fluorinated gases, and other critical fluorochemicals broadly defined as PFAS. Otherwise, sourcing of mission critical PFAS may come from China and other foreign entities of concern, defeating the purpose of establishing domestic supply chains for key sectors such as semiconductors, batteries, and energetics.

To mitigate obsolescence risks and mission impacts, the DoD must implement a strategy to ensure short term domestic availability of the end-to-end PFAS supply chain critical for defense (e.g. supporting the manufacturing base to develop better abatement technologies and reduce emissions) while proactively seeking long term PFAS alternatives which meet both performance specifications and regulatory thresholds where possible.

Appendix A. Summary of Known Mission Critical PFAS Uses
(from 2023 DoD PFAS Report with February 2025 updates in red font)

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
Kinetic Capabilities				
Fluoropolymers (e.g., Teflon™) Fluoroelastomers (e.g., Viton™)	Ingredients in binders and resins used in PBX, pyrotechnics, and propellant components that are used in a variety of applications across the DoD. MIL-DTL-32757, PAX-73-P-Q Explosive Molding Powder. Covers the requirements, examinations, and tests for manufacture and acceptance of two types of PAX-73-P-Q, a high-energy explosive molding containing crystalline HMX and a fluoropolymer binder.	High temperature resistance Teflon™: • In pyrotechnics acts as oxidizer and ensures proper ignition/effects. Viton™: • Pyrotechnics – serves as oxidizer and binder; essential to the safe functioning of pyrotechnic flares • Energetics – used as high density binder for certain DoD and DOE booster and lead charges.	Early stage, initial DoD R&D investment into alternatives is ongoing.	NA* (no information provided through data collection efforts)
Fluorochemical specialty fluid	Used in energetic slurry processing.	Enables high levels of mixing between key energetic components during energetic material preparation.	Early stage, initial DoD R&D investment into alternatives is ongoing.	NA
Fluorinated performance fluids (e.g., 3M™ Fluorinert™ fluids)	Enable energetics laboratory research. Are critical for developing and transitioning new energetic materials.	NA	NA	NA
Energy Storage and Batteries				
Fluoropolymers (e.g., polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), fluorinated ethylene propylene (FEP), fluorine rubber materials (FKM)) Polyfluoroalkyl acids (polyFAAs) Lithium (Li) salts with PFAS anions (e.g., Li-triflate, LiTFSI, LiBETI)	Multiple subcomponents in modern Li-ion batteries: electrolyte solutions, cathode binders, separator coatings, casing materials, valves, separator coatings, and gaskets. Multiple subcomponents are also used in solid-state batteries and lead based batteries.	Provide weather-resistance, UV light-resistance, and deterioration-resistance properties. Fluoropolymers and polyFAAs (but not Li salts with PFAS anions) can serve as heat transfer material or insulation.	NA	Fully eliminating PFAS from energy storage in the U.S. economy would likely take 10+ years.

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
Fluoropolymers (e.g., Chemours™ Nafion™)	Used in membrane for fuel cells and flow batteries technologies.	Serves as electrolytes separator. Provides high ionic conductivity, high selectivity, and chemical stability properties.	Possibly available (e.g., sulfonated polyether ether ketone (sPEEK) membrane).	Even after suitable alternatives for PFAS use in batteries are identified, long development times are anticipated.
PFAS (at this time unspecified)	Battery manufacturing: filters and other components essential to production.	NA	Possibly available	Time and cost to identify and qualify alternatives would be significant and have ripple effects throughout the economy.
Microelectronics and Semiconductors				
Fluoropolymers Fluoroelastomers PolyFAAs Other PFAS	Semiconductor fabrication: etching materials and masks in photolithography processes; cleaning gases. SAE-AMS-H-81829: Heat Transfer Fluid, Fluorochemical	Dielectric, heat transfer, and insulation functionalities.	Currently there are no alternatives to PFAS for photolithography. DoD is currently limited to U.S.-based suppliers. Without access to PFAS, DoD would have to revert to 2007-era microelectronics technology.	NA
Fluoropolymers	Semiconductor manufacturing equipment and factory infrastructure: equipment components (e.g., tubing, gaskets, containers, filters) and lubrication (various oils and greases).	Heat and chemical resistance, and chemical inertness.	Currently there are no alternatives for some applications in semiconductor manufacturing equipment. Replacing most PFAS uses in semiconductor fabrication would require industry-wide re-tooling and other process innovations. Some might be achievable within 10 years, but many would not.	Development of alternatives for some uses may require the invention of novel chemistries and processes. Due to the extremely complex qualification process, it would take another 15 years to deploy alternatives, once developed, in high-volume manufacturing. Replacing PFAS in semiconductor fabrication could be a 25-year effort and may not succeed in all respects if alternatives cannot be identified or qualified at the microchip level. Replacing PFAS has the potential to initiate costly requalification of specific components. Example: radiation hardened microelectronics applications typically mandate requalification if a manufacturer substantively alters the fabrication process, which can easily exceed $10 million.

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
PTFE PFA	Microelectronics applications: base laminate materials used in many RF and microwave circuits.	Provide unique properties related to isolating RF and microwave signals. Used in radar, antenna, guidance systems, 5&6 G infrastructure, and other network/ transmission applications.	There is no drop in alternative material. Any material replacement for fielded systems would require redesign of the printed board and potentially the electronic system to account for material property differences. Fielded systems that have been redesigned may require requalification.	Developing and or identifying suitable alternative materials and qualifying them could be a forward-looking action for all future DoD systems. This however does not address sustainment of existing systems. There will continue to be a need to have PTFE laminate materials available for system sustainment until all systems currently designed with PTFE are retired.
PFAS	Manufacture of printed circuit boards (PCBs): vapor phase solder and flux remover products.	Vapor phase soldering process is used for PCB assemblies with high thermal mass, fine-pitch structures, and temperature-sensitive components to minimize risk to materials, structures and components. The material stability and flame retardant qualities are well suited for the enclosed high temperature operation of the process.	It is unknown if there are suitable materials that can be used, however it is likely that current equipment may need to be replaced or modified to accommodate the replacement materials.	Developing and evaluating new materials could take 5 years or more. Equipment replacement would add time and have a cost impact.
PTFE	PCBs: cable jackets used in PCB connectors. Mil-W-22759 or SAE-AS22759E (Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy) – note the fluoropolymer insulation may be PTFE, FEP, PVDF, ETFE, or other fluoropolymer resin.	Used because it has excellent fire, smoke, and chemical resistance. Wide temperature range -200 to 260C constant use and up to 450C for peak exposure.	It is unknown if there are suitable replacement materials for all the applications for PTFE wire jacket material. PTFE is higher cost than some other wire jacket materials. When it is selected for use there are typically no other suitable replacement materials.	Qualification of alternatives will be both costly and time consuming. Many materials will require new UL or other certification body approval before they can be implemented. Many current products are MilSpec certified.
Fluorochemical gases/fluids	Leak testing for microelectronics Mil-Std-883-1, DoD Test Method Standard, Environmental Test Methods for Microcircuits, Part 1: Test Methods 1000-1999	NA	NA	NA

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
Castings and Forgings and Strategic and Critical Minerals				
Specialty fluorochemical gases and fluids	Advanced metalworking, casting, and fabrication processes used in the production of advanced metal parts throughout U.S. industry, including military-specific parts.	Temperature and wear resistance.	NA	Moving to alternatives in under 10 years may require returning to previous construction methods and may make construction using certain alloys impossible.
PTFE, PVDF, other PFAS	Mold release chemicals and release films typically used in composite manufacturing processes.	Prevent composites from strongly adhering to mold hardware.	NA	NA
Refrigeration and Air Conditioning, Cooling, Electronics Thermal Control				
HFOs	Next-generation refrigerant alternatives (to HFCs) used in civil and military cooling and thermal control applications.	NA	Known non-PFAS alternatives (e.g., hydrocarbon or ammonia alternatives) pose flammability, toxicity, or high-pressure concerns. Early stage, initial DoD R&D investment into alternatives is ongoing.	NA
Specialty fluorochemical fluids (e.g., 3M™ Novec™ products)	Used for electronics cooling.	Each fluid has a specific viscosity and range as a function of temperature and is chosen for an application depending on the hardware (pumps) and operational environment.	NA	NA
Fire Suppression in Aircraft and Ground Combat Vehicles				
Fluorochemical specialty gases	"Clean agent" fire suppression in aircraft and ground combat vehicles.	NA	Most known clean agent, low-corrosion, low-weight, low-toxicity alternatives will likely be classified as PFAS, broadly defined.	NA
Specialty fluorochemical fluids (e.g. FK-5-1-12 sold as 3M™ Novec™ 1230)	Used for fire suppression in hush houses	NA	3M will cease production of Novec™ 1230 by the end of 2025. FK-1-5-12 is produced by other companies.	NA
Aqueous Film Forming Foam (AFFF)				
PFAS	AFFF use to combat Class B (flammable/combustible liquid) fuel spill fires on mission critical ocean-going vessels employed by DoD and the Military Services.	MIL-PRF-24385 qualified AFFF meets Navy requirements for rapidly controlling and extinguishing shipboard fires	Current fluorine-free foams (F3s) have significant limitations compared to AFFF that preclude their use on DoD ocean-going vessels, including the U.S. Coast Guard.	NA

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
Lines, Hoses, O-Rings, Seals and Gaskets, Tapes, and Cables and Connectors				
Fluoropolymers (e.g., PVDF, ECTFE, PTFE) Fluoroelastomers (e.g., FKM/FFKM)	Critical to modern "rubberized" fuel lines. Key materials in hoses, tubing, hydraulic system lines, O-rings, seals and gaskets, tapes, and cables and connectors widely used in civil and military aircraft, space systems, vehicles, weapon systems, utility systems, and other applications. Multiple specifications and industry standards exist, many of which specifically call out fluoropolymers and fluoroelastomers: • MIL-I-22129C • MIL-P-24074B • MIL-P-24396A • MIL-DTL-25579H • MIL-DTL-25988 • MIL-DTL-27072F • MIL-DTL-27267C • MIL-DTL-27272D • MIL-DTL-28840/24D • MIL-DTL-32434 • MIL-DTL-83296B • MIL-DTL-83298C • MIL-DTL-83528J • MIL-DTL-85800A • ASTM-D3159-22: Modified ETFE fluoropolymer molding and extrusion materials • SAE-AS22759E: Wire, electrical, fluoropolymer-insulated, copper or copper alloy • SAE-AS23053C: Insulation sleeving • SAE-AS81765/1A: Insulating components • AMS3216J specification (supersedes MIL-R-83248) • SAE-AMS7257E	Functionalities include UV-resistance, ozone-resistance, weather-resistance, temperature-resistance, high pressure-resistance, and chemical resistance.	Alternatives are not as resistant to embrittlement and break-down and have a much shorter useful life, leading to more frequent part replacement, which is not feasible for space or satellite uses.	NA

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
Electronic/Dielectric Fluids				
Fluorochemicals	Used in electronic and dielectric fluids used in civil and military radars, high-power electronics, and electrical system/utility system components.	Provide dielectric and heat transfer properties.	Industry and DoD have repeatedly investigated alternatives in these applications. Known alternatives (e.g., sulfur hexafluoride, polychlorinated biphenyls) may pose health/environmental risks.	NA
	In performance fluids (e.g. 3M™ Fluorinert™ and Novec™) used in satellite applications.	Provide heat transfer properties	NA	NA
Advanced Oils, Greases, Fluids, and Lubricants				
PFAS (e.g., Chemours™ Krytox™ aerospace greases)	Used in many advanced turbine engine oils, greases, fluids, and lubricants common throughout the U.S. civil transportation, industrial, and space sectors. Analogous oils, lubricants, and fluids are used in military critical ground, sea, air, and space applications. MIL-PRF-27617 Types I, II, III, IV	Wear- and heat-resistant properties. Perfluorinated greases exhibit excellent shelf lives due to their intrinsic inertness.	Previous generations of oils, fluids, and lubricants approached, but did not equal, the performance of PFAS additives that have become more prevalent in high performance oils, greases, fluids, and lubricants over the past 20 years.	NA
Precision Cleaning Fluids				
Fluorochemicals (e.g. 3M™ Novec™ engineering fluids)	Precision cleaning applications such as cleaning of sensitive oxygen systems in civil and military aerospace. NPFC-A-A-59150A: Cleaning Compound, Solvent, Hydrofluoroether (HFE)	NA	Alternatives (e.g., Honeywell Solstice® products) being qualified by NAVSEA (under a NASA spec for oxygen systems) for specific applications.	NA
Degreasing / Cleaning Fluids				
PFAS	Degreasing/cleaning products and contact cleaners used in vapor degreasing and flux removal.	NA	NA	NA
	Non-destructive testing solvent cleaner/remover used for precleaning and for removing excess surface penetrant before applying developer during liquid penetrant testing.	NA	NA	NA

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
	Degreasers used to effectively remove grease, oil, tar, and other substances from military equipment to increase its operating efficiency.	Leaves no residue, has no flash or fire point, and serves as an alternative to chlorinated solvent-based cleaners (e.g., 1,1,1-trichloroethane).	NA	NA
Butane, 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy	Connector cleaner and preparation fluid used for cleaning fiber optic connectors in secure link manager assemblies and primary modem assemblies.	NA	NA	NA
Insulation and Foam Blowing				
Fluorochemicals	Components of insulation and foam blowing products used in civil and military aircraft and space vehicles/rocket motors.	NA	NA	NA
Resins for Specialty Composites				
Fluoropolymers	Resins for specialty high-temperature or weather-/UV-resistant composites.	Temperature-, pressure-, wear-, and chemical-resistance properties.	NA	Moving to alternatives in under 10 years may require a return to previous methods of parts construction and an acceptance of lower performance, shorter life, and higher weight composites.
Specialty Filters and Membranes				
Fluoropolymers PFAS	Used in specialty filters and membranes (e.g., aviation filters); and in air filtering masks and air filtering respirators used by DoD.	Temperature-, pressure-, and wear-resistance properties.	NA	NA
Fabrics, Fabric Liners, Fabric Barriers				
PFAS	• Fabrics in a variety of uniform clothing and footwear items, shelters/tents, load carriage, extreme cold weather garments, fuel handling garments and ballistic protection, and duffle bags. • Reported use in chemical, biological, radiological, and nuclear protective equipment. • Used in the biological protective fabric lining used in the Joint	• Provides salt water resistance and soil and stain release through low surface energy properties in addition to anti-microbial properties. • Provides chemical resistance properties. • Reduced friction on parachute components.	No PFAS-free alternative has been developed which can provide any level of oil repellency against fuels and chemicals. Early stage, initial DoD R&D investment into alternatives is ongoing. Alternatives exist for water repellency, but do not provide the same level of durability as their PFAS counterparts. Current alternatives cannot provide both	A major technological breakthrough is needed to provide oil repellency (protection against fuels and chemicals) with non-PFAS alternatives. A suitable replacement could be 10+ years away.

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
	Biological Agent Decontamination System. • Parachute components (canopy, packs, carrying crate). • Enamel paint finishes (zippers, snaps). • Polyurethane foams (footwear). • Wetting/antifoaming agents used in dyeing and bleaching textiles. • Sewing thread. • Adhesives (for laminated clothing systems, vacuum sealed bags). Multiple standards exist for bags, boots, caps, gloves, jackets/parkas/ raincoats/windbreakers, jumpers, shirts, shoes/soles, trousers/pants, and cloth.[17] Majority of affected items meet performance specifications by utilizing PFAS. Some standards explicitly require PFAS (e.g.MIL-C-85637 "Cloth, Laminated, Fire Resistant, Waterproof and Moisture Vapor Permeable" requires use of PTFE film). In addition, many other specifications (e.g. GL-PD-12-19) do not explicitly call out the use of PFAS-based textile finishes but require achieving a minimum '4' rating on the oil repellency test, AATCC 118, which only PFAS-based finishes are capable of.		water repellency and soil release at the same time. No alternative has been identified to replace PTFE membranes.	

[17] Examples of specific specifications for items in the *Fabrics, Fabric Liners, Fabric Barriers* use category. Apron: A-A-55240; Army Gen III ECWCS (multiple purchase descriptions); Belt: A-A-55207; Beret: A-A-5518A; Cloth, Duck, Textured Nylon: MIL-DTL-32439B; Cloth, Plain Weave, Nylon: Water Repellent Treated and Untreated: MIL-DTL-43128F; Explosive handler's coverall: MIL-DTL-14610H; Field Pack Cover, Snow Camoflage: GL/PD 15-09A; Fire Resistant Environmental Ensemble (FREE) Intermediate Weather Outer Layer (IWOL): GL-PD-12-16, GL-PD-12-17, and GL-PD-12-18; FREE Extreme Weather Outer Layer (EWOL), GL-PD-12-19, GL-PD-12-20, and GL-PD-12-21; Fuel Handler Glove: GL-PD-07-06; Helmet: GL/PD 18-2; AR/PD 10-02; Hood: A-A-50194; Load Carriage MOLLE (multiple purchase descriptions); Modular Lightweight Load-Carrying Equipment: CO/PD 02-02N; Skirt: MIL-S-29631; Sleep System: GL/PD 14-01; Tarp: GL/PD 09-03C; Thread: A-A-55195, A-A-59991, A-A-59963; Treatment: MIL-PRF-2312G; Uniform: A-A-55110A, CR/PD 03-08, GL/PD 19026A; Webbing: MIL-DTL-530.

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
Customized Applications				
Specialty fluorochemicals	Used in customized applications like gyroscope suspension fluids and analytic gases and fluids for thermometric and other sensors.	Pressure-resistant, wear-resistant, and temperature control properties.	NA	NA
Fluoropolymer (e.g., 1H, 1H-pentadecafluorooctyl)	Used in a lubricant-migration-deterring barrier coating solution. MIL-B-81744A: Barrier Coating Solution, Lubricant Migration Deterring	NA	NA	NA
Specialty fluorochemical fluid	Used in quality control testing of particle contamination testing of plastic blasting media MIL-DTL-85891 – Engineered Media for Removal of Organic Coatings	NA	NA	NA
PFAS (2-(p-chlorophenyl)-3-cyano-4-bromo-5-trifluoromethyl pyrrole; CASRN 122454-29-9)	Component in copper free antifouling paint products. MIL-PRF-24647 – Paint System, Anticorrosive and Antifouling Ship Hull	Marine fouling biocide.	NA	NA
Medical Applications				
Fluoropolymers (PTFE, ETFE, FEP, PVDF, EPTFE, HFEs) and fluorosurfactants used to produce the fluoropolymers	• Implantable devices (stents, grafts, hernia mesh, surgical mesh). • Prosthetics. • Circuit boards, leads, foil in large equipment such as MRI, CT, and mammography machines. • Instruments and equipment (shears, cutters, staplers) used in minimally invasive endoscopic surgical procedures. • Blood collection bags, suction devices used in respiratory therapy and for anesthesia, IV solution bags.	Provide thermal stability, chemical resistance, low friction, and biocompatibility properties.	Currently, there are no functional alternatives for PFAS in medical devices.	It is estimated that to go from conception to market for a viable PFAS alternative would take 10 to 15 years.

PFAS	Application and Technical Standards	Functionality	Availability of Alternatives	Time Frame / Cost to Develop and Qualify Alternatives
	• Guidewires and delivery systems used in minimally invasive procedures. • Automated medication dispensing systems. • Additionally, PFAS are present in batteries and in electro-mechanical equipment used in health care devices and products.			