Management of PFAS in the Environment: Research & Demonstrations

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DoD's Environmental Technology Programs

Science and Technology

- Statutory program established 1991
- DoD, DOE, EPA partnership
  - ♦ Advanced technology development to address near-term needs
  - ♦ Fundamental research to impact real world environmental management

Demonstration and Validation

- Demonstrate innovative cost-effective environmental and energy technologies
  - ♦ Transition technology out of the lab
  - ♦ Establish cost and performance
  - ♦ Partner with end user and regulator
  - ♦ Technology transfer
    - ▪ Accelerate commercialization or broader adoption
    - ▪ Direct technology insertion

PFAS in the Environment

www.serdp-estcp.org

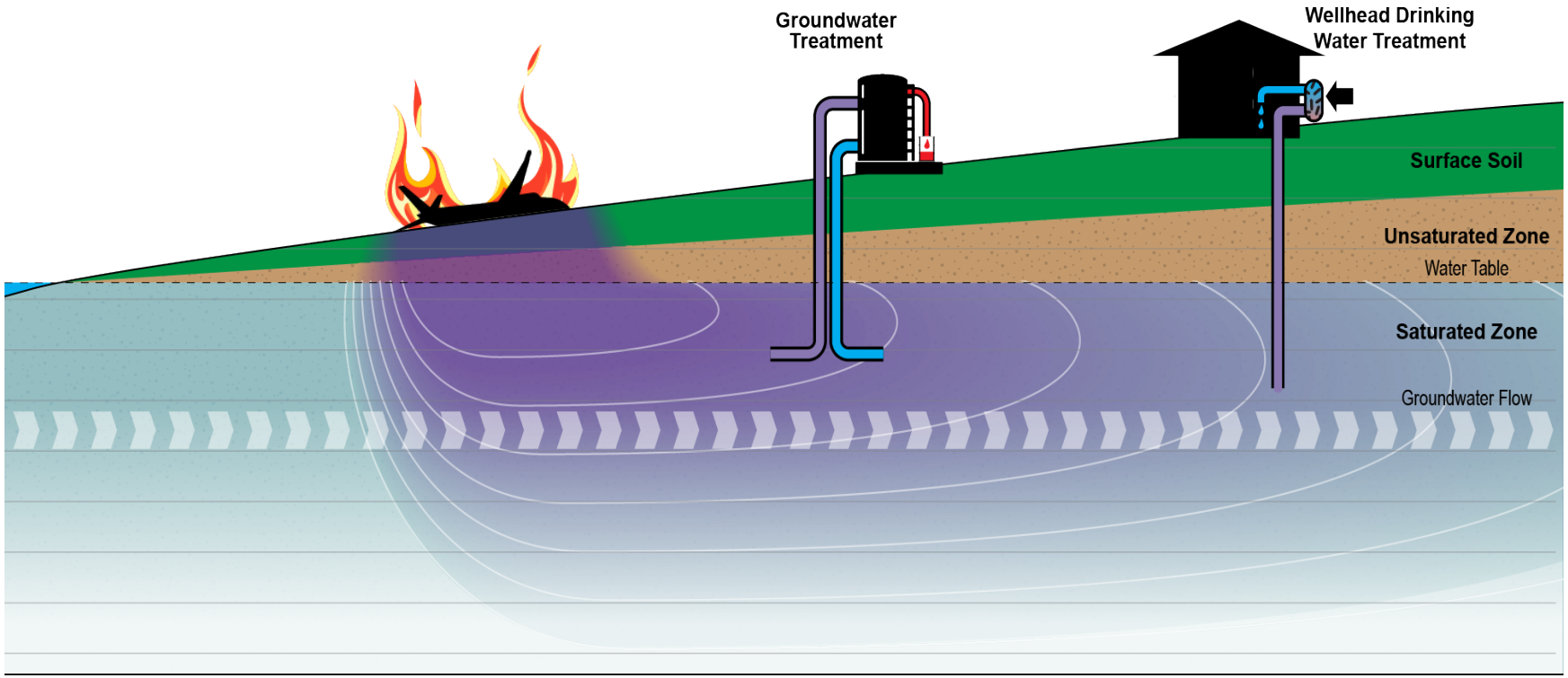
Major Lines of R&D & Demonstration Efforts on PFAS

- Cleanup of PFAS
  - Treatment technology development & assessment
  - Sampling and analysis
  - Fate and transport
  - Ecotoxicity
- AFFF Replacement
  - Development & demonstrations of PFAS-free firefighting formulations
  - Ecotoxicity

Research Impetus

- Develop, validate, and commercialize technologies to improve management and treatment of PFAS in the environment
- Successful projects implement cost-effective and efficient approaches

Conceptual Site Model



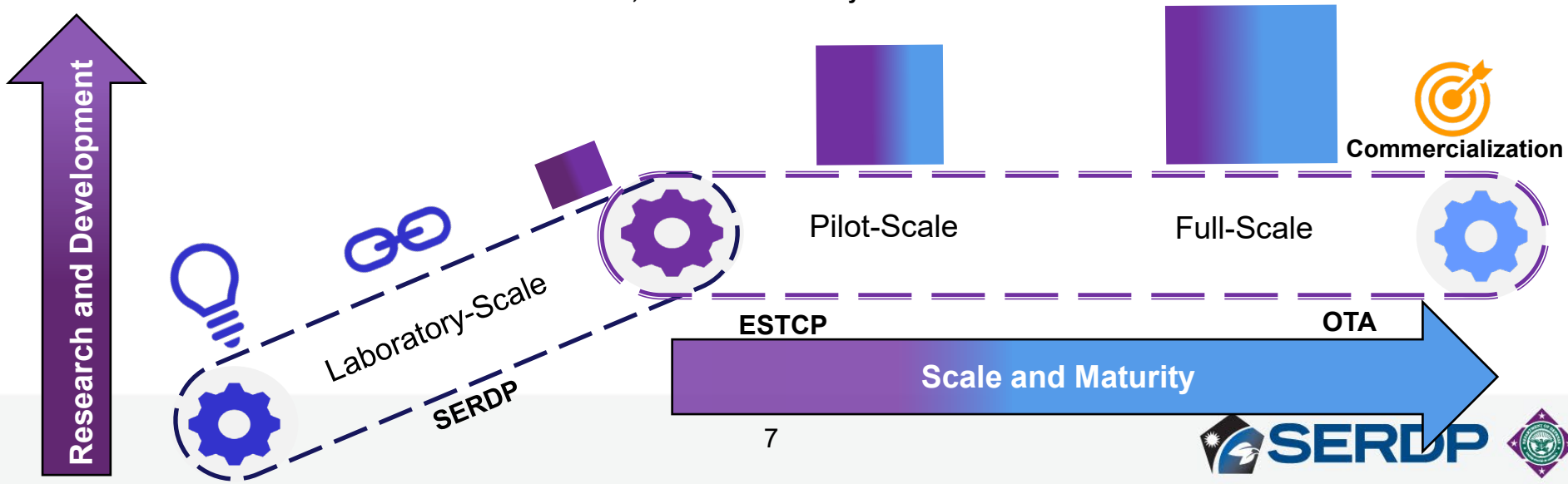
Systematic Efforts on PFAS Management

SERDP is the DoD's environmental and resilience science and technology program, planned and executed in partnership with the DOE and the EPA, with participation by numerous other federal and non-federal organizations. SERDP invests across a broad spectrum of basic and applied research, as well as advanced development.

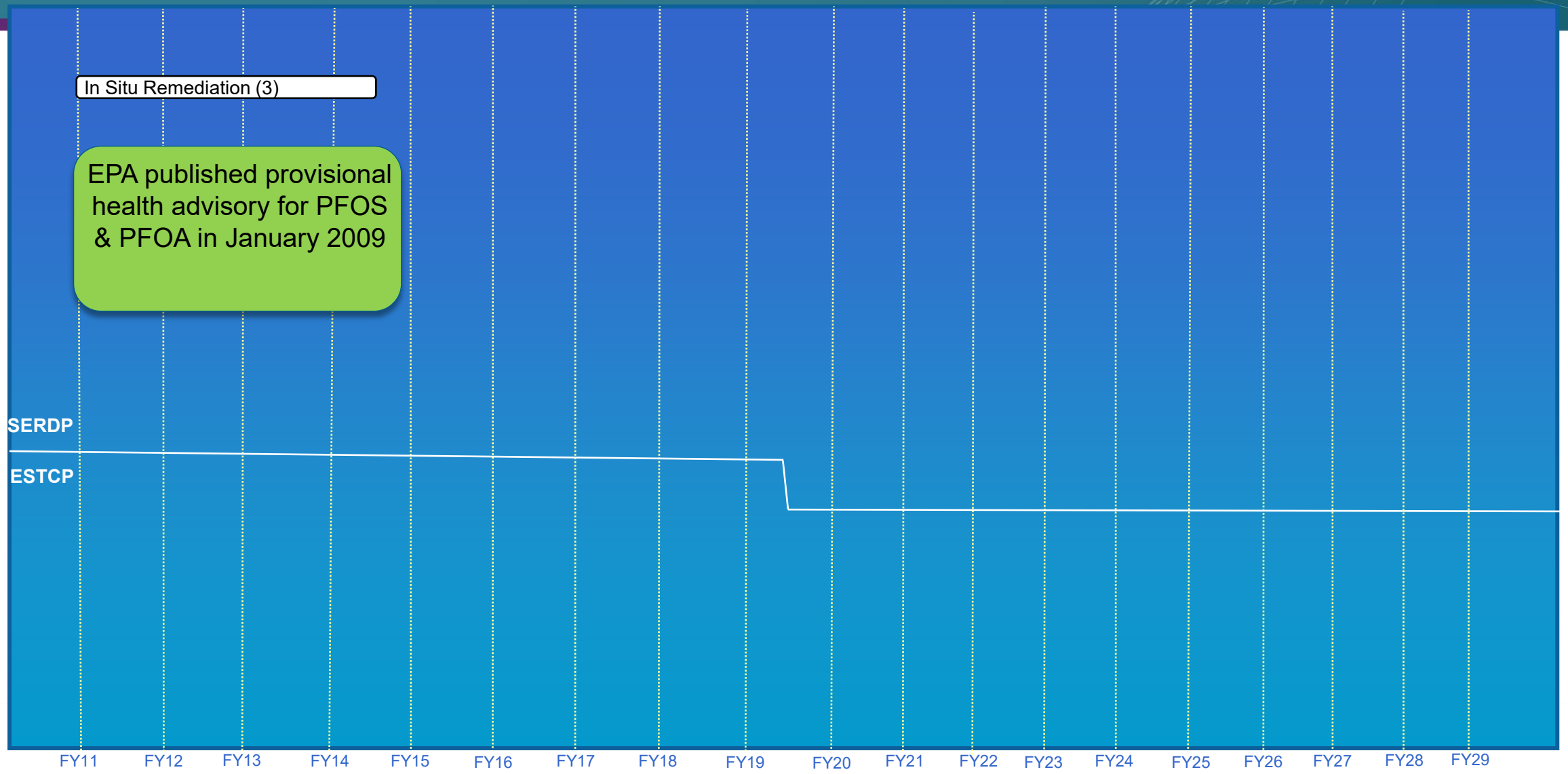
ESTCP is the DoD's environmental, resilience, and installation energy and water technology demonstration and validation program. ESTCP demonstrations collect cost and performance data to overcome the barriers to employ an innovative technology because of concerns regarding technical or programmatic risk, the so-called "Valley of Death."

Other Transactional Authority (OTA)

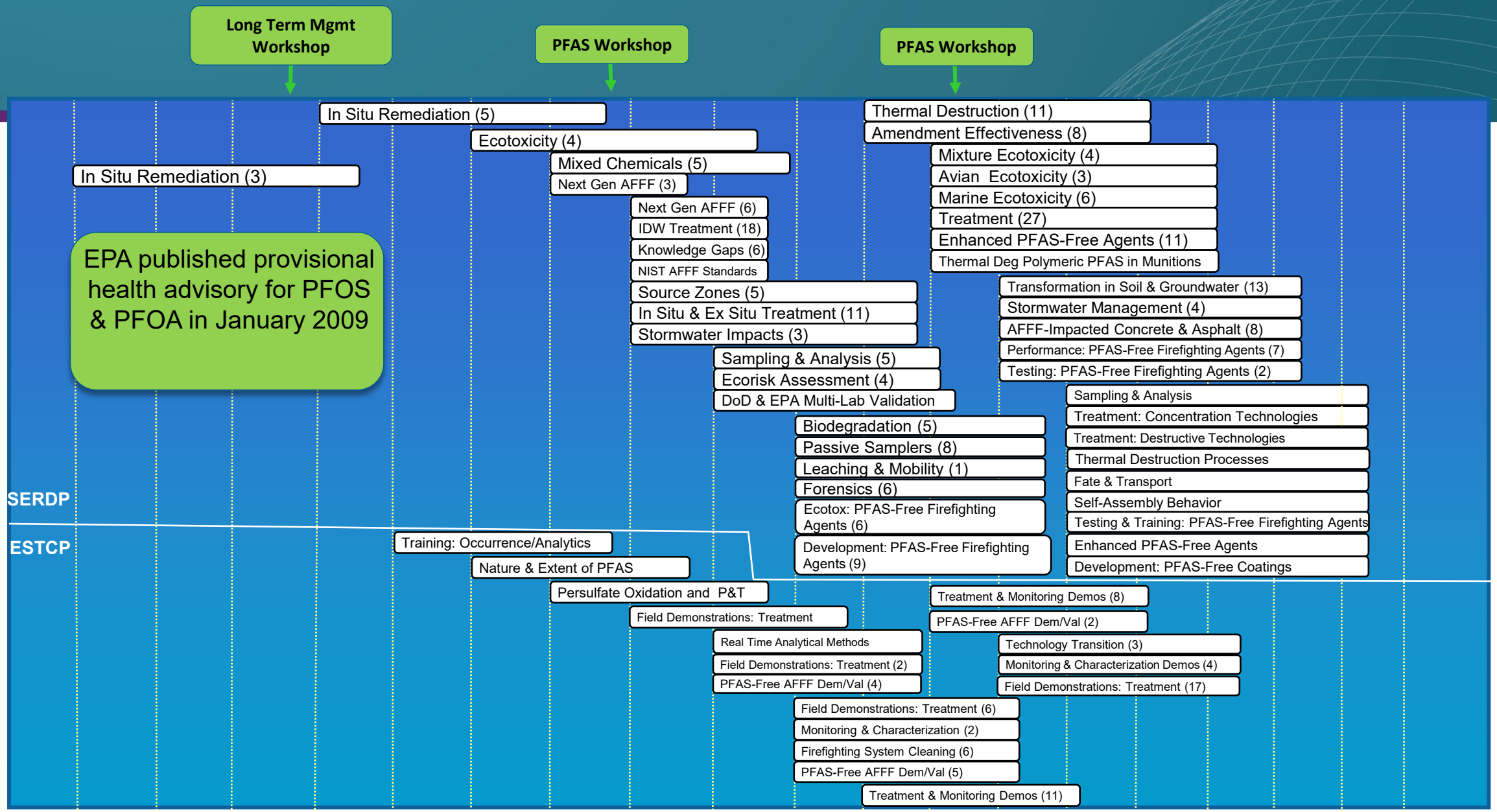
Contracting mechanism that allows federal agencies to streamline prototype development and production.



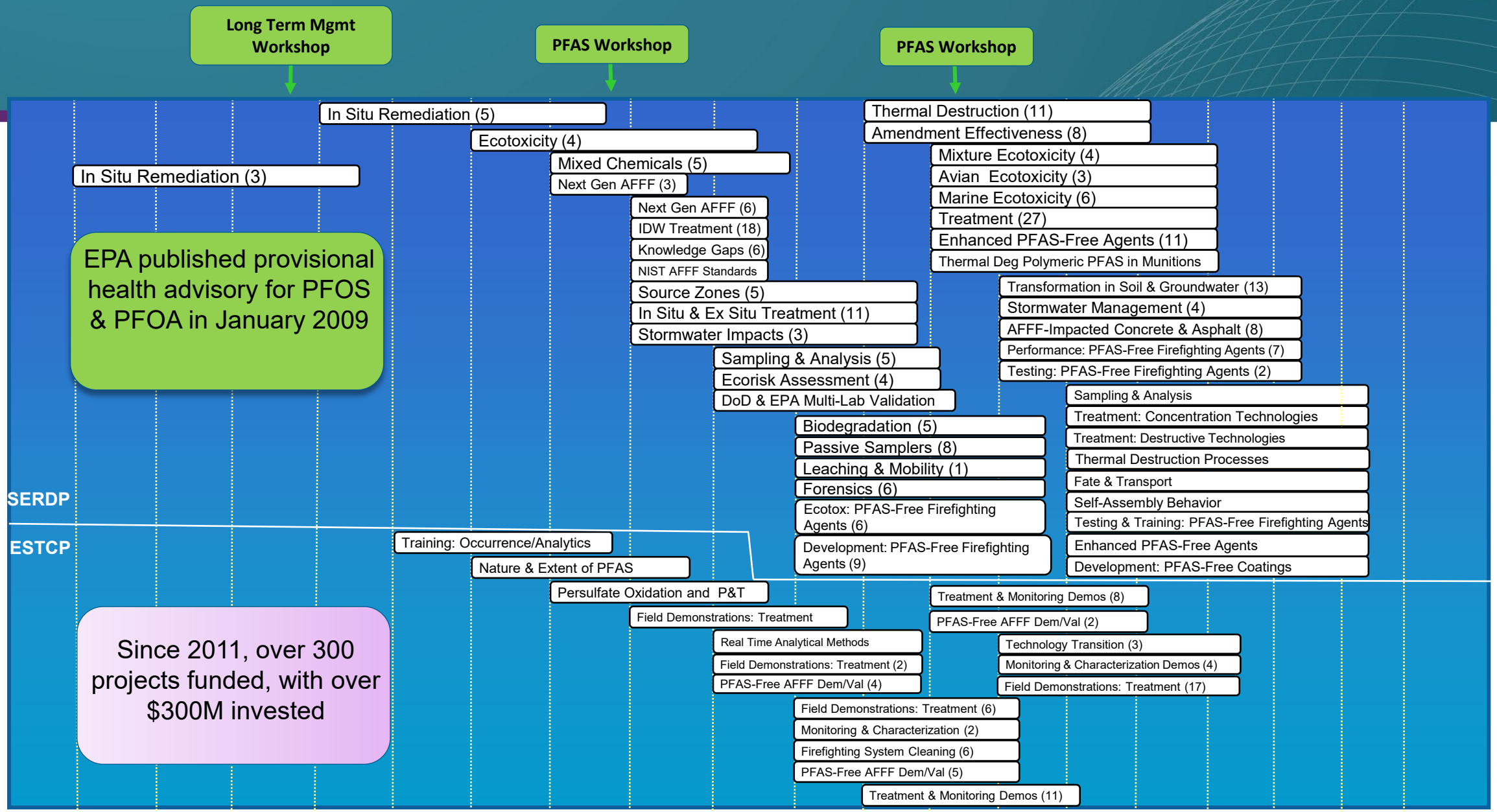
SERDP & ESTCP Efforts on PFAS



SERDP & ESTCP Efforts on PFAS

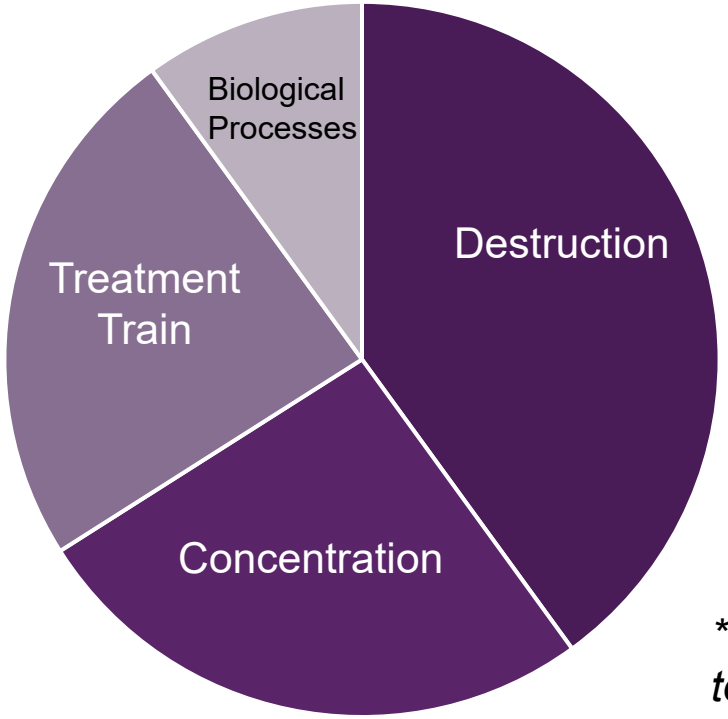


SERDP & ESTCP Efforts on PFAS



SERDP & ESTCP PFAS Treatment Projects

Classes of Treatment Technologies under Investigation



- Over 50 PFAS treatment technologies have passed proof of concept & are further in development and/or demonstration phase.
- All treatment projects are ultimately designed to reduce the amount of impacted material that must be landfilled or incinerated.
- Treatment projects are discussed in terms of the four categories shown.

**More than one project possible for some technologies.*

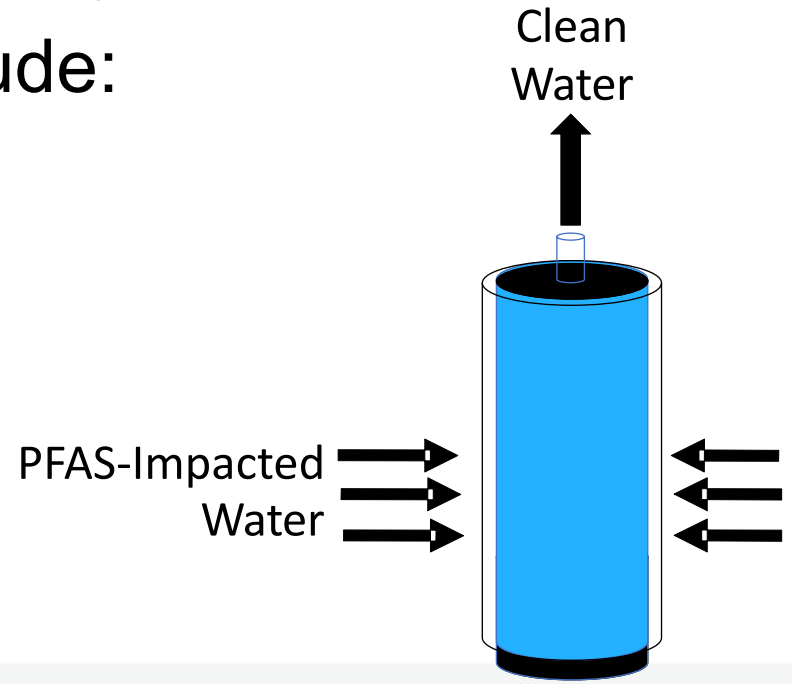
Destruction Technologies Under Investigation by SERDP & ESTCP

- Thermal processes
  - Low temperature thermal
    - Less energy intensive
    - Flexible application
  - Hydrothermal treatment
    - Liquid wastes
    - Less energy intensive
  - Smoldering combustion
    - Solid wastes
    - Less energy intensive

- Non-thermal processes
  - SCWO (super critical water oxidation)
    - High temperature, high pressure
    - Liquid wastes, potentially solids and concentrates
  - Plasma
    - Liquid and AFFF concentrate (testing)
  - Chemical & Catalytic Processes
    - Widely applicable to liquids and solids depending on process

Concentration Technologies Under Investigation by SERDP & ESTCP

- Not efficient to run destruction on low concentration wastes
- Often used as part of a treatment train, to concentrate PFAS, then use another process to destroy
- Concentration technologies include:
  - Modified GAC
  - New sorbents
  - Foam technologies



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Larger-Scale Demonstrations

Ex Situ Soil Treatment

- ACES Mobile Remediation System (Thermal desorption/thermal oxidation)
- STARx (smoldering combustion)
- Thermal conduction heating

Ex Situ Groundwater Treatment

- Regenerable ion exchange treatment
- Surface active foam fractionation (SAFF)
- Cyclopure cyclodextrin adsorbent (DEXSORB)

Excavated Sediments

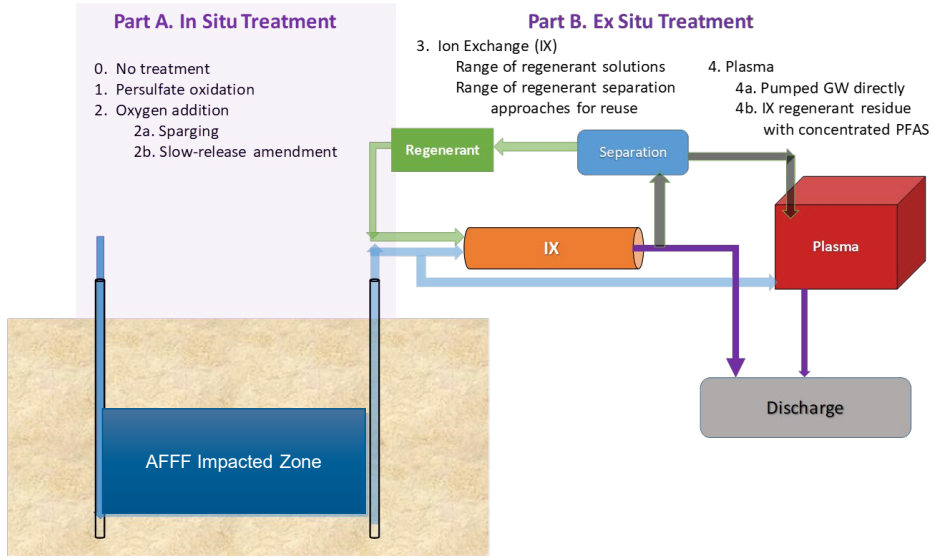
- Treatment train (ball milling, soil washing, plasma)
- Treatment train (PFAST, destruction)
- Smoldering combustion
- Thermal desorption

Concentrated Aqueous (Foam fractionate, still bottoms, IX regenerant)

- SCWO (PFAS Annihilator)
- SCWO (iSCWO)
- SCWO (AirSCWO)
- Hydrothermal alkaline treatment (HALT)

Treatment Trains Likely to be Necessary at Most Sites

- Treatment trains typically combine concentration and destruction technologies to achieve the best result
- Research is looking at best combination of technologies based on location (i.e., liquid, solids, etc.) and concentration of PFAS

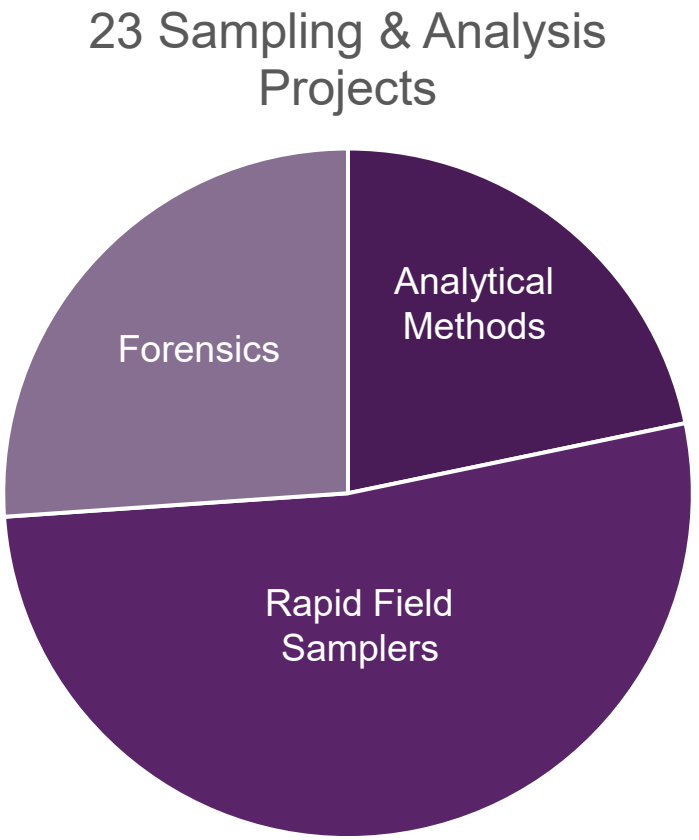


Treatment Summary

- PFAS treatment market is exploding (with many marketing claims)
- No one technology will meet the needs of all PFAS-impacted materials
- Technology assessment MUST evaluate several critical questions (i.e., destruction and removal efficiency, mass balance)
- Concentration most efficient for large dilute groundwater applications with residuals management
- Treatment trains are likely to offer best options for concentration and destruction

Sampling & Analysis Efforts

- Sampling & analysis efforts were initiated in FY18 to improve measurement of PFAS
- Focus has been on improving analytical methods, development of rapid field samplers, and forensics

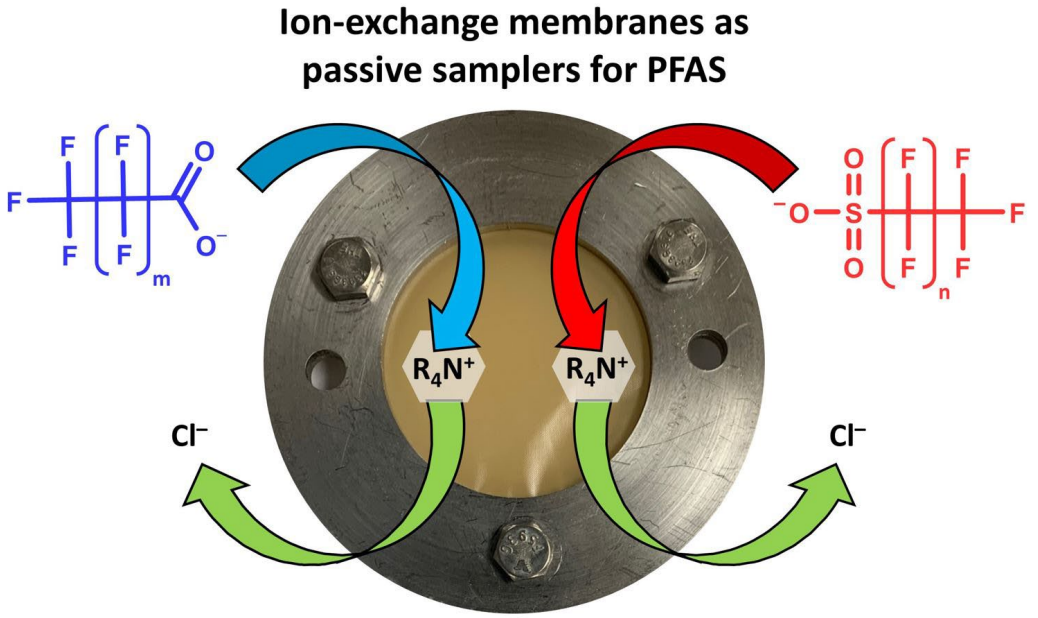


Development of EPA Method 1633 for PFAS Analysis

- Previous published analytical methods for PFAS were only for drinking water matrix
- Expansion to include other matrices:
  - Aqueous (groundwater, surface water, wastewater, landfill leachate)
  - Solids (soils, sediments, biosolids)
  - Tissues
- Draft method published in 2021; recently updated in January 2023
  - Involves developing then testing method at a commercial analytical lab
  - Commercial labs are adopting these methods now
- Next step – test method at multiple commercial labs
  - In process
  - Validation reports for each matrix will be published as they are completed, beginning in 2022

Project Highlight: Development of Ion Exchange Membranes and Fibers for Passive Sampling of PFAS (ER20-1073)

- **Background:** There is concern regarding the lack of standardized sampling procedures for PFAS in the environment. Passive sampling methodologies can provide repeatable and environmentally measures of PFAS present in soil, sediments, and water matrices. However, PFAS are chemically complex, and complicate traditional passive sampling approaches.
- **Objective:** This project will develop ion exchange membrane- and ion exchange fiber-based methodologies for passive sampling of PFAS. This effort will enhance PFAS monitoring and cleanup capabilities and will inform further development of ion exchange passive samplers for other chemicals of concern.
- **Project Lead:** University of Baltimore, Maryland County
- **Research Portfolio:** Funded in 2020.



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Status and Future Directions

- Joint effort with EPA on additional analytical methods has cleared the first objective with the next step in progress.
- Additional field sampling methods are in process with some validated.
- Forensics techniques showing promise for differentiating between AFFF and non-AFFF sources.
- Dozens of treatment options are under investigation with many having passed the proof-of-concept phase and others moving into field demonstrations.
- Future focus will be on demonstrating more treatment technologies in the field under actual site conditions.

Additional Resources

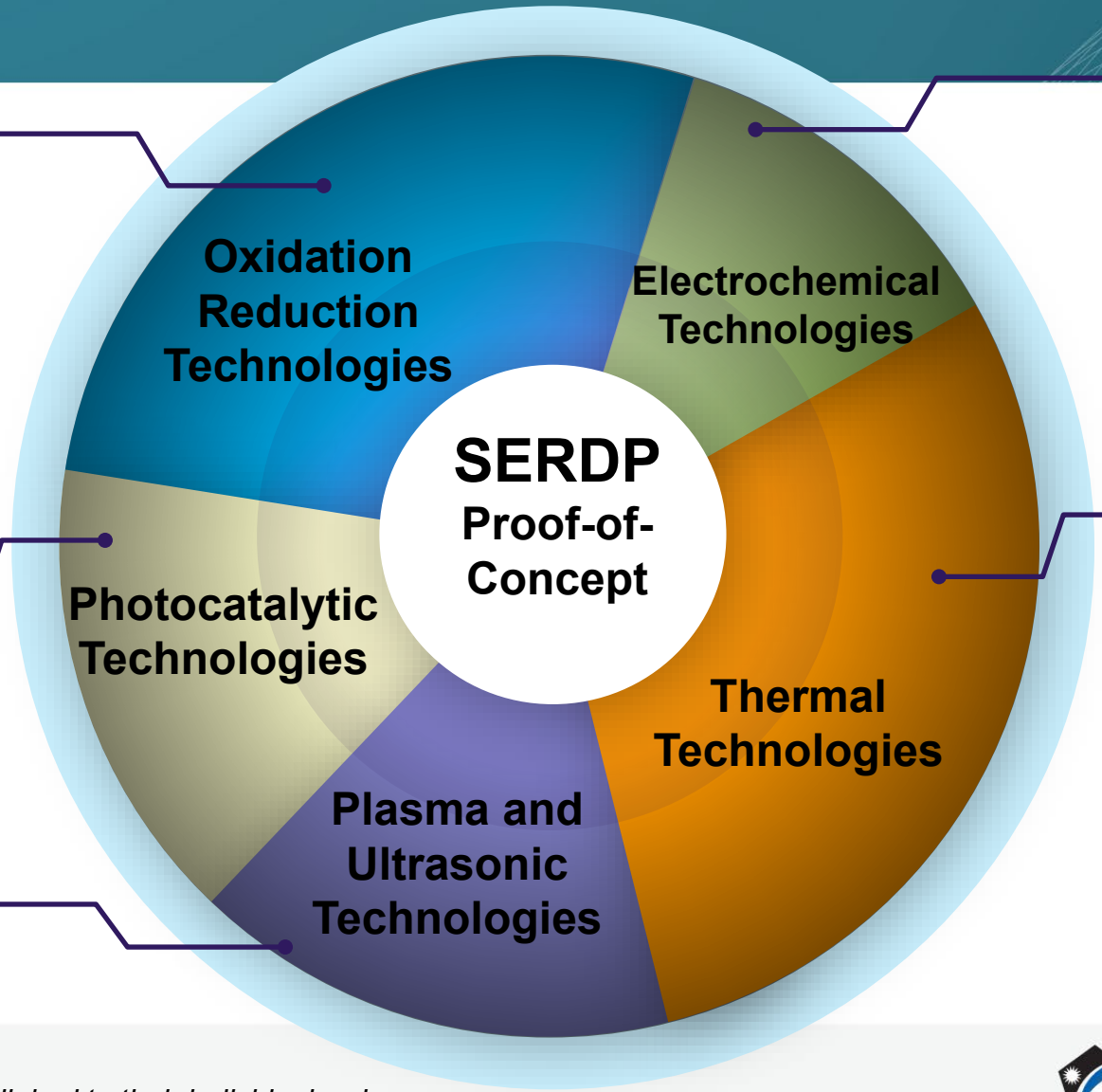
- For more information on PFAS-related projects funded by SERDP & ESTCP:
  - https://serdp-estcp.org/focusareas/e18ec5da-d0de-47da-99f9-a07328558149/pfas-afff

Backup

Management Approach

- Formation of PFAS Technical Workgroup
  - Comprised of representatives from Army, Air Force, Navy, EPA as well as technical consultants
  - Assist with selection and review of PFAS related projects
  - Assist with common location for collection of impacted soils and waters
  - Developed standardized documents to track QA for all projects
- Annual in progress review required to PFAS Technical Workgroup and Technical Committee
- Annual project meeting
  - All funded projects are represented via panel and poster presentations
  - Other federally funded projects also represented
  - Primary purpose is to provide time for investigators to view other research, form collaborative efforts, etc.
- Annual Symposium

Innovative Approaches for PFAS Destruction of Investigation Derived Waste: Proof-of-Concept



Project Number
ER18-1482
ER18-1497
ER18-1545
ER18-1526
ER18-1620

Project Number
ER18-1491
ER18-1595

Project Number
ER18-1513
ER18-1515
ER18-1599

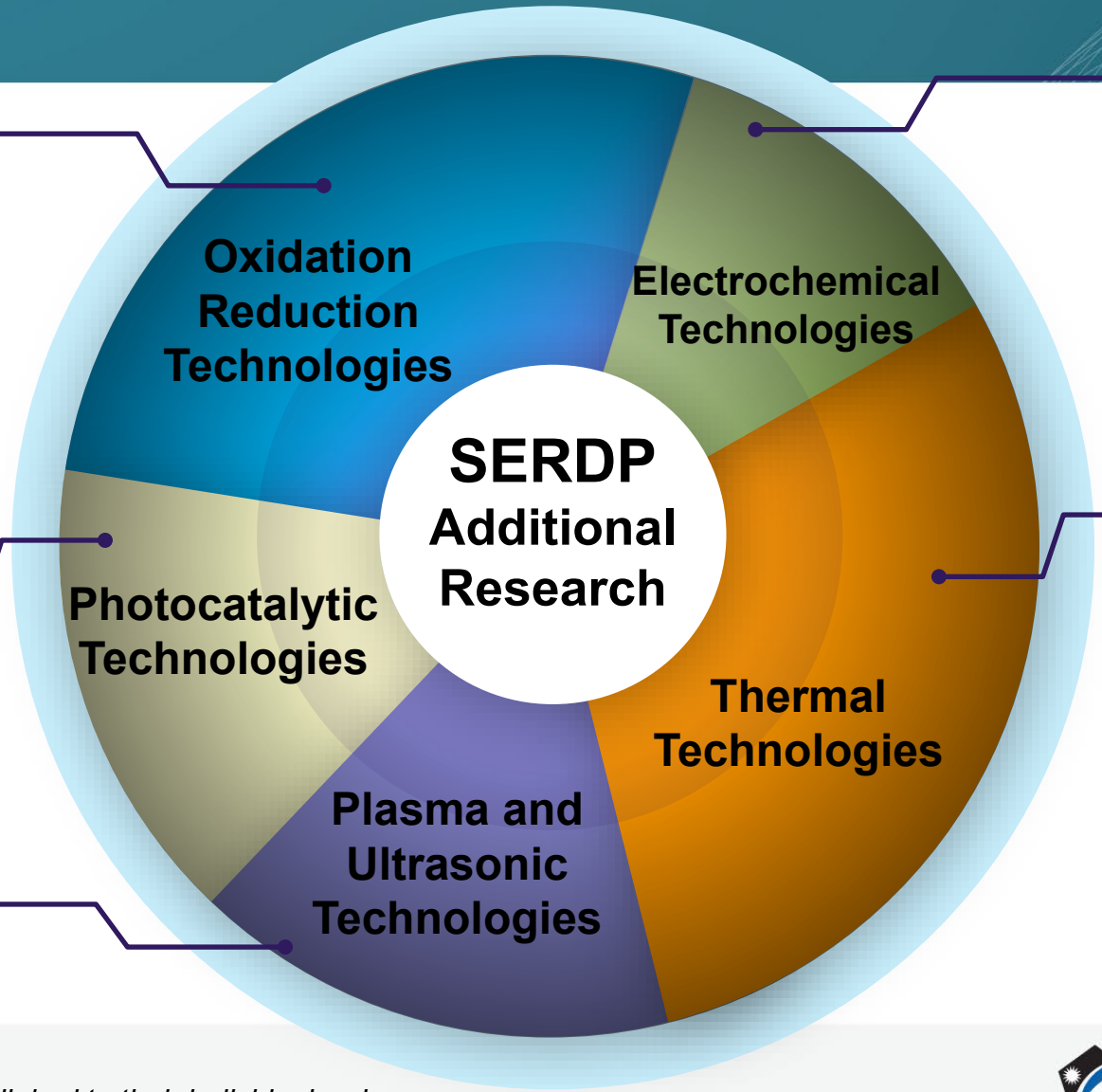
Project Number
ER18-1501
ER18-1556
ER18-1572
ER18-1593
ER18-1603

Project Number
ER18-1570
ER18-1624
ER18-1652

Projects were initiated under SERDP as a proof-of-concept

All project numbers are linked to their individual web pages

Additional Research under SERDP



Project Number

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ER18-1501
ER18-1556
ER18-1572
ER18-1593
~~ER18-1603~~

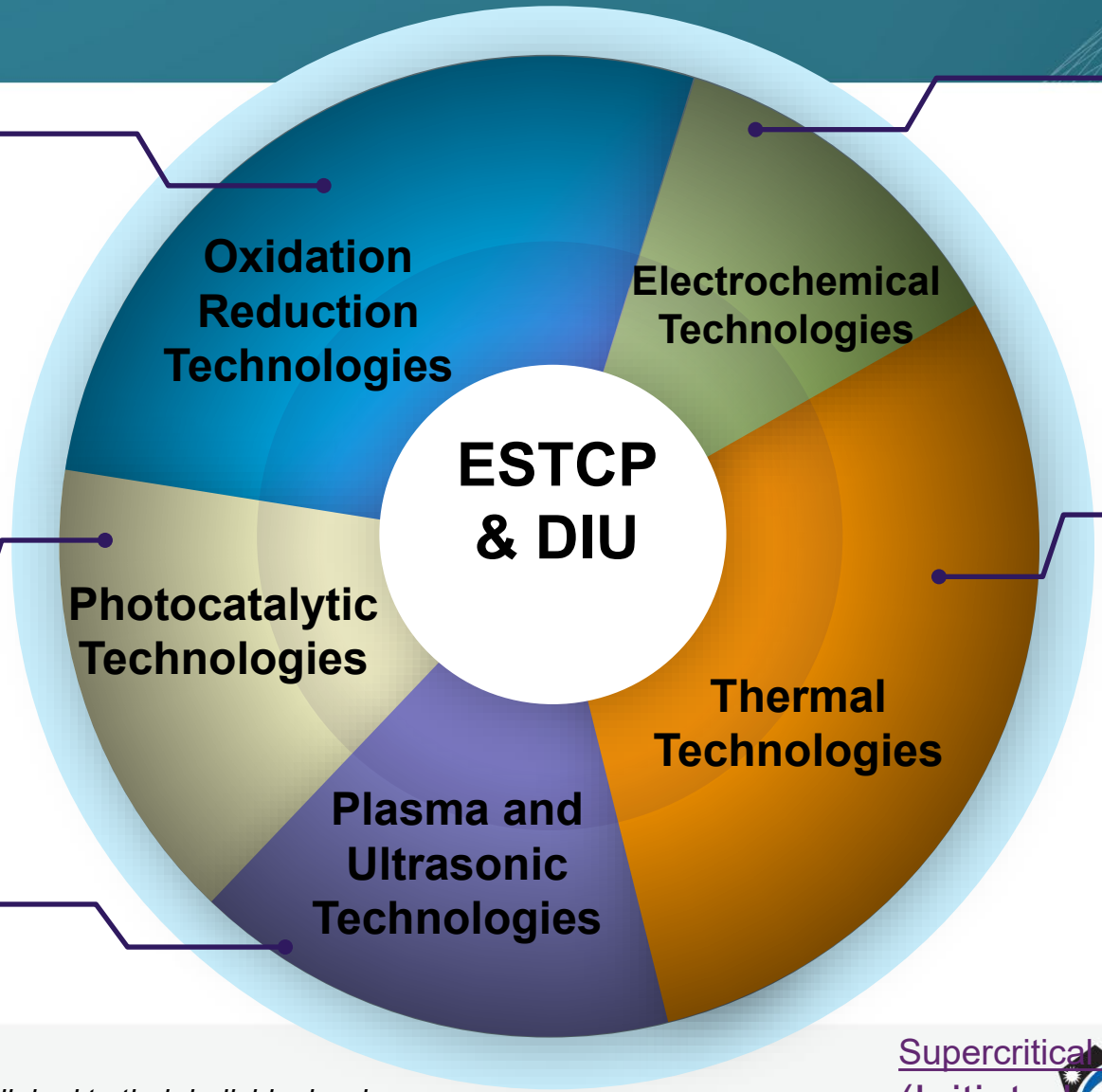
Project Number

ER18-1570
ER18-1624
~~ER18-1652~~

11 projects passed the first phase and have continued with additional research

All project numbers are linked to their individual web pages

ESTCP and DIU Efforts



Project Number

~~ER18-1482~~
~~ER18-1497~~
~~ER18-1545~~
~~ER18-1526~~
ER18-1620 (Electron Beam)

Project Number

~~ER18-1513~~
~~ER18-1515~~
~~ER18-1599~~

Project Number

~~ER18-1570~~
~~ER18-1624~~
~~ER18-1652~~

Project Number

~~ER18-1491~~
~~ER18-1595~~

Four technologies are being demonstrated under ESTCP and DIU (plus SCWO)

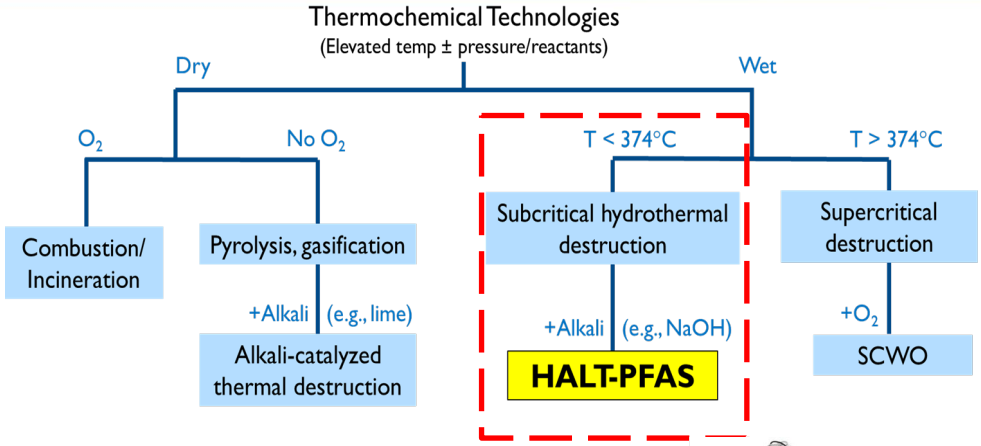
Project Number

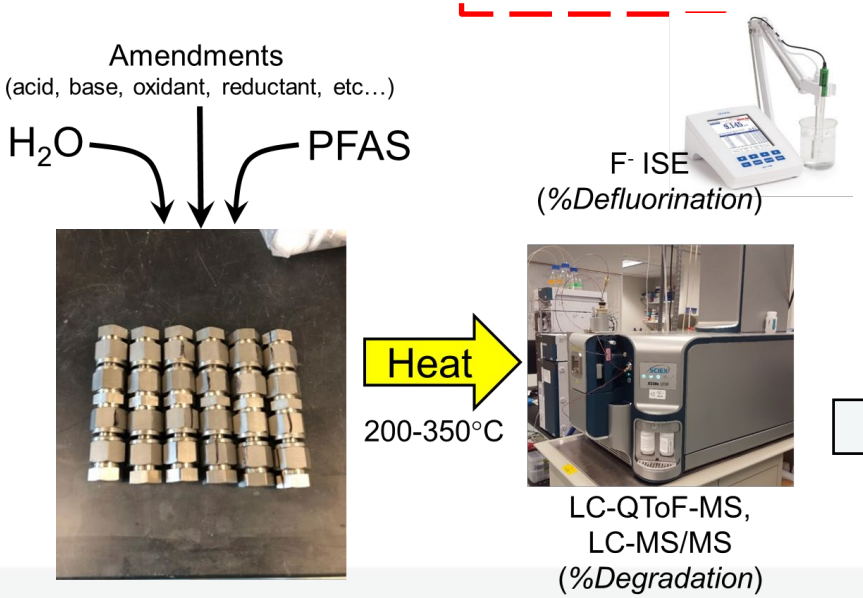
ER18-1501 (HALT)
~~ER18-1556~~
ER18-1572 (Thermal Desorption)
ER18-1593 (Smoldering Combustion)
~~ER18-1603~~

All project numbers are linked to their individual web pages

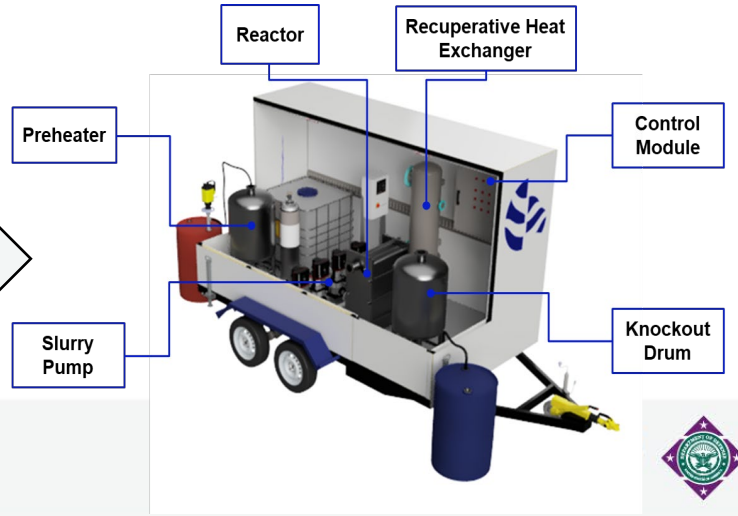
Supercritical Water Oxidation (Initiated under ESTCP)

Thermal Technologies





Scale up

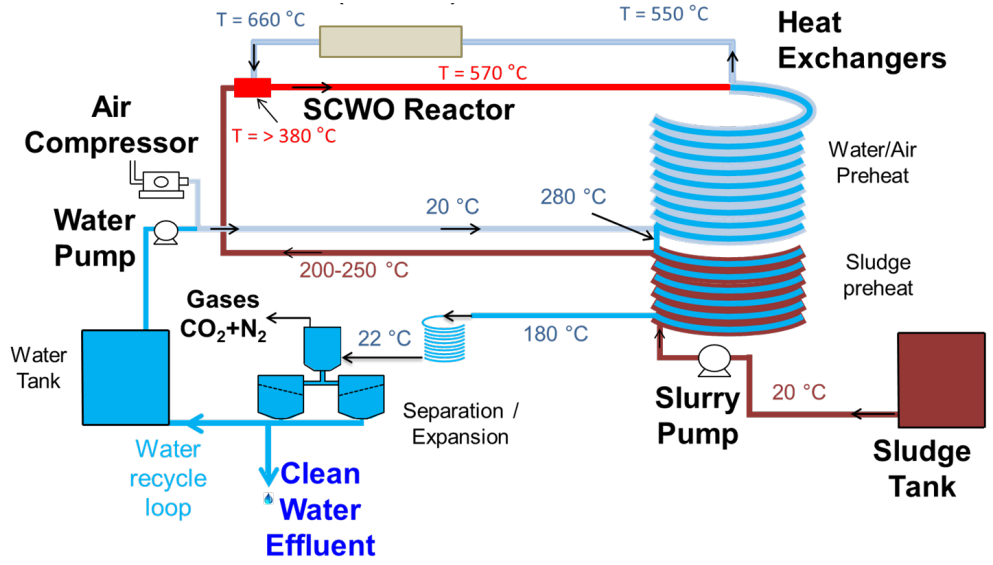


- Subcritical hydrothermal treatment is a thermochemical process employing high-temperature (170–350 °C) and high-pressure (2–22 MPa)
- Hydrothermal processing eliminates energy-intensive drying steps required of “dry” thermochemical technologies like pyrolysis and incineration

ESTCP

Oxidation-Reduction Technologies

- Supercritical Water Oxidation (SCWO) is a treatment technology that utilizes high temperature and pressure (700-1200 F° and 3200 psi)
- At these conditions, when air is injected, organics can be oxidized to carbon dioxide and water, without a catalyst



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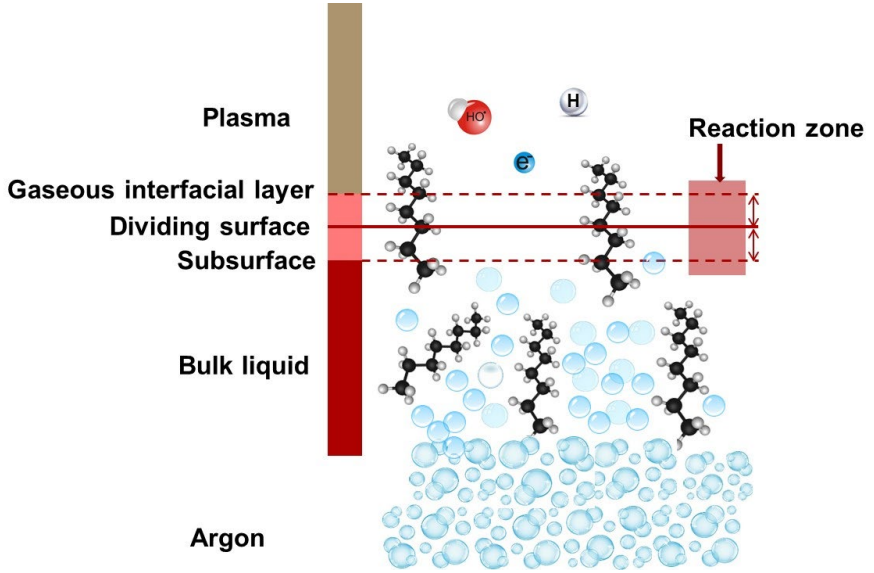
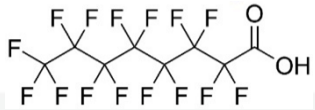
Plasma Technologies

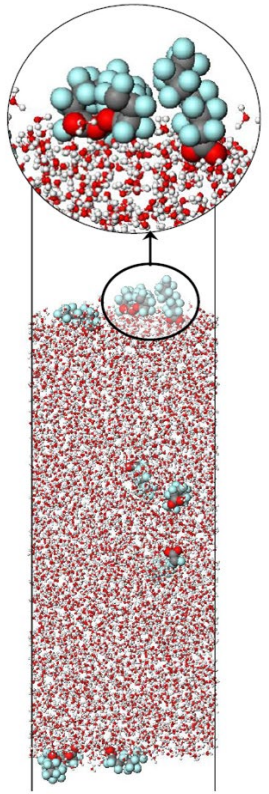
- Uses electricity to convert water into a mixture of reactive species
- No chemical additions and no production of residual waste
- Argon gas is recycled



PFOA

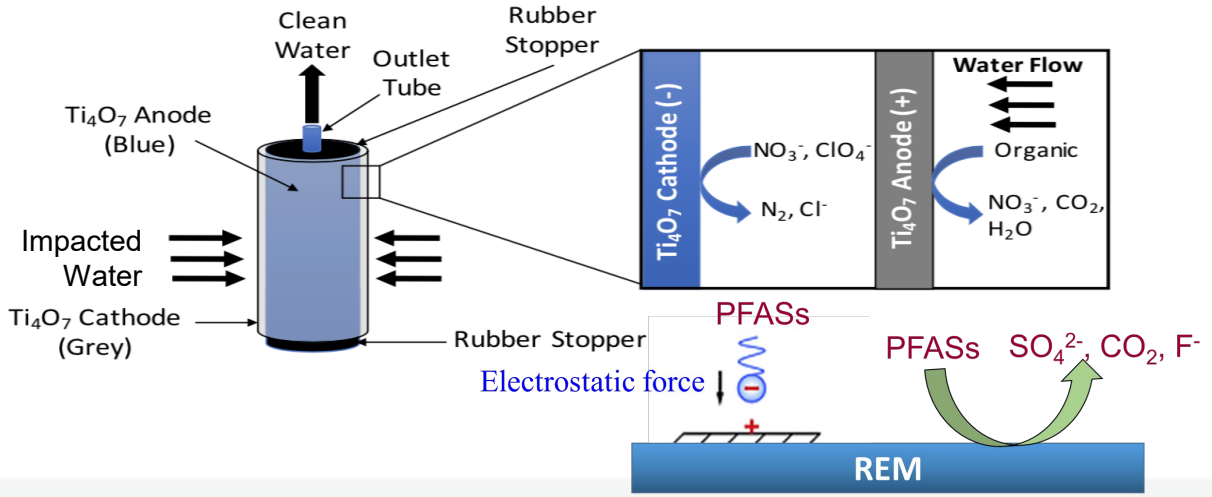


Majority of PFOA at the interface protrudes out into the plasma



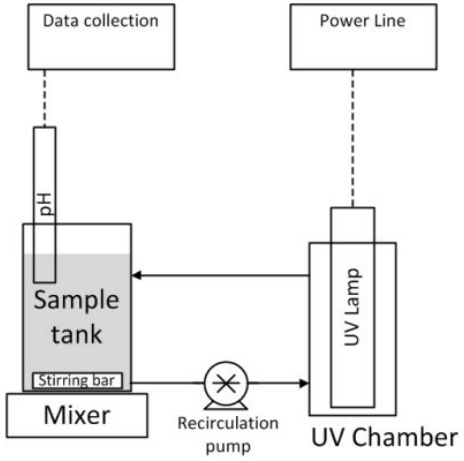
Electrochemical Technologies

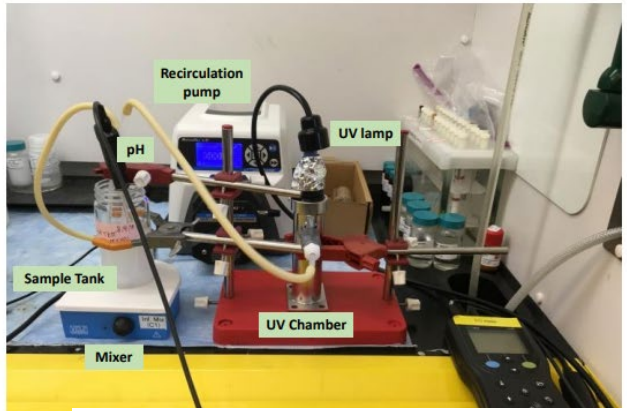
- Reactive Electrochemical Membrane (REM) is capable of simultaneous adsorption and electrochemical destruction of PFAS and associated chemicals
- The REM is a novel electroactive membrane made of porous Ti_4O_7 with micron-sized pores
- Anodic polarization of the REM results in degradation of PFAS through a combination of direct electron transfer reactions and reactions with OH radicals



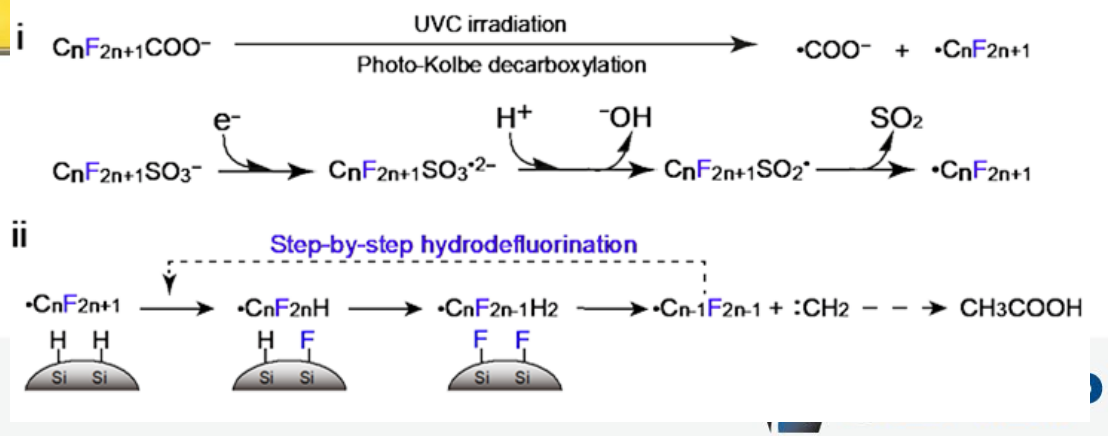
Photocatalytic Technologies

- Photocatalysts facilitate subsequent destruction of the contaminants under UV or solar light
- Catalyst material has the ability to enhance the ultraviolet (UV) based carbon-fluorine bond cleavage





PFOA/PFOS Destruction Mechanism using Pt/SiC Catalyst



Commercial PFAS Treatment Technologies

- SERDP & ESTCP have supported the development of many PFAS treatment technologies, and continue to evaluate & require demonstrations on the effectiveness of these technologies
- SERDP & ESTCP do not endorse vendors; rather, we provide the means to collect cost & performance data so that informed decisions can be made