



OSCG 2025

PFAS: Updates on Regulations and Replacements

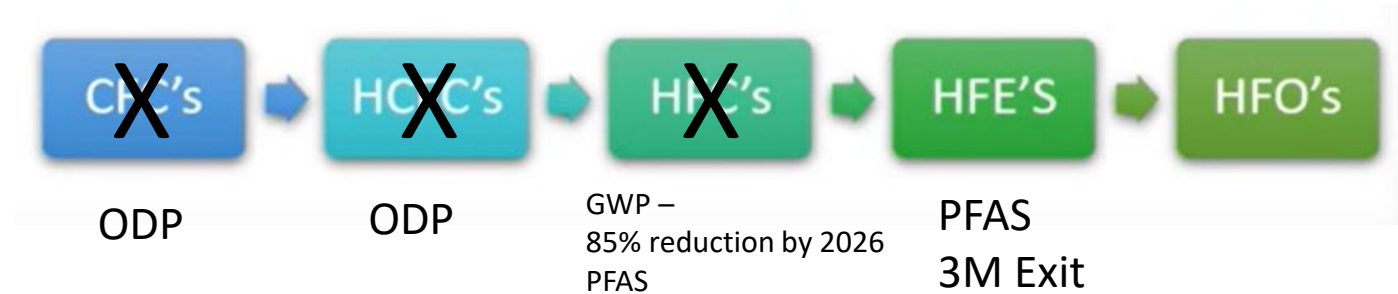
Fluorinated Solvents for Oxygen System Cleaning

- Past
- Present
- Future

Evolution of Fluorochemicals for O2 System Cleaning



Evolution of Fluorochemicals- Current Status



ODP and GWP Refresher

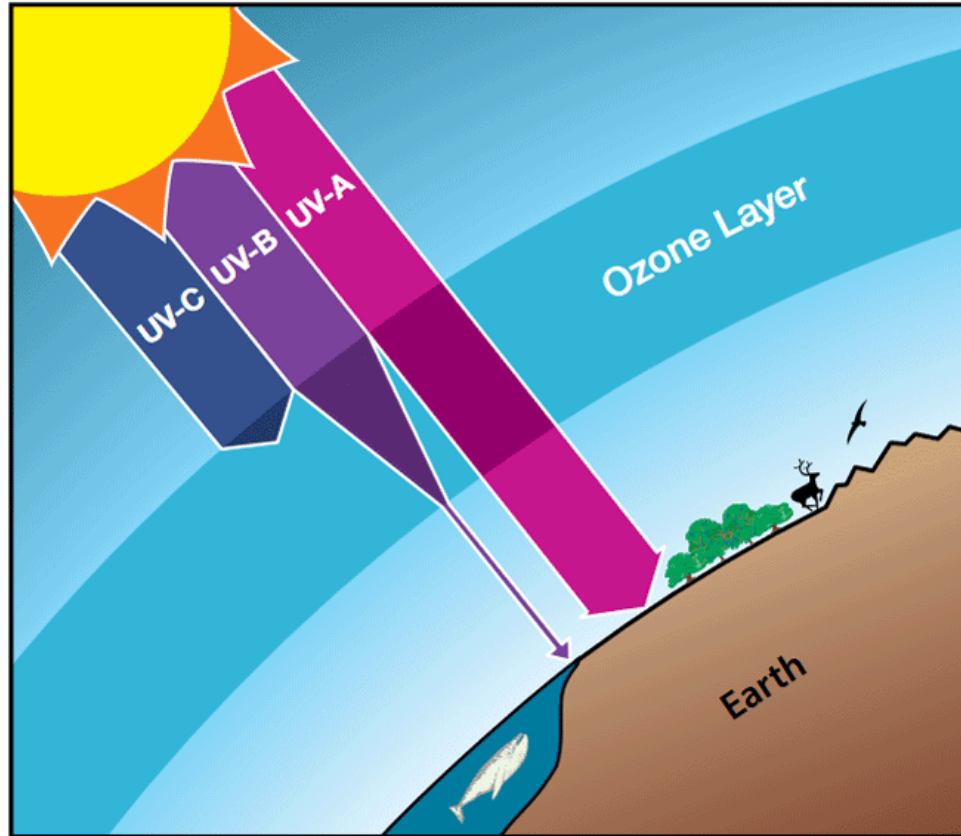
ODP

- Depletion of ozone layer allows more UVB radiation to reach earth
- UVB radiation is damaging to not only humans, but plant and aquatic life
- CFCs and HCFCs slowly rise into the stratosphere, where they are bombarded with UV radiation, breaking the C-Cl bond.
- Highly reactive Cl molecules react with ozone in the stratosphere

GWP

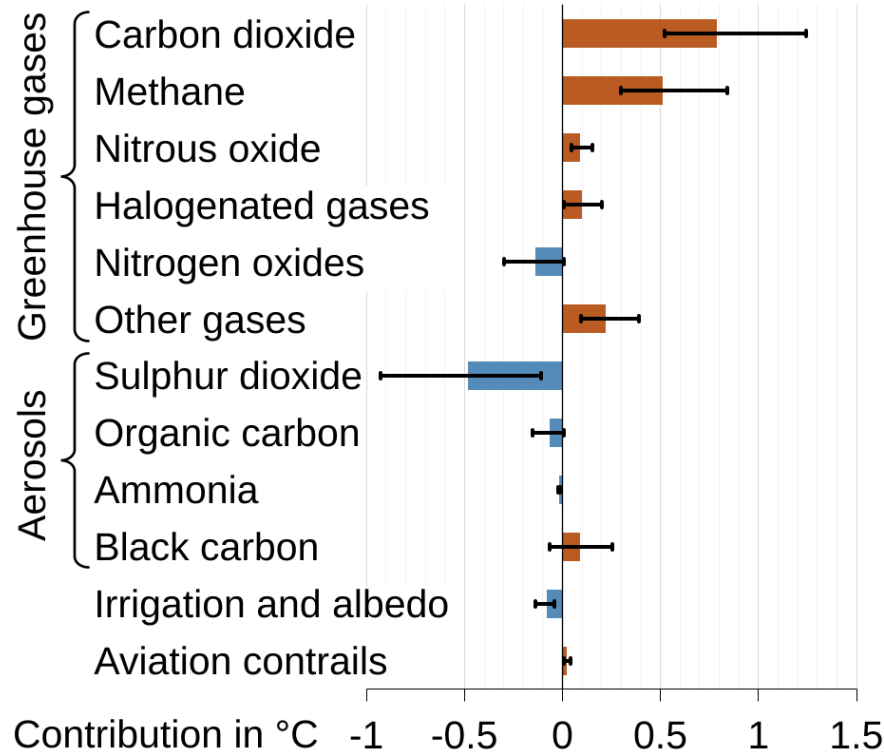
- Greenhouse gases pass sunlight that heats the earth, but trap some of the heat from the sun

UV Protection by the Stratospheric Ozone Layer



Source: US EPA

Physical drivers of climate change



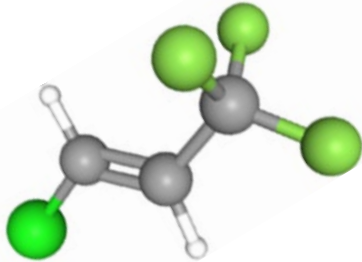
By Eric Fisk - Own work, CC BY-SA 4.0,
<https://commons.wikimedia.org/w/index.php?curid=81034563>

PFAS Basics

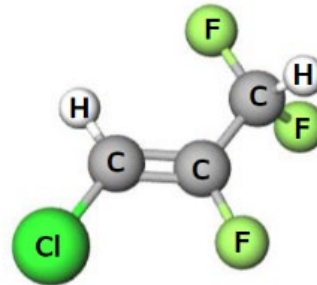
- Per- and Polyfluoro alkyl substances
- Referred to as “forever chemicals” due to very stable C-F bond
- PFOA and PFOS, which have not been manufactured in over 20 years, still persist in groundwater
 - Health effects not completely known, but US EPA has set MCL of 4 ppt in drinking water
- PFAS commonly used in textiles, consumer products

US EPA Definition of PFAS

- $R-(CF_2)-CF(R')R''$, where both the CF_2 and CF moieties are saturated carbons;
 - $R-CF_2OCF_2-R'$, where R and R' can either be F , O , or saturated carbons; and
 - $CF_3C(CF_3)R'R''$, where R' and R'' can either be F or saturated carbons.
-
- All HFEs and HFCs meet the above definition
 - Solstice PF and PF-HP (HFO) and the HCFO solvent below are exempt



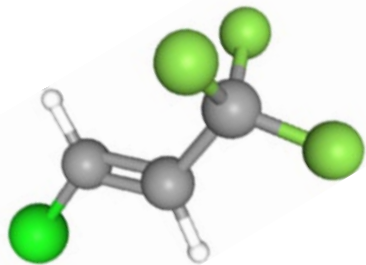
Solstice PF-HP 1-Chloro-3,3,3,-
Trifluoropropene



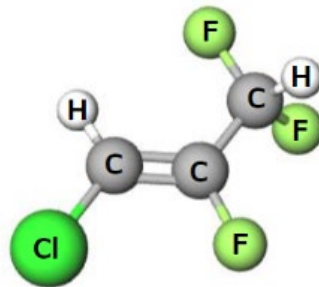
HCFO - 1-Chloro-2,3,3,-
Trifluoropropene (Primary constituent)

ECHA (EU) Definition of PFAS

- More restrictive than US EPA Definition
- Any material with a fully saturated C-F
- Therefore, Solstice is currently classified as PFAS by EU (also HFEs and HFCs)
- 1-Chloro-2,3,3-Trifluoropropene is not PFAS
- Canadian definition is almost identical



Solstice PF-HP 1-Chloro-3,3,3-Trifluoropropene

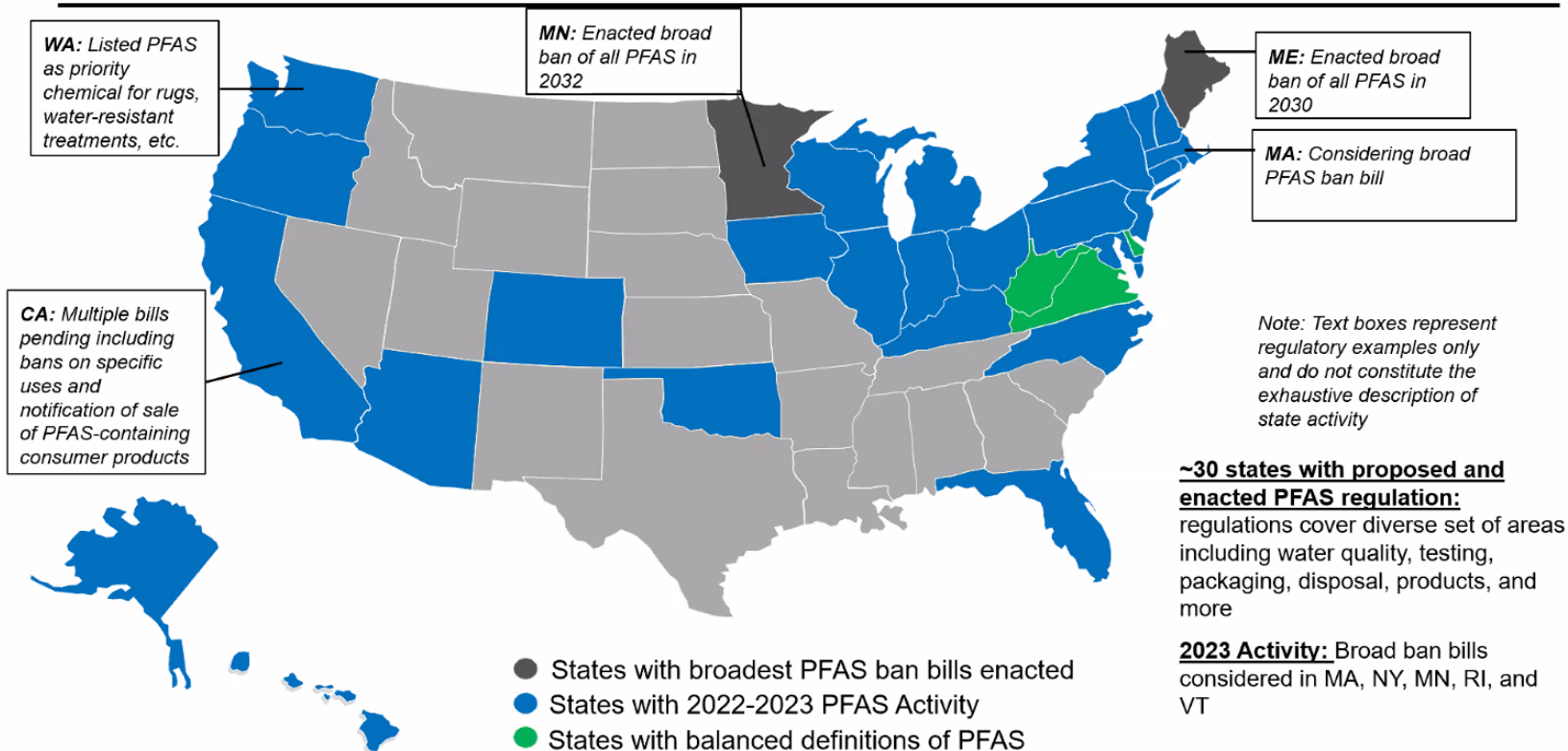


HCFO - 1-Chloro-2,3,3-Trifluoropropene (Primary constituent)

US PFAS Regulation - 2025 Updates

- “Major EPA Actions to Combat PFAS Contamination” – April 2025
 - <https://www.epa.gov/newsreleases/administrator-zeldin-announces-major-epa-actions-combat-pfas-contamination>
- EPA intends to continue advancing PFAS regulation, but with a more measured approach – extensions to compliance deadlines proposed:
 - Will retain the Maximum Contaminant Levels (MCLs) for PFOA and PFOS in water
 - Extension of the date to comply from 2029 to 2031
 - Reporting requirement under TSCA for manufacturers and importers (all PFAS) changed from July 2025 to April 2026

US STATE PFAS LANDSCAPE



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State Level - 2025 Updates

- CUU = “Continuous Unavoidable Use”
- Maine, Minnesota and New Mexico all have legislative updates
- More regulations taking effect in CA
- Maine
 - 100% PFAS ban still in effect
 - Reporting required starting January 1, 2026, except for products with a CUU designation
- Minnesota
 - 100% PFAS ban still in effect (definition is more restrictive than US EPA, identical to EU)
 - Manufacturers required to report the function of PFAS in their product
 - Reporting for ALL PFAS (including exempt products) beginning January 1, 2026

State Level - 2025 Updates

- New Mexico
 - Adopted ban in 2025 on almost all PFAS starting in 2032
 - 2027 – cookware, food packaging, dental floss, youth products, firefighting foam
 - 2028 – carpets, cosmetics, textiles, ski wax
 - Adopted Minnesota's language for the ban, but reporting not required for exempt products
- California
 - Bans on intentionally added PFAS in textiles starting 1-1-25
 - Ban on manufacture, sale or distribution of cosmetics containing intentionally added PFAS, effective 1-1-25
 - Disclosure requirement for PFAS in “outdoor apparel for severe wet conditions” (including PPE for firefighting)
- New Jersey - \$2 billion settlement with DuPont, Chemours and Corteva

EU- 2025 Updates

- ECHA will resume discussions in September 2025
 - Committee for Risk Assessment (RAC) and Committee for Socio-economic Analysis (SEAC)
 - Discussion of impacts on specific sectors (electronics, semiconductors, lubricants, etc.)
- July 8, 2025
 - EU-Wide PFAS monitoring framework launched
 - Monitor contamination, map hotspots, promote remediation
- Stricter Water Limits starting 2026
 - Caps 20 individual PFAS at 100 ppt and total PFAS at 500 ppt

DoD Report on Critical Uses of PFAS*

- Report finds that with respect to the cleaning of oxygen systems, no viable alternative to fluorochemicals currently exists
- DoD Cleaning Specification, MIL-STD-1330E(SH), 16 May 2022, **PRECISION CLEANING AND TESTING OF SHIPBOARD OXYGEN, HELIUM, HELIUM-OXYGEN, NITROGEN, AND HYDROGEN SYSTEMS** allowed solvents:
 - CFC-113
 - Solstice (PF-HP)
 - Novec 7100 (HFE-7100)

*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

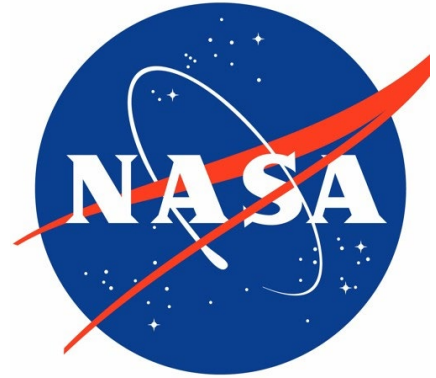
HFE-7100

- Still available, however
 - 3M (only US manufacturer) exiting the market, no shipments after 12-31-25
 - Other manufacturers are all in China
 - Several US companies selling Chinese HFEs

HFO (Solstice PF-HP)

HFO's are currently used to clean LOX Components and Breathable Oxygen Devices by NASA and the US Navy

- **Extensive flammability testing by Marshall Space Flight Center, Stennis Space Center and White Sands**
- **Certified non-flammable by NASA: RPT STD-8070-0001**
- **Certified safe for breathable oxygen systems: MIL SPEC 1330**
- **Cytotoxicity and extensive health studies performed by the US Navy**
- **Not a PFAS in the US (except in MN)**



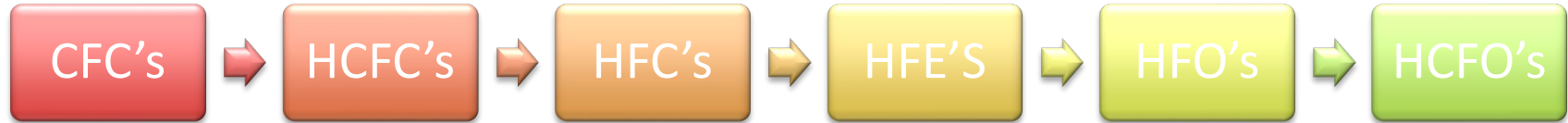
HCFOs

HCFO's are currently being evaluated as viable replacement solvents for GOX/LOX and other applications

- **Completed "OXYGEN COMPATIBILITY TESTS" for AIT-1 and LOXMIS-1 by WHA International Labs**
- **Current being tested by Marshall Space Flight Center and Stennis Space Center**



The Long Line of Greener Solvents



Forever Chemicals?

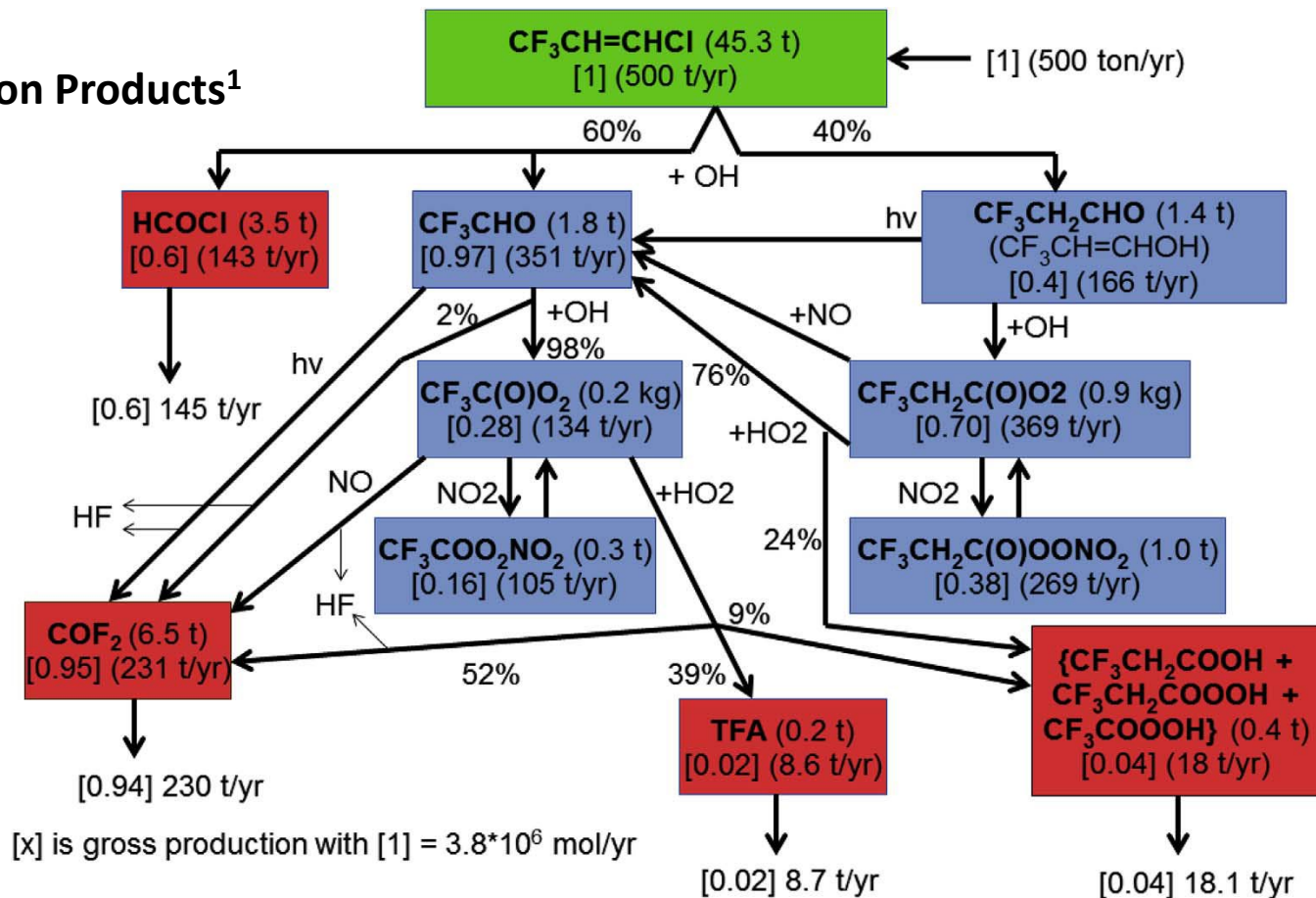
- Atmospheric Life of Solstice PF-HP: **~27 Days**
 - VOC: **Exempt**
 - Ground Water: **Does not accumulate**
- Atmospheric Life of new HCFO Solvent: **~2.3 Days**
 - VOC: **Yes**
 - Groundwater: **Does not accumulate**

Atmospheric Fate – trans 1-chloro 3,3,3-trifluoropropene (Solstice PF-HP)

- ODP is 0.00034 – EPA designated as “statistically insignificant”
- Using 3-D modeling, Sulbaek Andersen, et al¹ determined
 - Atmospheric degradation is initiated by reaction with –OH radicals, which leads to several degradation products
 - Of most concern is TFA (trifluoroacetic acid), which comprises only 2% of the degradation products
 - Majority of chlorine atoms will be released and deposited in the lower atmosphere
 - Conclusion – degradation products have negligible environmental impact

1 Mads P. Sulbaek Andersen, Johan A. Schmidt Aleksandra Volkovaa, Donald J. Wuebbles “A three-dimensional model of the atmospheric chemistry of E and ZCF₃CH=CHCl (HCFO-1233(zd) (E/Z))”. Atmospheric Environment 179 (2018); 250-259.

Reaction Products¹



Atmospheric Fate – 1-Chloro-2,3,3,-Trifluoropropene (HCFO)

- ODP is essentially 0 (0.00002)
- Main degradation product is likely TFA
- Minor side products – HFC-123 (at trace levels), trifluoroacetaldehyde (as intermediate)

Conclusions

- PFAS Regulation and Reporting is not going away
- The time is now to find other replacements for HFE-7100 for O2 cleaning
- HFO (Solstice PF-HP) is already well established as an alternative
- 1-Chloro-2,3,3,-Trifluoropropene (HCFO) is another viable alternative that should be considered for addition to MIL-STD 1330

Questions and Contact Information

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