PFAS Technical Group

October 15, 2021

Agenda

- Welcome and Introductions
- Michigan Airport Grant & Sampling Initiative – Mike Jury, MI
- Validation of Fluorine-Free AFFF against Military Specificiation Performance Criteria – Satya Chauhan, Battelle Memorial Institute
- Conclusions & Next Steps

Wisconsin DNR's PFAS Technical Group - Michigan Airport Results
October 15, 2021

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Review of Potential Aviation Sources/Release Locations

- AFFF
  - Fire Training Areas
  - Fire Stations
  - Emergency Response Location
- WWTP Facilities
- Landfills
- Maintenance Shops
  - Hydraulic Oils
- Storage Areas
  - Surface Drainage
  - Spray Test Areas
  - Hangars

Potential AFFF Sources at Airports

Fire Training

Emergency Response

Bulk Fuel Storage

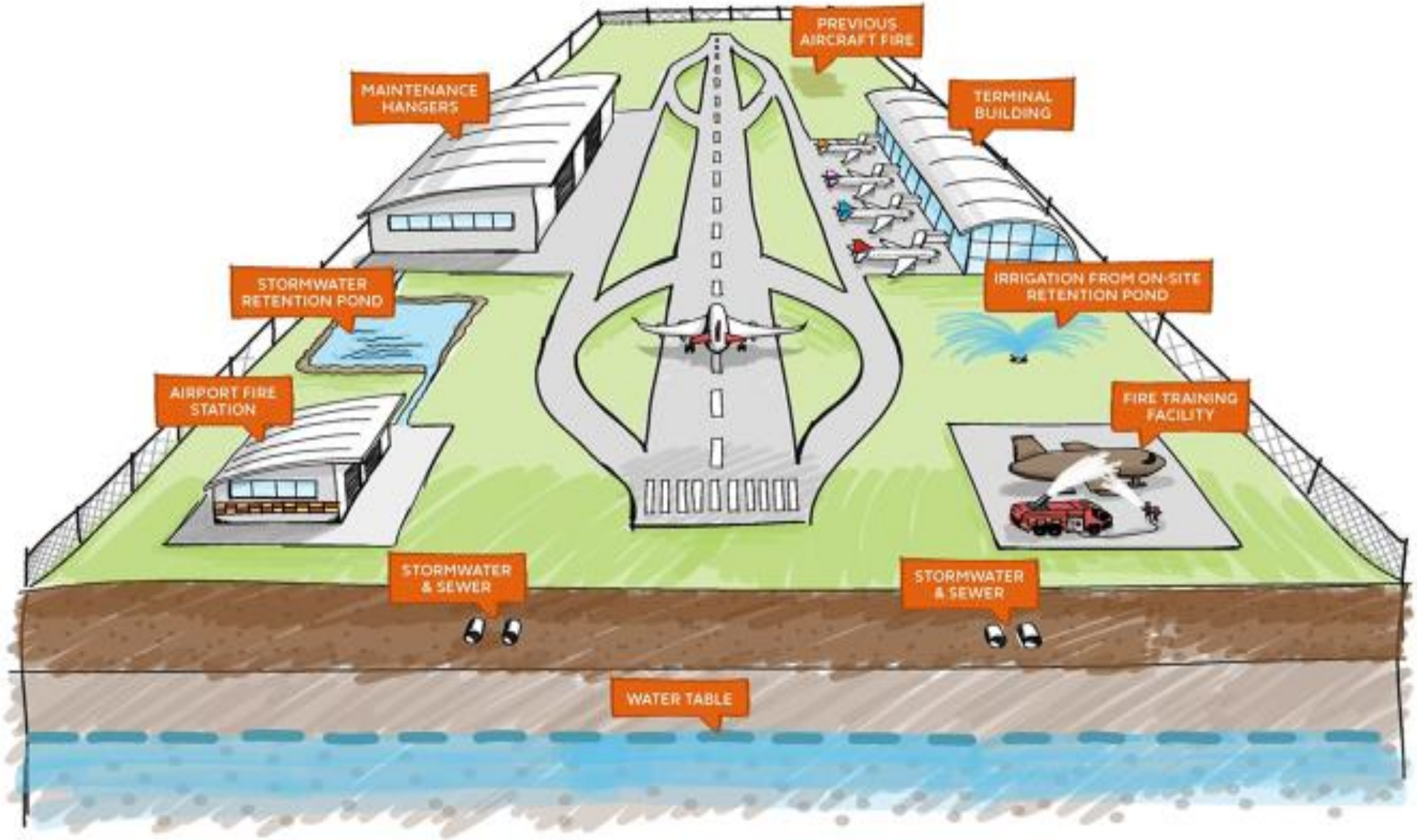
Fire Station

AFFF Storage Areas

Hangar Suppression Systems

Storm Water Drainage

Equipment Testing


PREVIOUS AIRCRAFT FIRE
MAINTENANCE HANGERS
TERMINAL BUILDING
STORMWATER RETENTION POND
IRRIGATION FROM ON-SITE RETENTION POND
AIRPORT FIRE STATION
FIRE TRAINING FACILITY
STORMWATER & SEWER
STORMWATER & SEWER
WATER TABLE

AECOM

Sampling Considerations

- Purpose
- Locations
- Procedures
- Analytical Methods

Sampling Considerations

- Purpose
  - Nature of Investigation
  - Extent of Investigation
  - Potential Pathways
    - Drinking Water, Groundwater, Surface Water, Storm Water
  - Soil Movement

Sampling Considerations

- Locations
  - Historic Use Areas
  - Accident Areas
  - Storm Water
  - Movement of soils on property can create multiple locations

Sampling Considerations

- Procedures
  - Quantification levels - how low?
  - How many compounds to sample for - what method?
  - Cross contamination from decontamination water - sample it before you use it
  - QA/QC, how about that QAPP?

Sampling Considerations

- Analytical Methods to Consider
  - EPA 537.1 and EPA Method 533 (Drinking Water)
  - LC MS/MS, Isotope Dilution Method (all other media)
- ASTM D7979 (water)
- ASTM D7968 (soil)
- DOD QSM 5.3 (QA protocol)

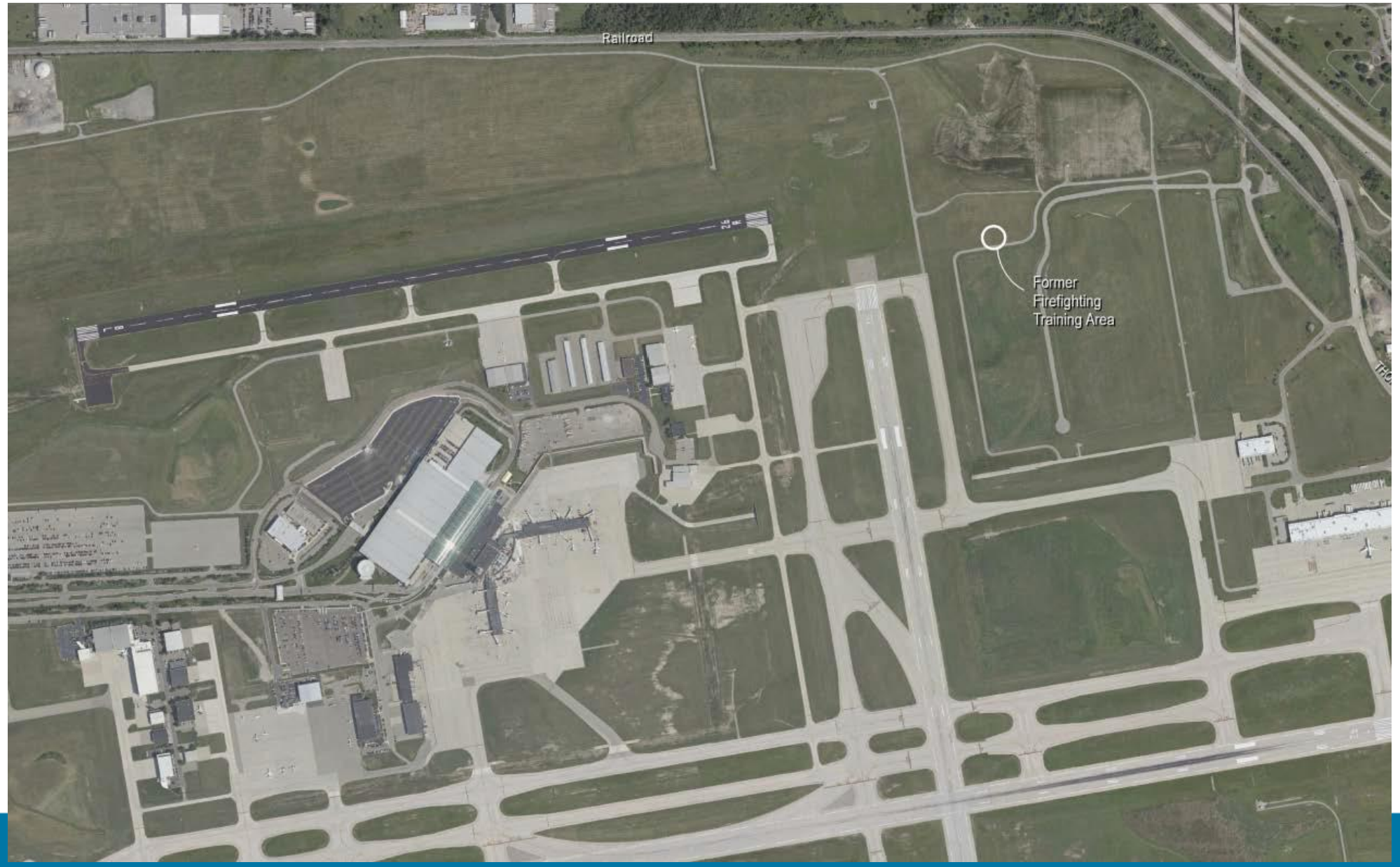
Michigan PFAS Groundwater Clean-up Criteria and Drinking Water Standards

Compound	Michigan Standards
PFNA	6 ppt
PFOA	8 ppt
PFOS	16 ppt
PFHxS	51 ppt
GenX (HFPO-DA)	370 ppt
PFBS	420 ppt
PFHxA	400,000 ppt

Michigan Airport Grants

- MI awarded grants to 19 airports in the fall 2020 to conduct testing at commercial services airport
- Up to $250,000 grant per airport
- Two rounds (RFPs) were done to allocate the funds
- Grants had two conditions:
  - Had to submit Phase 1 results and proposed phase 2 plans to MDOT and EGLE for review/approval
  - Had to follow EGLE sampling protocols
- Grant funds were generally used for soil, groundwater, and storm water sampling on-site
- In some cases, EGLE sampled residential wells, groundwater, and surface water around the airports

On-Site Investigations



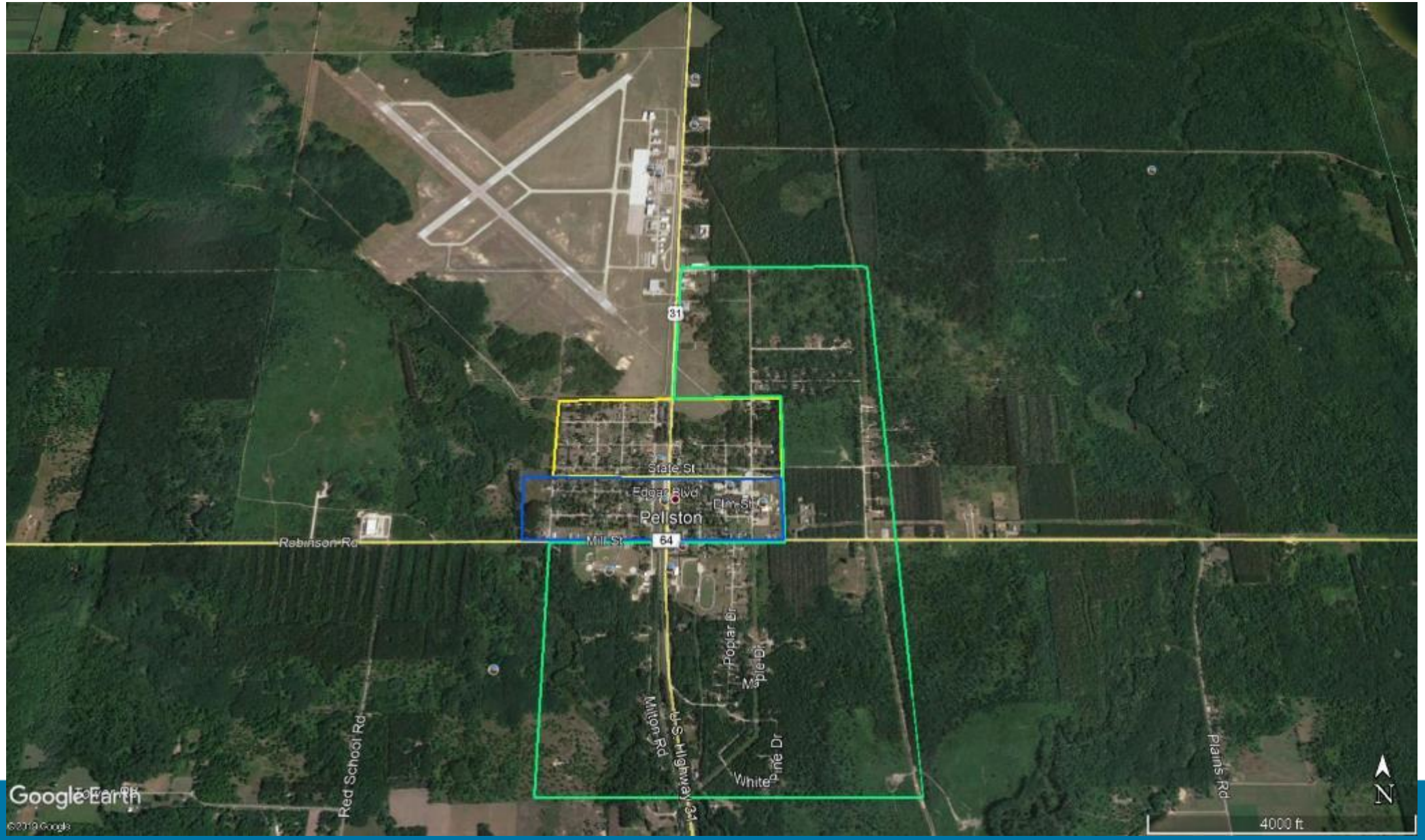
Michigan Airport Grants - Findings

- One entity did not follow all protocols – used an untested hose for decon water
- Otherwise, having the 2 grant requirements worked well
- Recommend having a Phase 1 results call with the airport, contractor, remediation and water staff; discuss proposed phase 2 work, too
- If AFFF was used to fight a fire/accident, for training or testing, or was spilled, you can expect to find it in soil, groundwater or surface water

Michigan Airport Grants - Findings

- Highest groundwater result was 730,000 ppt PFOS
- Highest storm water result was 9,100 ppt PFOS
- Surface water sampling was done by EGLE staff near many of the 19 airports
- EGLE sampled res wells adjacent to all of these airports if any were found to exist after reviewing res well data in a state-wide database and in consult with the local Health Department
- DHHS and local health lead the health response (notifications, bottled water, filter units) for res well sampling

Off-Site Investigations



Next Steps

- Airport grants need to be finished by early spring 2021
- Airports will have ongoing obligations to delineate plumes, address storm water issues per any storm water permits, and conduct interim responses/remediation efforts

Michigan PFAS Action Response Team (MPART)

www.Michigan.gov/PfasResponse

Progress in Enhancing Performance of PFAS-free Foams (PFFs) against Military Specification Criteria

Dr. Satya P. Chauhan
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Presented to Wisconsin Dept. of Natural Resources
October 15,2021

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Agenda

- SERDP and ESTCP R&D program on replacing AFFF for military applications
- Objectives of ESTCP-funded Battelle Projects
- PFF products and vendors
- Results for environmental, corrosion, and other properties
- Selected technologies to enhance firefighting performance
  - Compressed Air Foam (CAF); Ultra High Pressure (UHP); Additives
- Firefighting performance data
- Key points and future plans

SERDP and ESTCP Programs on AFFF Replacement for Firefighting

- SERDP is supporting R&D on emerging PFFs that have better firefighting performance than COTS PFFs
  - Initiated evaluation of toxicity of COTS and emerging PFFs
  - Just initiated R&D program to develop functional additives to enhance performance of PFFs
- ESTCP is funding validation testing of COTS and maturing PFFs as well as alternative foam delivery technologies
- Supporting compliance with NDAA of FY20
  - Prohibition on use of AFFF for on-shore use beginning Oct 1, 2024
  - Navy to publish new Mil-Spec for PFFs by Jan 31, 2023 and ensure that such agents are available no later than Oct 1, 2023

Objectives of Battelle's Projects

- Assessment, optimization, and demonstration of 16+ mature PFFs against MIL-PRF-24385F
- Assessment including
  - Environmental (LC_{50}, IC_{25})
  - Corrosivity
  - Fire Performance (extinguishment time and burnback time)

- Optimization of PFFs using commonly available technologies
  - Compressed Air Foam (CAF)
  - Ultra-high Pressure (UHP)
- Demonstration/Validation against military relevant firefighting scenarios
- Technology Transition

Candidate PFF Product and Vendor Names

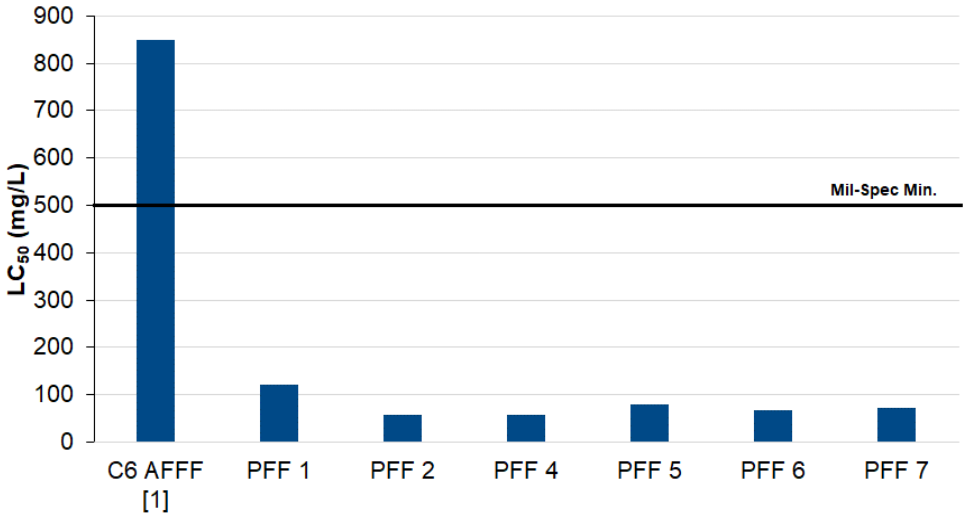
WP19-5299 ESTCP Project	WP20-5335 ESTCP Project
Enviro USP 2-3%/ Fomtec®	Phos-Chek® FF 1%/ Phos-Chek®
Re-Healing™ 3%/ Solberg	Ecopol Premium/ BioEx
Phos-Chek® FF 3-6%/ Phos-Chek®	Novel foam/ BioEx
Ecopol A and Ecopol A+/ BioEx	Pyrocool®/ Pyrocool
FireAde®/ Fire Service Plus	FireBull/ Fire Service Plus
Avio® Green (Jet Foam)/National Foam (Jet/Angus)	GFFF/ Green Fire
Universal Green/ National Foam	Avigard/ Solberg
Novacool UEF/ Novacool	FT Slam/ Fire Terminator

Performance Objectives

Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Quantitative Performance Objectives (Laboratory-based Mil-Spec Testing)			
Corrosion	As described in MIL-PRF-24385F	• Corrosion rates for 4 substrates	• 3 PFFs passed all • 3 PFFs with partial failures • More being tested
Environmental Impact	• LC_{50} /IC_{25} • Ultimate Biological Oxygen Demand (BOD_{20}) • Chemical Oxygen Demand (COD)	• $LC_{50} > 500 \frac{mg}{L}$ • $\frac{BOD_{20}}{COD} < 0.65$ • $COD < 1{,}000k \frac{mg}{L}$	• No PFF passes • C6 AFFF does not pass BOD_{20}/COD • BOD and COD complete for 13/16 products
Other Physical Properties	• Viscosity • Refractive Index • pH • Spreading coefficient (surface and interfacial tension)	• $Viscosity(25℃) > 2\ cSt$ • $Viscosity(5℃) < 20\ cSt$ • $Refractive\ Index > 1.3630$ • pH (7.0-8.5) • $Spreading\ Coeff > 3$	• No PFF meets all requirements; all fail spreading coefficient • Some PFFs are highly non-Newtonian • Complete for 13 of 16 products

Environmental Impact

- LC_{50} and IC_{25} data obtained for fathead minnows
- LC_{50} for as-rec'd PFFs is 50-100 mg/L (EPA Tox Category: Slightly Toxic)
  - As-delivered foam value is 1,500-3,000 mg/L
- All PFFs fall below the 0.65 BOD20/COD spec (typically 0.3-0.4)
- All PFFs pass the COD requirement of <1,000,000 mg/L



[1] Schaefer, T. (2013). *Aquatic Impact of Firefighting Foams* [White paper]. Retrieved January 23, 2020 from Solberg Foam: https://www.solbergfoam.com/getattachment/b1698ff8-e0f5-4e09-b3ac-426a59c4bb7e/WP-Aquatic-Impact-of-AFFF-F-2012007.aspx

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Corrosion and Various Physical Properties

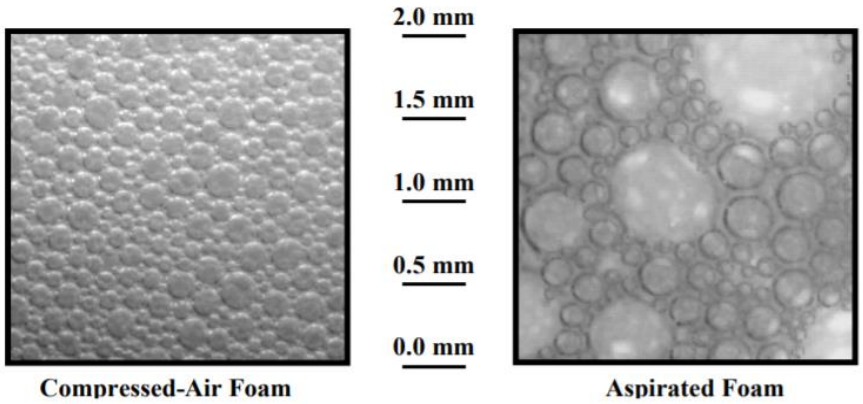
- MIL-SPEC corrosion testing to date indicates that the primary concern is with failures for the C70600 Cu-Ni coupons for several PFFs
  - Diluted 10% by volume in seawater; metal coupons submerged for 60 days
- Some products marginally failed specs for physical properties like pH and refractive index, but these have no bearing on fire performance
- No PFFs have a positive spreading coefficient or exhibit inherent film-forming behavior; values are 0.0 to minus 5.0 vs. spec of ≥3.0.
- The Mil-Spec requires viscosity of ≥2 cp at 25℃ which all PFFs meet
  - Some are highly non-Newtonian and far exceed the maximum spec viscosity of 20 cp at 5℃

Firefighting Performance Objectives

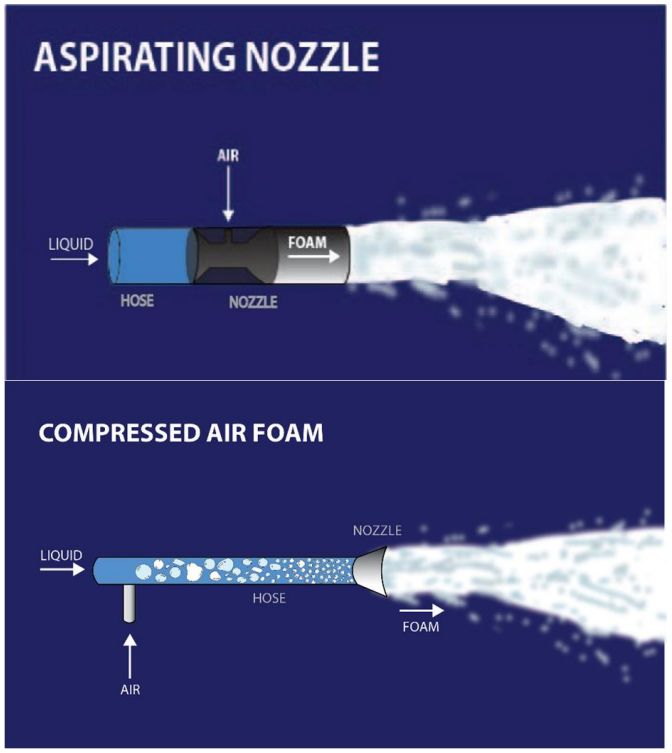
Performance Objective	Data Requirements	Success Criteria	Success Criteria Achieved?
Quantitative Performance Objectives (28-ft^2 Mil-Spec, Gasoline Fires)			
Foamability/Drain Time	As described n MIL-PRF-24385F	• 25% foam drain time ≥150 s • Foam expansion ≥5	• Yes
90% Control	• Heat Flux	• NA	• NA
Fire Extinguishment	• Stopwatch	• Extinguishment time ≤30 s	• No
Burnback/Cold Burnback	• Stopwatch • Heat flux	• Burnback time ≥360 s	• Yes for 5 of 7 PFFs • Yes for 1 other with CAF only
Qualitative Performance Objectives (20-ft diameter and 91-ft Diameter Fuel Fires)			
Handling/usability	• Testing notes	• Fire control and extinguishment	• Yes for 20-ft diameter

CAF vs. Air-aspirated Foam

- More uniform bubble distribution influences foam stability
  - Measured by 25% drain time



Laundess, A. J., et.al., Fire Technology, 47(1), 149-162



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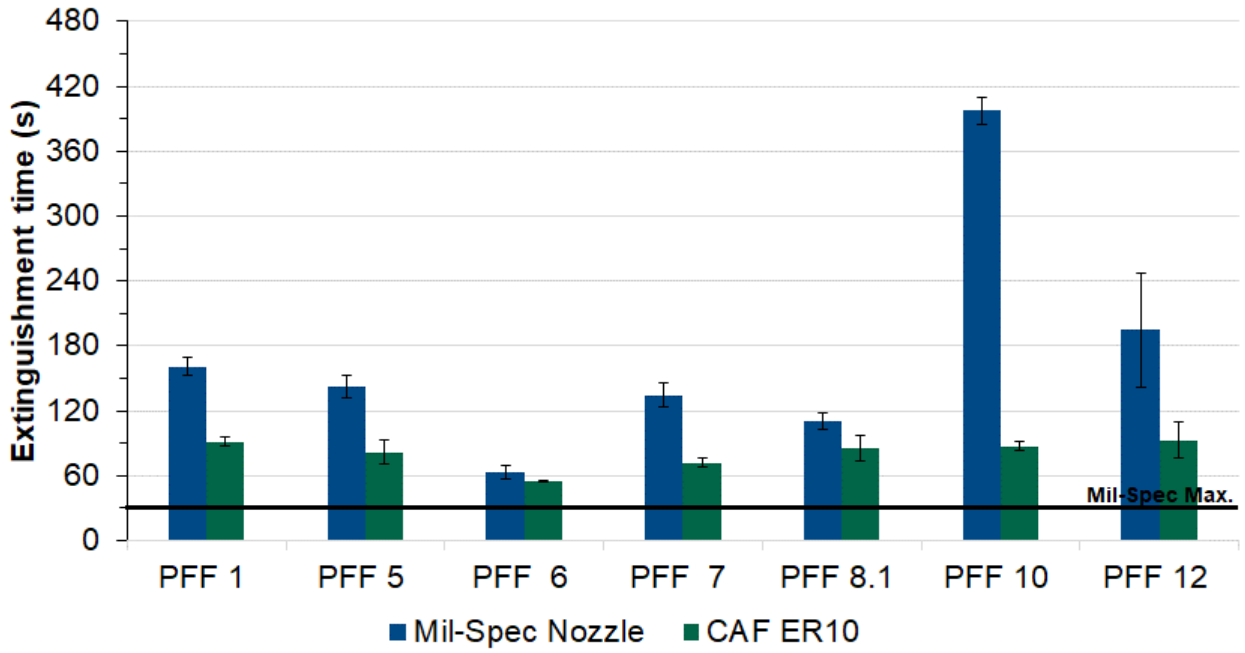
Site Description-SKY X Fire Hanger

- **AFCEC/Tyndall AFB**
  - Located near Panama City, FL
- **Mil-Spec Fire Testing**
  - 28-ft^2 fires

Extinguishment Time vs. Foam Delivery Method – E10 Gas

- Average reduction of 47% in extinguishment time with CAF



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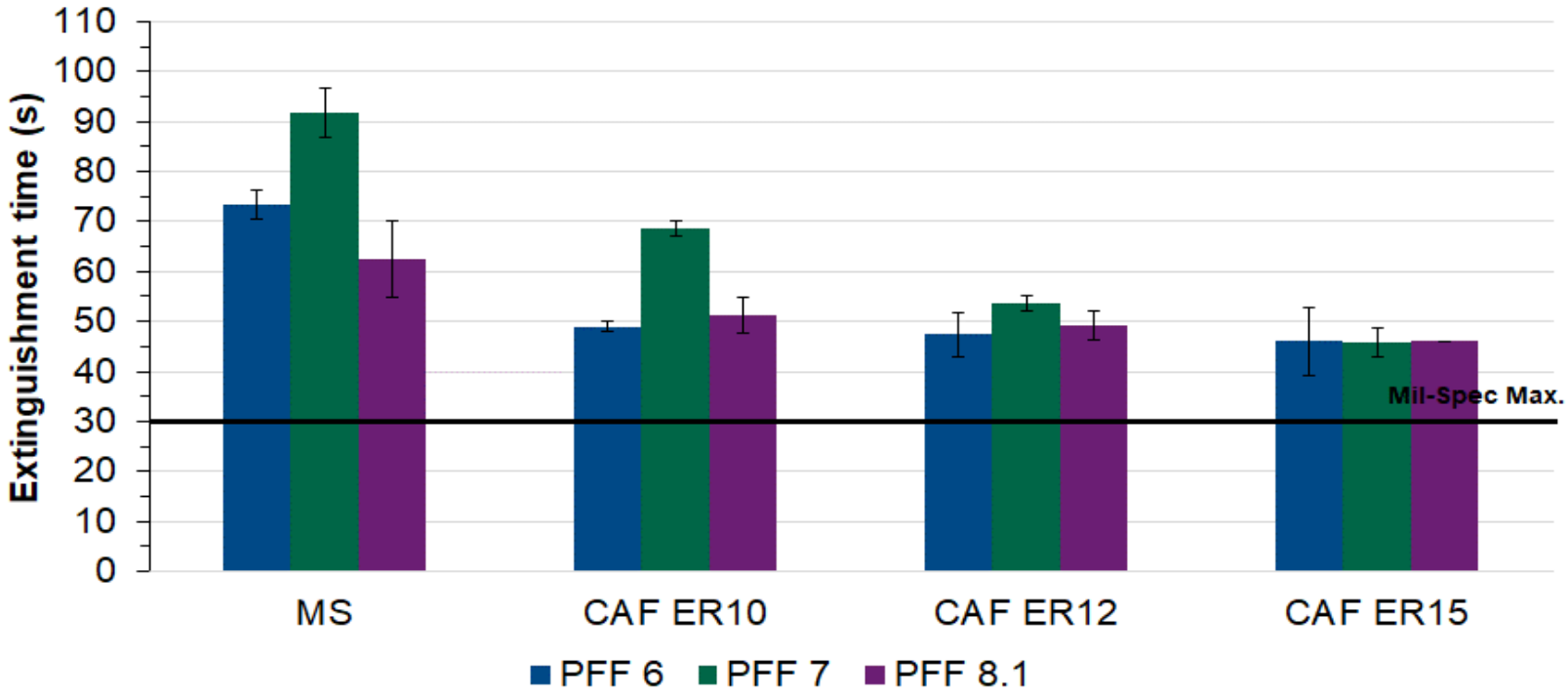
Extinguishment Time vs. Foam Expansion Ratio – Ethanol-free Gas

- Average 39% decrease in extinguishment time; optimum near foam Expansion Ratio (ER) of 12



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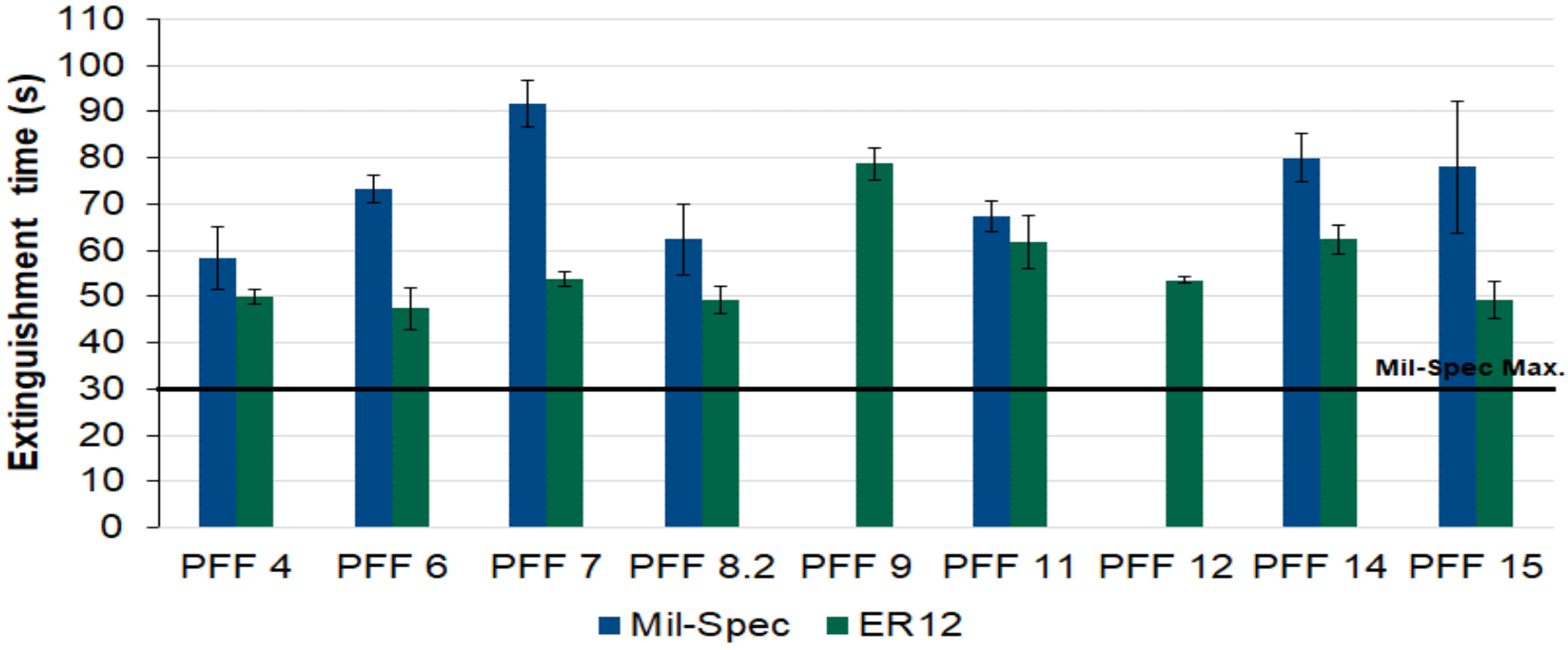
Extinguishment Time– E-free Gas at Optimum Foam Expansion Ratio of 12

- Average ~20 seconds (40%) reduction in extinguishment time (25% w/o PFF 9)



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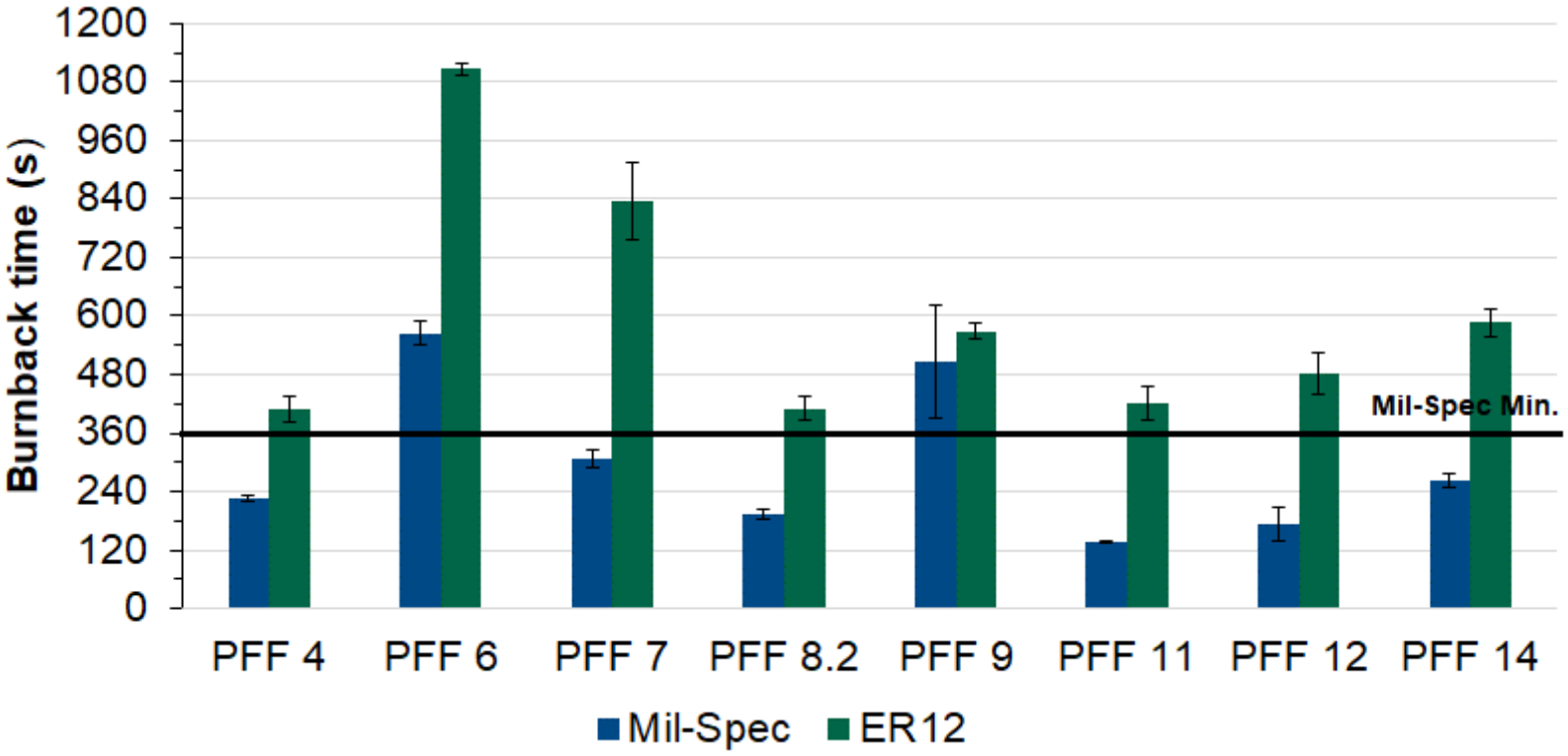
Burnback Time for WP20 PFFs – E-free Gas

- Average 100% increase in burnback time
- All CAF data at optimum ER of 12



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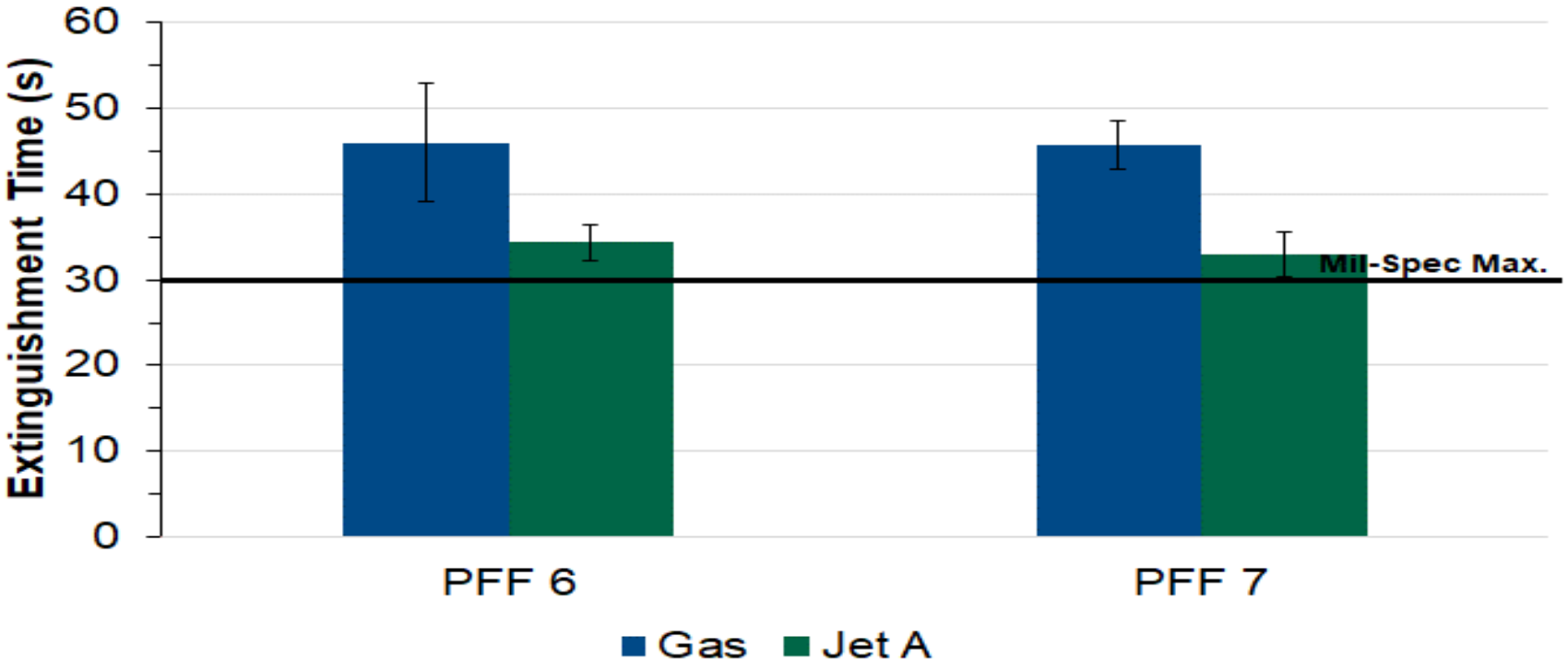
Extinguishment time – E-free Gas vs. Jet A Fuel

- Extinguishment time for Jet A fire is about 27% lower than for E-Free gas with CAF at ER 15



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Mil-Spec-scale Testing Summary for PFFs Selected for Large-scale Fire Testing

Product	Mil-Spec Extinguishment	Mil-Spec Burnback	Optimum CAF Extinguishment	Optimum CAF Burnback
PFF 4	58±7	226±4	50±3	407±26
PFF 6	73±3	565±25	46±7	1088±54
PFF 7	92±5	308±20	46±3	755±32
PFF 8.2	62±8	195±10	46±0	451±26
PFF 12	195±65	198±44	54±.7	Pending
PFF 15	78±14	262±15	49±4	586±29

Site Description-Silver Flag Training Site

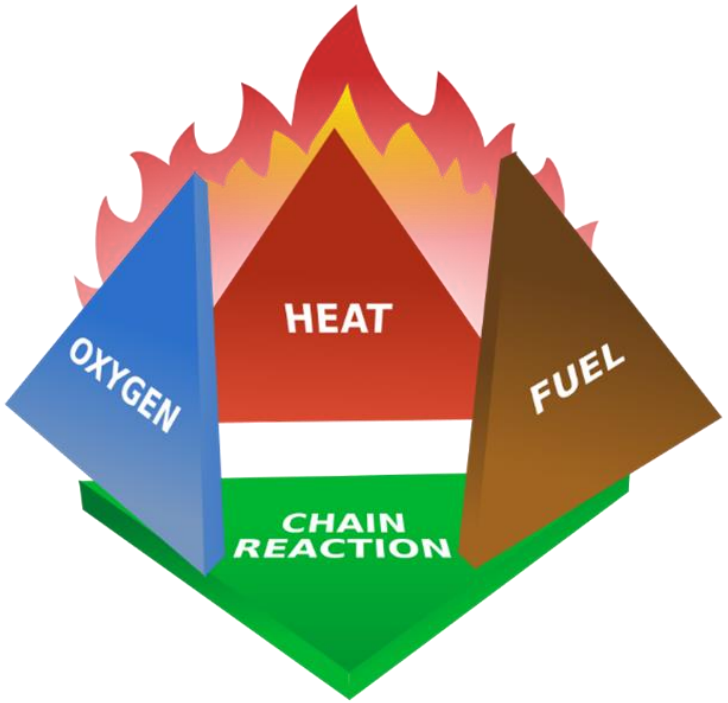
- **AFCEC/Tyndall AFB**
  - Located near Panama City, FL
- **Large Fire Testing**
  - 91-ft diameter (6,504-ft^2) fire training pit
  - Outdoor facilities at Silver Flag training area
  - Home to RED HORSE (Air Force Rapid Engineer Deployable, Heavy Operational Repair Squadron)

Large-scale Fire performance- CAF at 454-ft^2 Fire Size

- Initial results with Jet-A fire (454-ft^2 at 0.053 gpm/ft^2 application rate)
  - PFF 8.2: 33, 32, and 33 seconds
  - PFF 6: 28, 26, and 28 seconds; compared to 35 seconds at 28-ft2

Ultra High Pressure (UHP) Technology

- Truck pressure 1100−1400 psi
  - Typically uses aspirating nozzle
- Reduces foam application rate
- Small droplet size enhances cooling effect
  - Can be combined with dry chemical to take out three sides of the “Fire Tetrahedron” at once to improve firefighting



Large-scale Fire performance- UHP

- A 454-ft^2 fire set up using a 24-ft diameter fire ring was set up and tested with a P-34 fire truck with UHP capability, using Jet-A fuel
  - The extinguishment times with PFF 8.2 were 44, 55, and 82 seconds, at an application rate of 0.030 gpm/ft^2 (42% of Mil-Spec application rate)
  - The results are encouraging, so we are continuing with testing other down-selected PFFs
  - Also plan to test using a smaller, 314-ft^2 size to achieve higher application rates, to see if the fire extinguishment time can be reduced

Key points

- No PFFs tested so far meet the Mil-Spec
  - Aquatic, acute toxicity EPA Category: “Slightly Toxic”
  - Viscosity of several leading products is very high; may require equipment changes to reduce handling problems
  - Some products have corrosivity concerns
- All fail fire extinguishment time requirements and a few fail burnback time requirement
  - Extinguishment times reduced with CAF by and average of 40+%
  - Burnback times increased with CAF by an average of 100+%, making several marginal PFFs meet the Mil-Spec
  - The top 3 products have very similar extinguishment times of ~45 seconds at optimum CAF conditions and near 30 seconds for Jet A (~35% lower)
- Six (6) PFFs have been down-selected for field-scale testing (PFFs 4, 6, 7, 8.2, 12, and 15), which have extinguishment times in 45-50 seconds range
- Scalability of CAF to 454-ft^2 size, for jet fuel, appears looks good so far

Remaining Testing

- Field-scale testing of CAF on 6 PFFs with Jet A at 6,504-ft^2 fire size
- Additional CAF testing at 314-ft^2 scale for 3 products @ 0.071 gpm/ft^2
- Exploration of 2-3 newly-developed PFFs, selected from recent SERDP testing
- Further exploration of best way to utilize UHP benefits
  - A 314 ft2 (20-ft diameter fire ring) set up ready for testing with E-free gasoline
  - Need to test at higher than the 0.030 gpm/ft2 explored so far
- Dual-agent testing (PFF plus Purple K) at 314-ft^2 fire size with E-free gasoline

Acknowledgements

- Dr. Bridgett Ashley (co-PI); AFCEC/Tyndall AFB
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DNR Updates, Conclusions & Next Steps