National Science Foundation (NSF) Efforts to Address Plastic Pollution & Marine Debris

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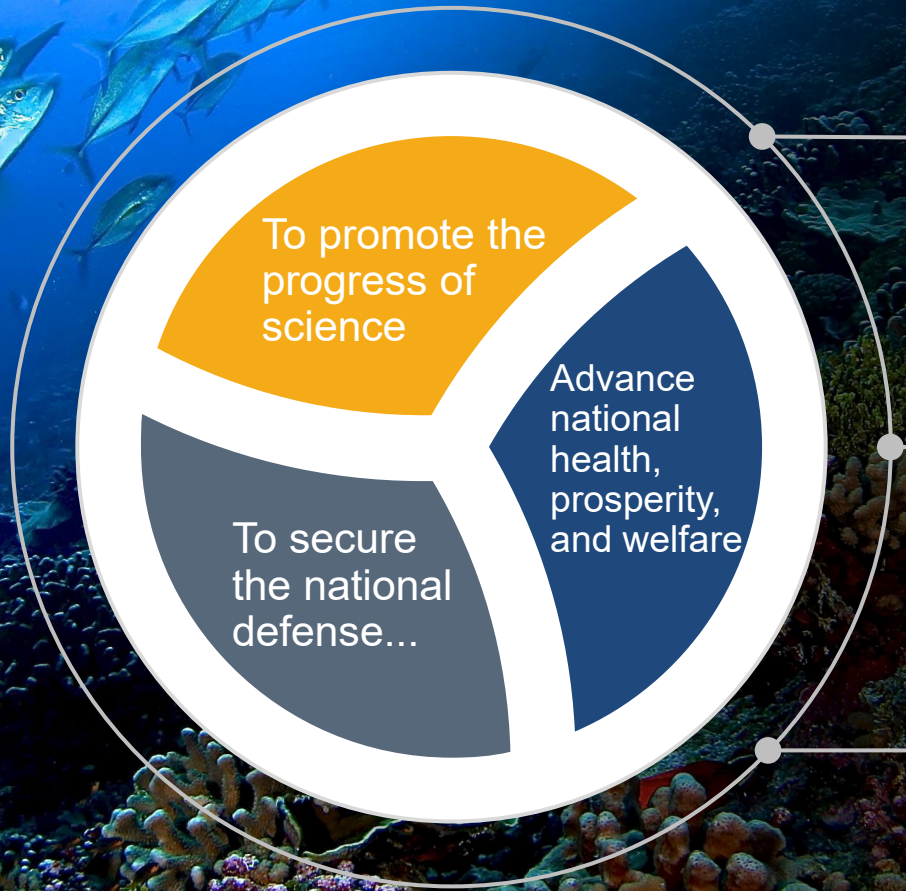
Our Vision – A Nation that creates and exploits new concepts in science and engineering and provides global leadership in research and education.



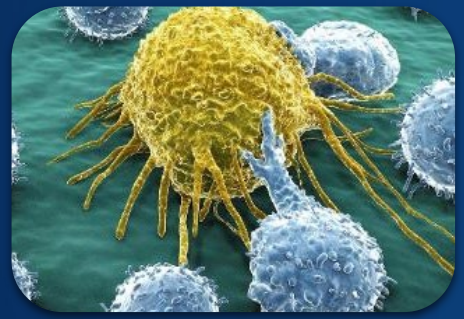
Investment in science, engineering, and education research and in actions that increase capacity to conduct and exploit research

Through contributions that NSF-funded research makes to the well-being of the Nation

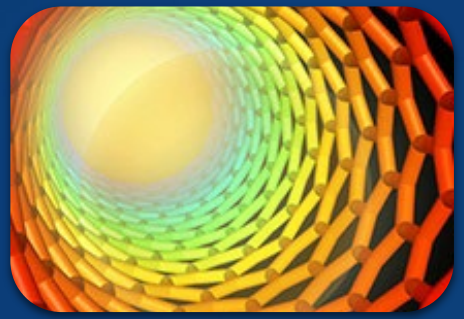
Support of research in cryptography, cybersecurity, novel materials, advanced data analytics, and communications technology

Mission: NSF Act of 1950: 42 USC § 1861-75 and 45 CFR Part VI

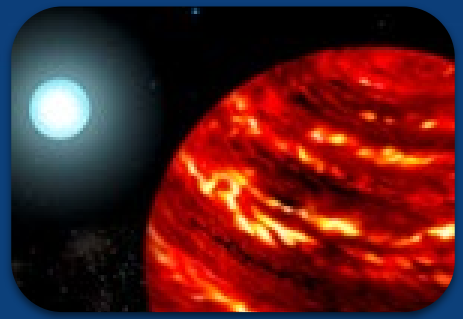
NSF Funds Research and Education across all Fields of Science and Engineering



Biological Sciences



Engineering



Mathematical and Physical Sciences

Computer & Information Science & Engineering

Geosciences & Polar Programs

Education and Human Resources

Social, Behavioral, and Economic Sciences

Integrative Activities

International Science and Engineering

Technology, Innovation and Partnerships

Engineering Core Programs Supporting Plastics Material Design, Processing, Deconstruction, Fundamental Systems Behavior, and Environmental Remediation

Chemical, Bioengineering, Environmental, and Transport Systems (CBET)

- Catalysis
- Cellular and Biochemical Engineering
- Interfacial Engineering
- Process Systems, Reaction Engineering, and Molecular Thermodynamics
- Environmental Sustainability
- Nanoscale Interactions
- Particulate and Multiphase Processes
- Fluid Dynamics
- Environmental Engineering

Civil, Mechanical, and Manufacturing Innovation (CMMI)

- Advanced Manufacturing
- Mechanics of Materials and Structures

Engineering supports projects that explore the frontiers of engineering science, foster innovation and technology transfer, address national needs and improve quality of life, and prepare future engineering leaders, entrepreneurs, and visionaries.

ENG/CBET - 2211704 (Pujara)

Regimes of particle settling for finite-sized particles in the inertial range of turbulence

ENG/CMMI - 2042740 (Jung)

Actuating and Sensing Objects on a Free Surface

ENG/CBET - 2038484 (Boymelgreen)

Real time analysis of impact of nanoplastics on marine species using AI integrated microfluidics

ENG/CBET – 2044877 (Rabnawaz)

Bridging the gaps among commodity thermoplastics, engineering polymers and thermosets via thermally reversible crosslinking

ENG/CBET - 1930594 (Gross)

Engineering increased activity of cutinase toward poly(ethyleneterephthalate) for recycling of plastic

ENG/CMMI – 1928448 (Dollar)

Shared autonomy for the dull, dirty, and dangerous: exploring division of labor for humans and robots to transform the recycling sorting industry

Gary Bell/zefa/Corbis. Source: The Guardian

Mathematical and Physical Sciences Core Programs Supporting Plastics Synthesis, Depolymerization, Characterization, and Design, and Chemistry Under Environmental Conditions

Chemistry (CHE)

- Chemical Synthesis
- Chemical Catalysis
- Chemical Measurements and Imaging
- Environmental Chemical Science
- Macromolecular, Supramolecular, and Nanochemistry

Materials Research (DMR)

- Condensed Matter and Materials Theory
- Condensed Matter Physics
- Polymers

Mathematical and Physical Sciences supports projects that explore the frontiers of chemical and materials science, develop the foundations for future technologies and industries that meet changing societal needs, and prepare the next generation of researchers.

MPS/CHE – 2203935 (Mezyk)

Radical-induced Weathering of Micro- and Nanoplastics in Water: Impacts on Suspensions, Agglomerations, and Contaminant Adsorptions

MPS/CHE – 2109097 (Aristilde)

Molecular Probing Surface Reactivity Dynamics of Native versus Photo-Oxidized Microplastics and Nanoplastics in Environmental Aqueous Media

MPS/CHE – 2038312 (Tarr)

Effect of Sunlight on Fate and Transport of Nanoplastics and Associated Organic Pollutants in Aquatic Systems

MPS/CHE – 2032497 (Bharti)

Understanding the Dispersibility of Aging Micro/Nanoplastics

MPS/DMR – 1810217 (Guan)

Silyl Ether Metathesis for Universal Vitrimer Design

MPS/DMR – 2301348 (Kumar)

Origins of Secondary Nanoplastics and Mitigating Their Creation

Will Parson/Chesapeake Bay Program)

Geosciences Core Programs Supporting Plastic Pollution and Marine Debris Fate and Transport, and Assessing Environmental Impacts

Ocean Sciences (OCE)

- Biological Oceanography
- Chemical Oceanography
- Marine Geology and Geophysics
- Physical Oceanography

Earth Sciences (EAR)

- Geobiology and Low-Temperature Geochemistry
- Geomorphology and Land-use Dynamics
- Hydrologic Sciences

Polar Programs (OPP)

- Arctic Natural Sciences
- Arctic System Sciences

Geosciences supports the development of knowledge and technological innovations to (1) understand and adapt to the changes in our earth, ocean, and atmosphere, (2) accelerate the societal benefits of our investments, and (3) train a diverse and inclusive geosciences workforce

GEO/EAR – 2045871 (Arienzo)

Microplastics in snow-dominated environments - sources, transport, and fate

GEO/OPP – 2138317 (Jahn)

Sea ice-ocean exchange of Arctic microplastics: linking small scales to the large-scale system

GEO/EAR – 2019546 (Jefferson)

Geomorphic effects and distribution of anthropogenic debris in urban streams

GEO/EAR – 2052956 (Pincus)

Microplastics and Nanoplastics as Vectors for Inorganic Pollution: Examining the Effect of Environmental Systems Conditions on Degradation Pathway and Sorption Potential

GEO/OCE – 2127503 (Law)

Assessing the contribution of plastics to marine particulate organic carbon

GEO/OCE – 2148370 (Kukulka)

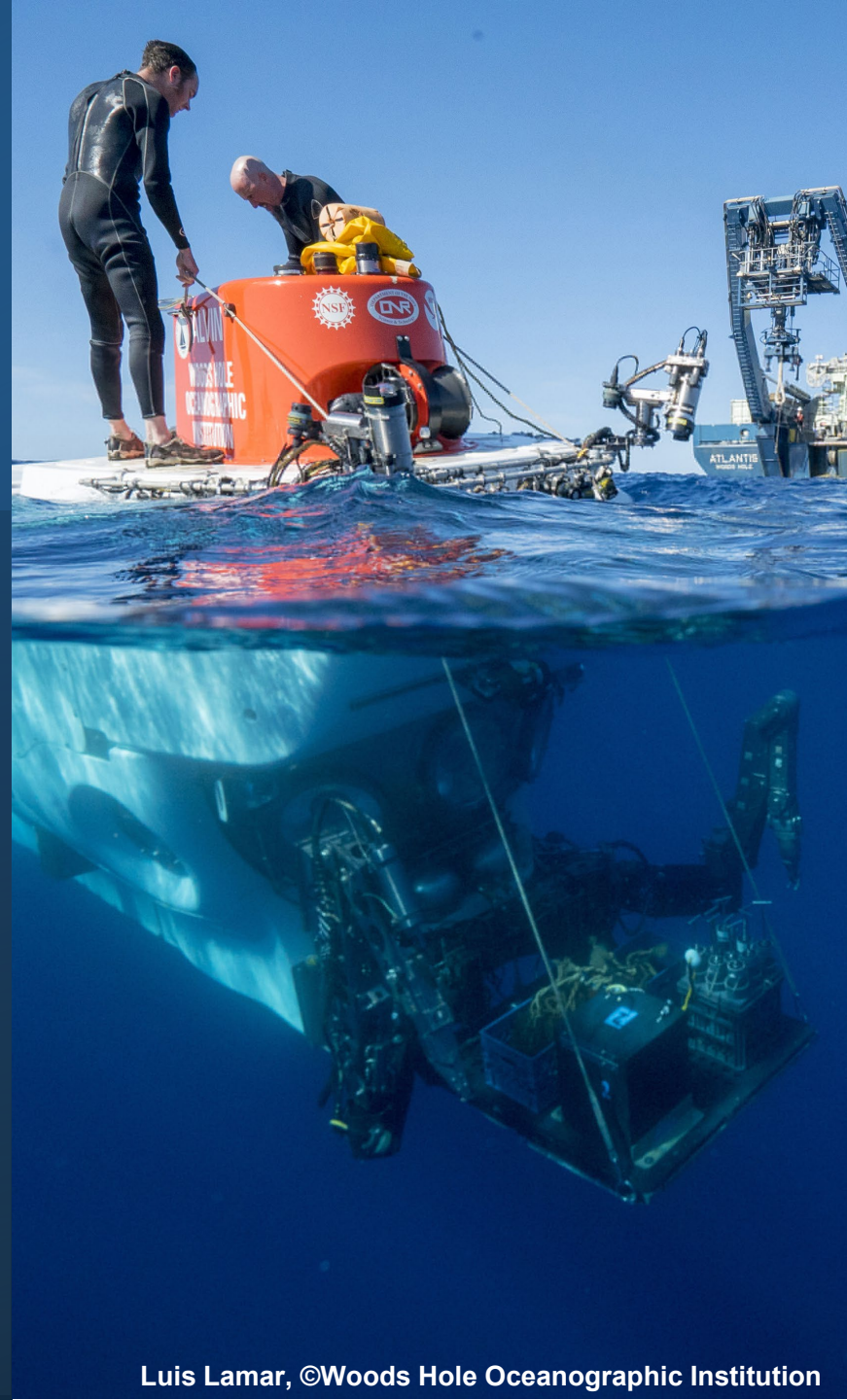
Lagrangian transport and patchiness of buoyant material in estuarine systems

GEO/OCE – 2019835 (Tedesco)

Spatio-temporal variability of microplastics in ocean and river cores using fluorescence microscopy

GEO/OCE – 2117987 (Lynch)

MRI: Acquisition of a Raman spectrometer for ocean acidification and marine debris research



Luis Lamar, ©Woods Hole Oceanographic Institution

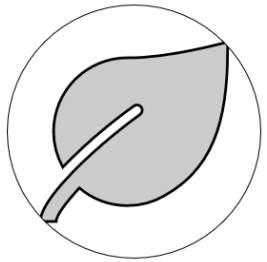
Support of Plastics and Marine Debris-Related Research Through Solicitations and Centers

- Critical Aspects of Sustainability (PD 21-9102, NSF 20-050, NSF 22-111)
- Designing Materials to Revolutionize and Engineer our Future (NSF 21-522)
- Centers for Chemical Innovation (NSF 22-596)
- Materials Research Science and Engineering Centers (NSF 21-625)
- Coastlines and People Hubs for Research and Broadening Participation (NSF 21-613)
- Emerging Frontiers in Research and Innovation (NSF 20-614, Closed) | Engineering the Elimination of End-of-Life Plastics
- Environmental Convergence Opportunities in CBET (NSF 21-596)
- Future Manufacturing (NSF 22-568)
- Engineering Research Centers (NSF 22-580)
- Navigating the New Arctic (NSF 22-520)

National Science Foundation

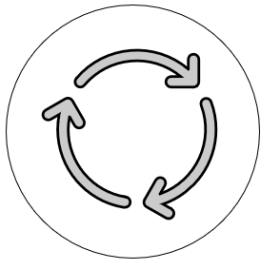
NSF Center for Sustainable Polymers

Marc Hillmyer | Univ. Minnesota | CHE-1901635



Efficient and sustainable conversion of biomass to polymer ingredients

High-performance sustainable plastics and elastomers



Sustainable polymer degradation, chemical recycling, and compatibilization

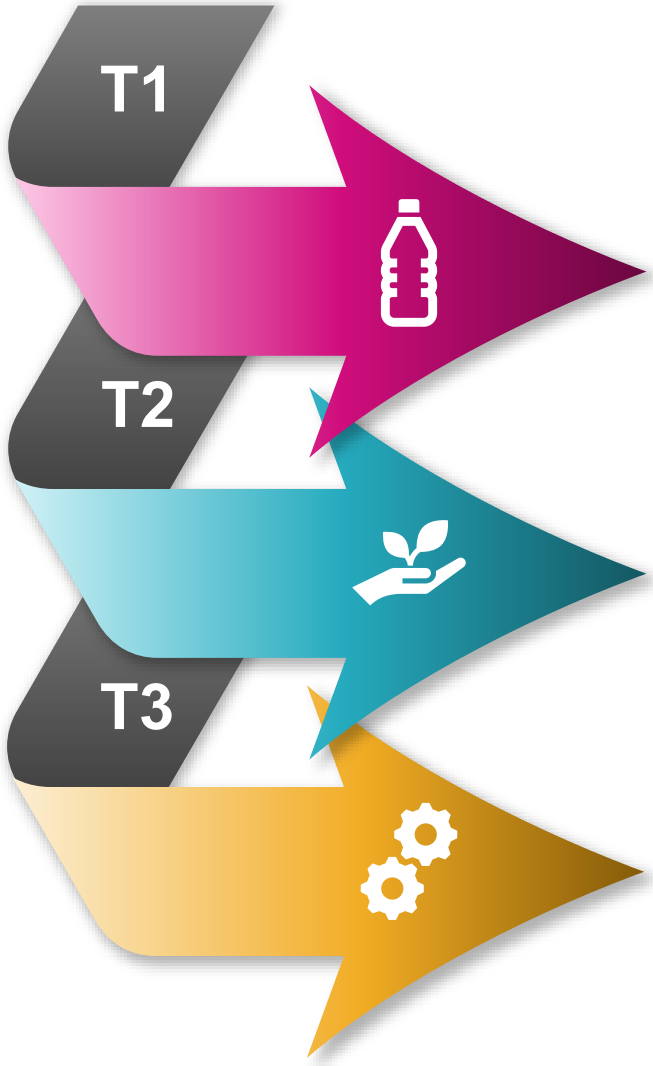
The mission of the NSF Center for Sustainable Polymers (CSP) is to transform how plastics are made, unmade, and remade through innovative research, engaging education, and diverse partnerships that together foster environmental stewardship

Centers for Chemical Innovation (NSF 20-574)

NSF 19-599 & NSF 20-614
Engineering the Elimination of End-of-Life Plastics

Support development of new engineering approaches for the elimination of, and reclamation of value from, end-of-life plastic materials

- Robust physical systems and materials for plastic lifecycle management
- Novel catalysts (chemical and biological) and reaction engineering for depolymerization and valorization of plastic waste
- Systems-level integration within existing manufacturing infrastructures



Depolymerization of plastic materials

Valorization of plastic materials and depolymerization-derived molecules

Enabling processes that eliminate plastic waste

EFRI E3P: Sustainable and Circular Engineering for the Elimination of End-of-life Plastics: A Framework for Assessment, Design, and Innovation (2029397 | Bhavik Bakshi)

EFRI E3P: Massive Microplastics Remediation using Novel Microcleaners and Microbiome Processing Accelerated by Artificial Intelligence (2029327 | Carol Hall)

EFRI E3P: Valorization of Plastic Waste via Advanced Separation and Processing (2029375 | Paschalis Alexandridis)

EFRI E3P: End of Life Plastics as Starting Materials for Filtration and Barrier Applications (2029387 | Steven Weinman)

EFRI E3P: Sequestering Microplastics Using Upcycled Plastic Waste (2029251 | Anne McNeil)

EFRI E3P: Reincarnation of Polymers for the Circular Economy (2029374 | John Dorgan)

EFRI E3P: Engineering Suspension Feeder Systems for Separation and Elimination of Microplastics from Water (2029428 | Leslie Shor)

EFRI E3P: Tuning Catalyst Design to Recycle Mixed Polymer Streams (2029394 | Steven Crossley)

EFRI E3P: Plastics Recycling Processes by Integrating Mechanocatalytic Depolymerization, Monomer Purification, and Consumer Behavior (2028998 | Carsten Sievers)

EFRI E3P: A Novel Sequential Catalytic Solvolysis Process for Deconstructing Municipal Waste Plastics (2132219 | Hongfei Lin)

EFRI E3P: High-throughput Synthetic Biology Approaches for Mixed Plastic Degradation and Reutilization (2132156 | Arum Han)

EFRI E3P: Hydrogenolysis for Upcycling of Polyesters and Mixed Plastics (2132033 | J. William Medlin)

EFRI E3P: Nonthermal Plasma-Assisted Hydrogenolysis of Waste Plastics to Value-added Chemicals and Fuels (2132178 | Steven S. Chuang)

EFRI E3P: Program Plastic Lifecycle by Rationally Designed Enzyme-containing Plastics (2132025 | Ting Xu)

EFRI E3P: Supercritical Extraction for the Elimination of End-of-Life Plastics (2132093 | Edward W. Davis)

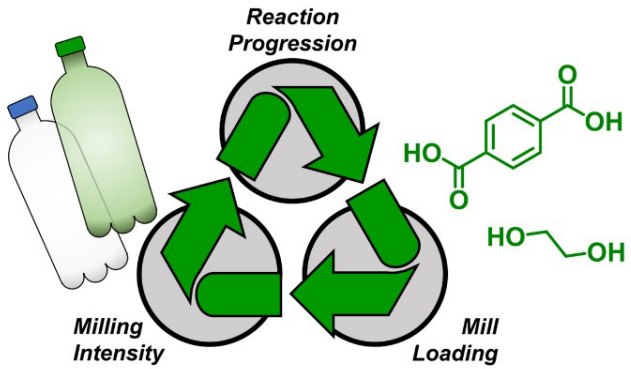
EFRI E3P: Transformative Upcycling of Polymers by Activating Chemistries (2132133 | Jason E. Bara)

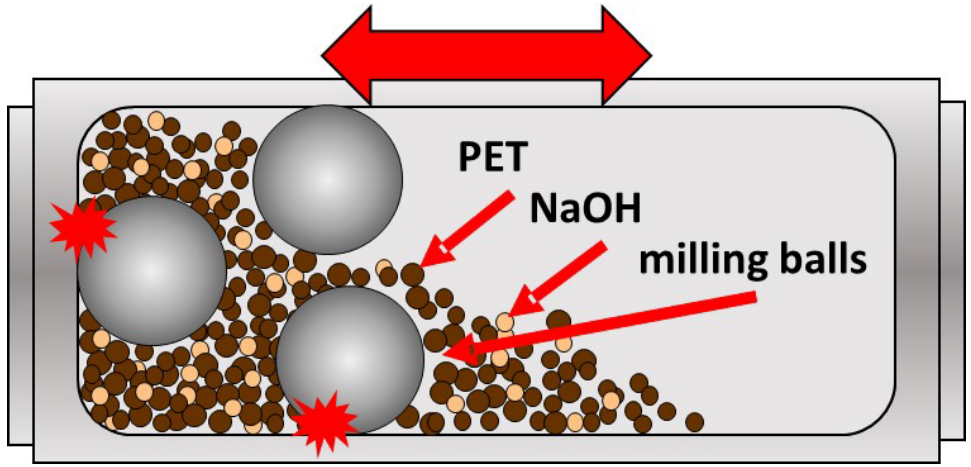
EFRI E3P: Waste Management and Circularity of Crosslinked Polyurethane Foams (2132183 | Timothy Long)

EFRI E3P: Plastics Recycling Processes by Integrating Mechanocatalytic Depolymerization, Monomer Purification, and Consumer Behavior

Carsten Sievers, Georgia Institute of Technology; 2028998

Research Objective: Develop mechanocatalytic processes for depolymerization of condensation polymers and poly(olefins) in ball mills along with multiscale process models and separation processes.





Motivation of the approach:

- Mechanocatalytic processes offer the unique opportunity to contact solid feedstocks with solid catalysts or reactants.
- They are well suited for conversion of solid polymers that are insoluble in environmentally benign solvents.

Results:

- When PET is milled with NaOH and steel balls in a steel vessel, it is completely depolymerized in less than 20 min.
- Discrete element models predict reaction environments at the sites of collisions.

Ongoing efforts:

- Mechanocatalytic processes for conversion of different plastics.
- 3D multi-body models to predict distribution of reaction environments.
- Membrane and adsorption-based product separation.
- Public perception of recycling.

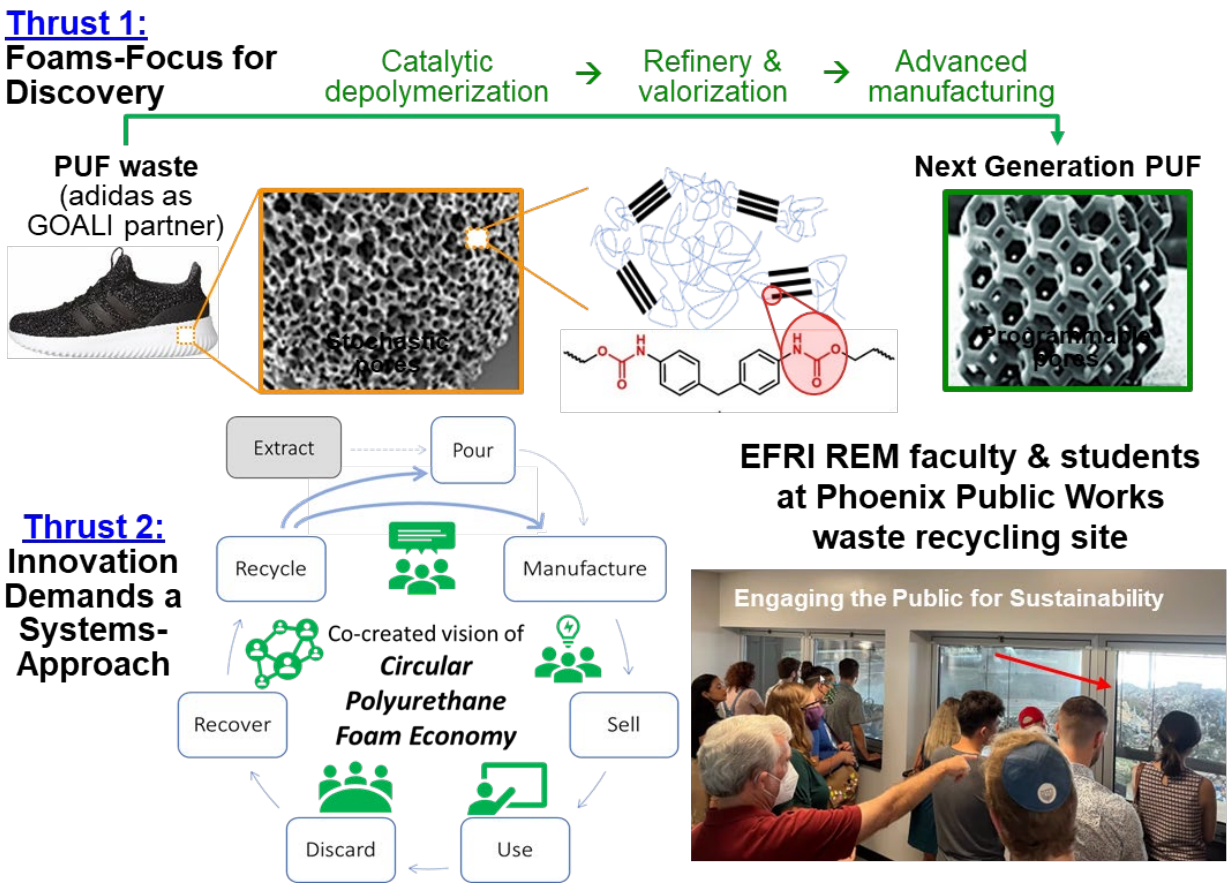
A.W. Tricker, A.A. Osibo, Y. Chang, J.X. Kang, A. Ganesan, E. Anglou, F. Boukouvala, S. Nair, C.W. Jones, C. Sievers, ACS Sust. Chem. Eng., 10.1021/acssuschemeng.2c03376.

EFRI E3P: GOALI: Waste Management and Circularity of Crosslinked Polyurethane Foams (PUFs)

Timothy Long, Arizona State University (ASU); EFRI E3P-2132183

Research Objectives: To engineer chemical and enzymatic depolymerization processes in porous PUFs with programmable microcellular structures; assess PUF valorization with "renewal-of-life" tools; develop training modules for circular PU stakeholders

- PUFs with **programmable microcellular structures** allow tailored depolymerization kinetics
- *In-situ* spectroscopic monitoring of chemical and enzymatic depolymerization processes in waste PUFs elucidates **role of porous structures for enhanced depolymerization kinetics**.
- Low-energy multi-stage **separation** platform will **recover** PUF depolymerization products as pure feedstocks for return to the marketplace for upcycling.
- Collaboration with PUF stakeholders including adidas, national organizations, and local waste management systems **facilitates assessment of circular PUFs** to address community needs. Backcasting, materials flow analysis and life cycle thinking are key integrated tools
- **Undergraduates conducted circular PUF research** with best recycling practices in summer 2022



EFRI REM faculty & students at Phoenix Public Works waste recycling site

Support for Translational Research and Technology Development and Catalyzing Partnerships

- Partnerships for Innovation (NSF 23-538)
- Industry-University Cooperative Research Centers (IUCRC) Program (NSF 20-570)
- Small Business Innovation Research (SBIR) Program (NSF 23-515, https://seedfund.nsf.gov/)
- Small Business Technology Transfer (STTR) (NSF 23-515, https://seedfund.nsf.gov/)
- Convergence Accelerator (NSF 22-583)
- Growing Convergence Research (NSF 19-551)

NSF Convergence Accelerator – Accelerating Solutions Toward Societal Impact

GOALS:

- Disrupt the usual way of NSF business through a new innovation model
- Expand and diversifies multidisciplinary teams and partnerships to include academia, industry, non-profits, government, and other sectors
- Deliver solutions that have a national societal impact

Characteristics

- Use-inspired research
- Clear goals, milestones, high-impact deliverables
- Leverages multidisciplinary teams
- **Larger, national societal scale**
- Requires **diverse partnerships** – industry, non-profits, academia
- **Acceleration at speed and scale**

Proactively & Intentionally Managed

- Teams and Cohorts—"Tracks"
- **Cooperation and Competition**
- **Intensive education and mentorship, human-centered design thinking, team science, and customer discovery**
- Mission-driven evaluation

Track E – Networked Blue Economy

GOAL: To interconnect the blue economy (ocean-related industries and resources) and accelerate convergence across ocean sectors — creating a smart, integrated, connected and open ecosystem for ocean innovation, exploration and sustainable use

Aurali Dade, PhD, Program Director for Track E, adade@nsf.gov

Phase II awards announced on September 21, 2022

- Six teams selected from 16 Phase I planning grant awardees

Track I – Sustainable Materials for Global Challenges

GOAL: To converge advances in fundamental materials science with materials design and manufacturing methods with the goal of coupling their end-use and full life-cycle considerations for environmentally and economically sustainable materials and products that address global challenges

Linda K. Molnar, PhD, Program Director for Track I, lmolnar@nsf.gov

Phase I planning grants announced on December 19, 2022

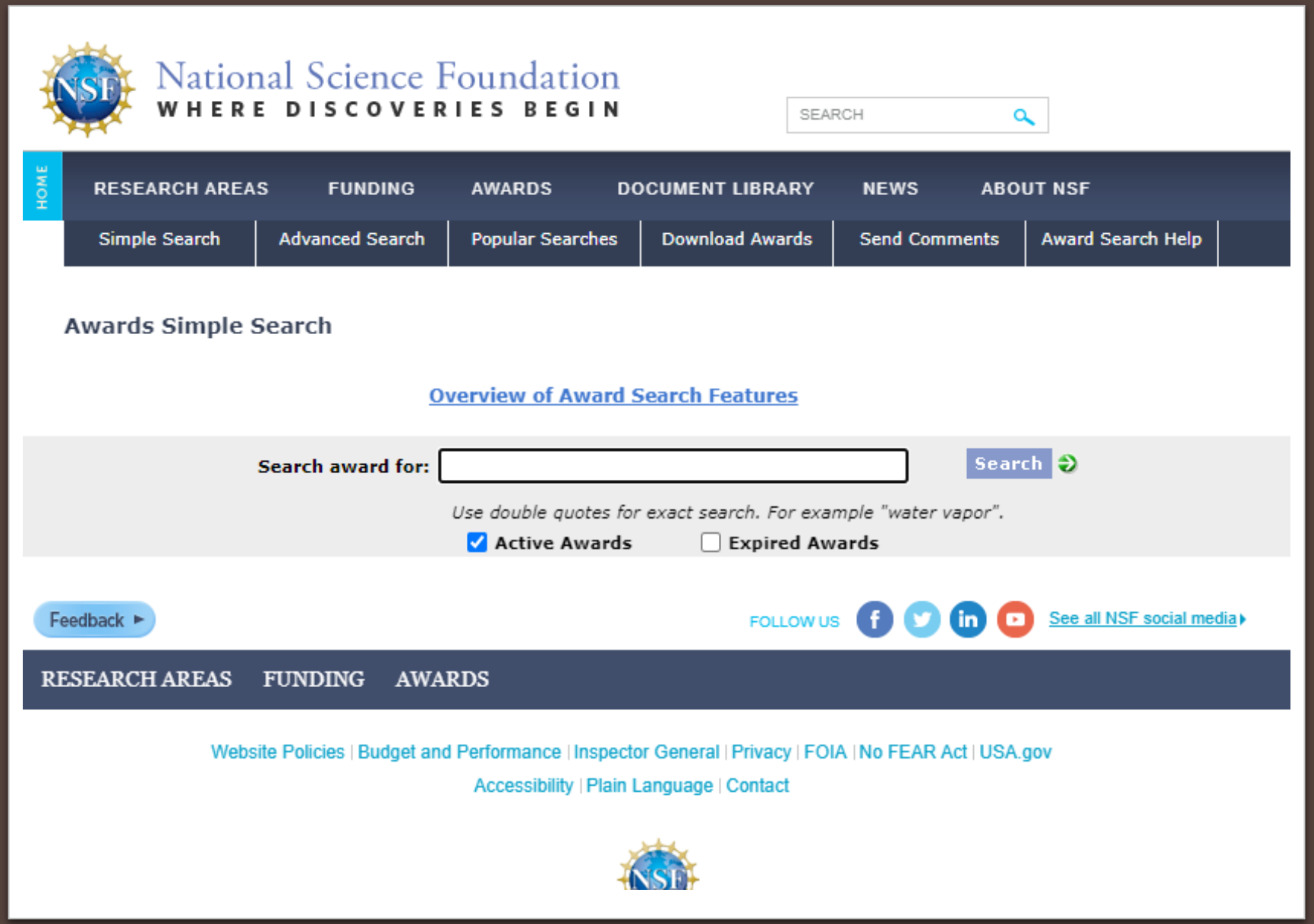
- 16 teams; two with Australian partners funded by CSIRO

Track E – Networked Blue Economy (Phase II)

- Nereid Biomaterials: Biodegradable plastics for tomorrow's ocean, led by UC – Santa Barbara
- Glass Recycling to Restore the Coast, led by Tulane University

Track I – Sustainable Materials for Global Challenges (Phase I)

- Designing for Circular Economies – Creating Impact from Local Plastic Waste Using Off-Grid Containerized 3D Printers & Practice Based Learning, led by re:3D Inc.
- Sustainable Nature-based Nanomaterials for Remediation Solutions to Climate Change, led by the Research Foundation for The State University of New York
- Economically Sustainable Polypropylene Recycled Plastics Enabled by Compatibilizer Additives, led by Black & Decker (U.S.) Inc.
- Sustainable Materials for Global Challenges: Recycled Textile and Apparel Manufacturing Ecosystems, or RETAME, led by the University of Delaware
- Enhanced Biobased Textiles and Composites Via Microbially Produced Silk Proteins, led Rensselaer Polytechnic Institute
- A Tale of Two Cities Optimizing Circularity from Molecules to the Built Environment, led by Jenna Jambeck @ University of Georgia



Search the NSF award database for more examples

https://www.nsf.gov/awardsearch/simpleSearch.jsp