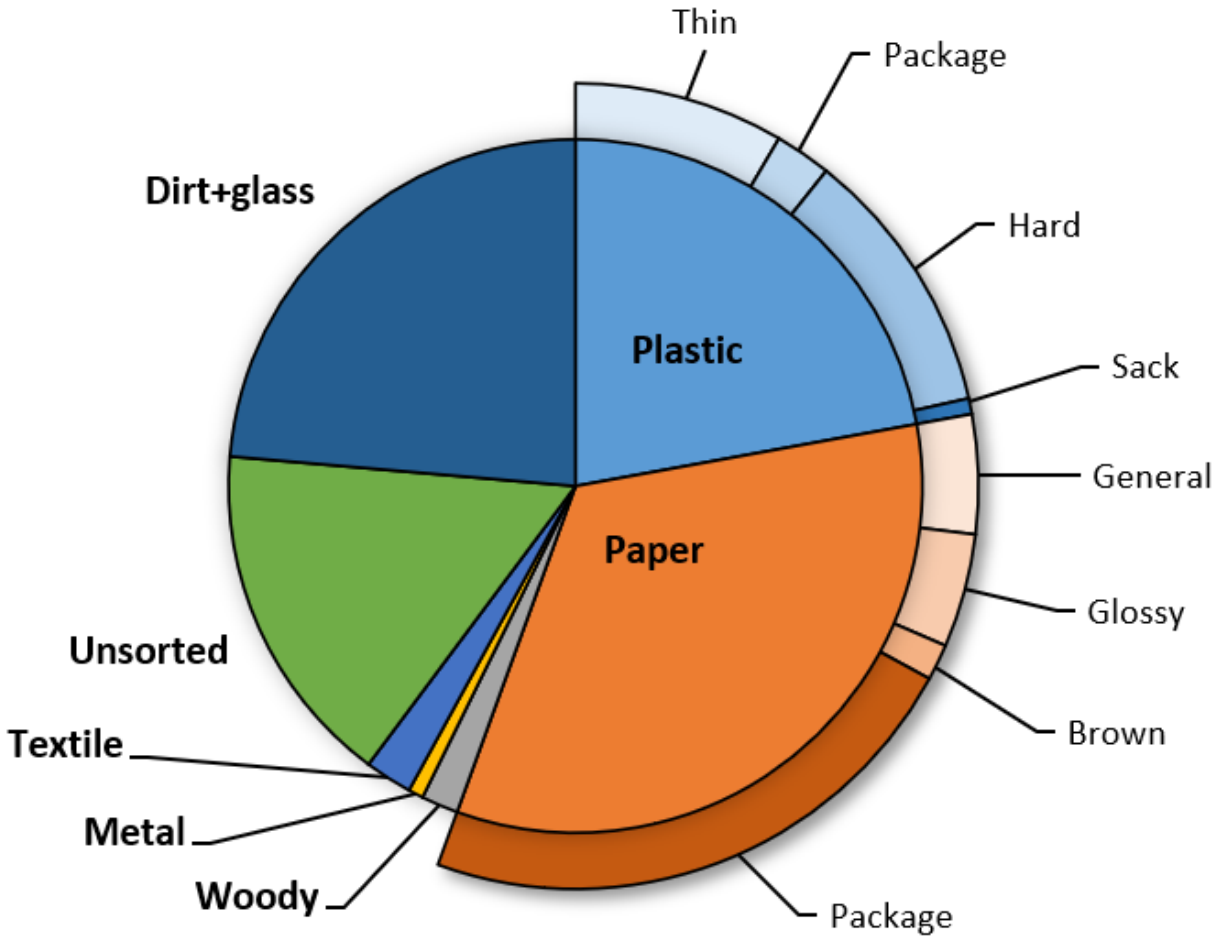
# Biomass Feedstock National User Facility Capabilities for Plastic Processing and Recycling

Idaho National Laboratory

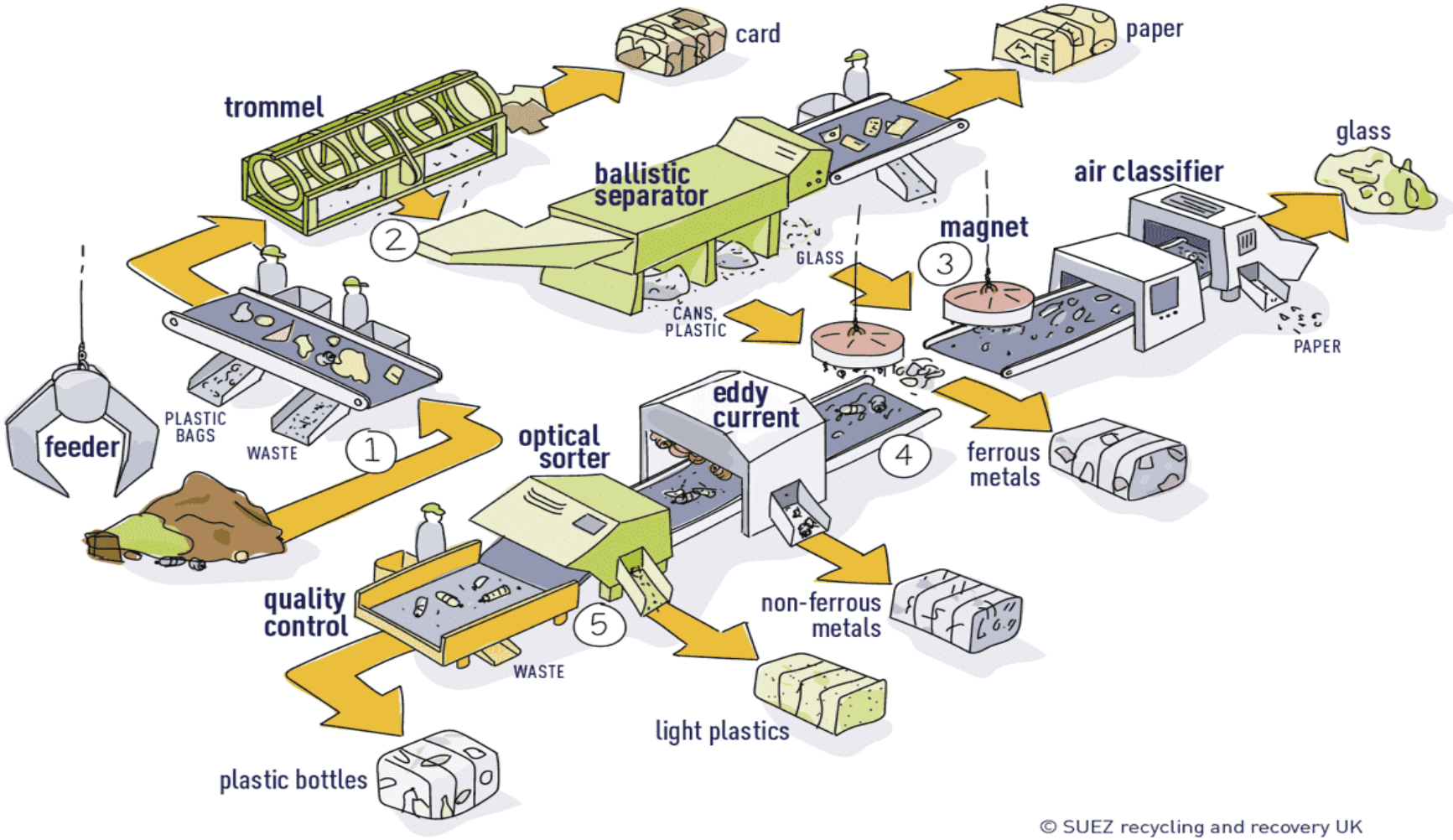
June 8, 2023

# "Waste" at Material Recovery Facilities

- Post-consumer recycling is collected at facilities for material recovery and recycling efforts
- Even state-of-the-art equipment can miss or reject significant material that could be recycled due to contaminants or lack of a market
- Significant plastics and biogenic fiber wastes are being landfilled that could be utilized as resources



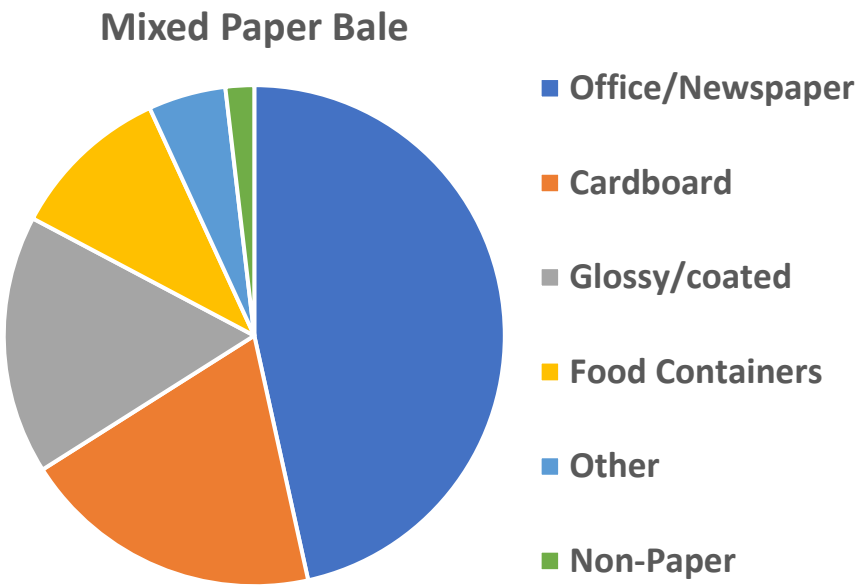
# Material Recycling Facility Schematic

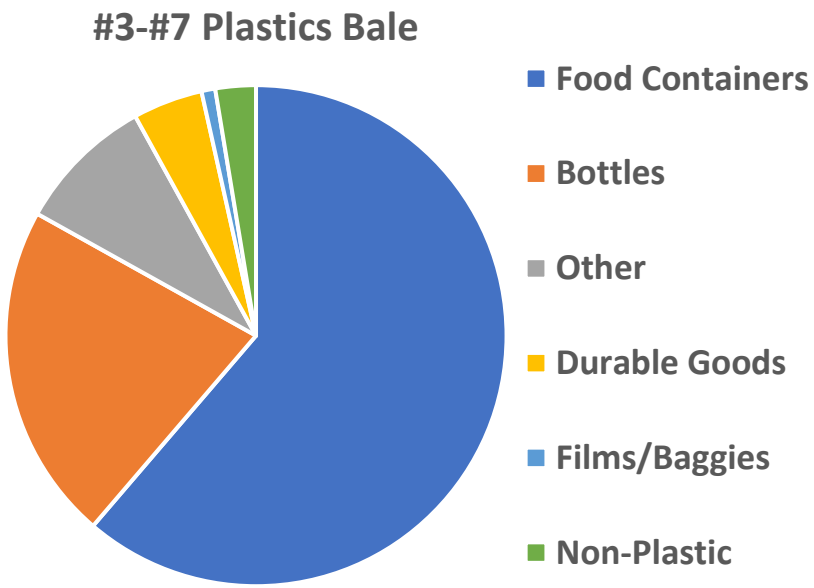


# MRF Residuals

*Emmet County Michigan*

- *Dual stream recycling facility*
- *#1 and #2 plastics and metals removed for recycling*
- *Office paper and corrugated cardboard removed for recycling*



# Fractionation – Pilot Scale Separations

Suitability of separations technologies to produce high-fidelity streams for a given end use

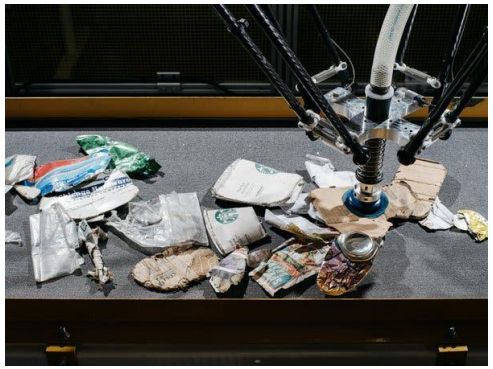
Orbital screens

Air classifiers

Nanoranch sorter

Ballistic screening

Eddy current separator



AMPs robotic separation

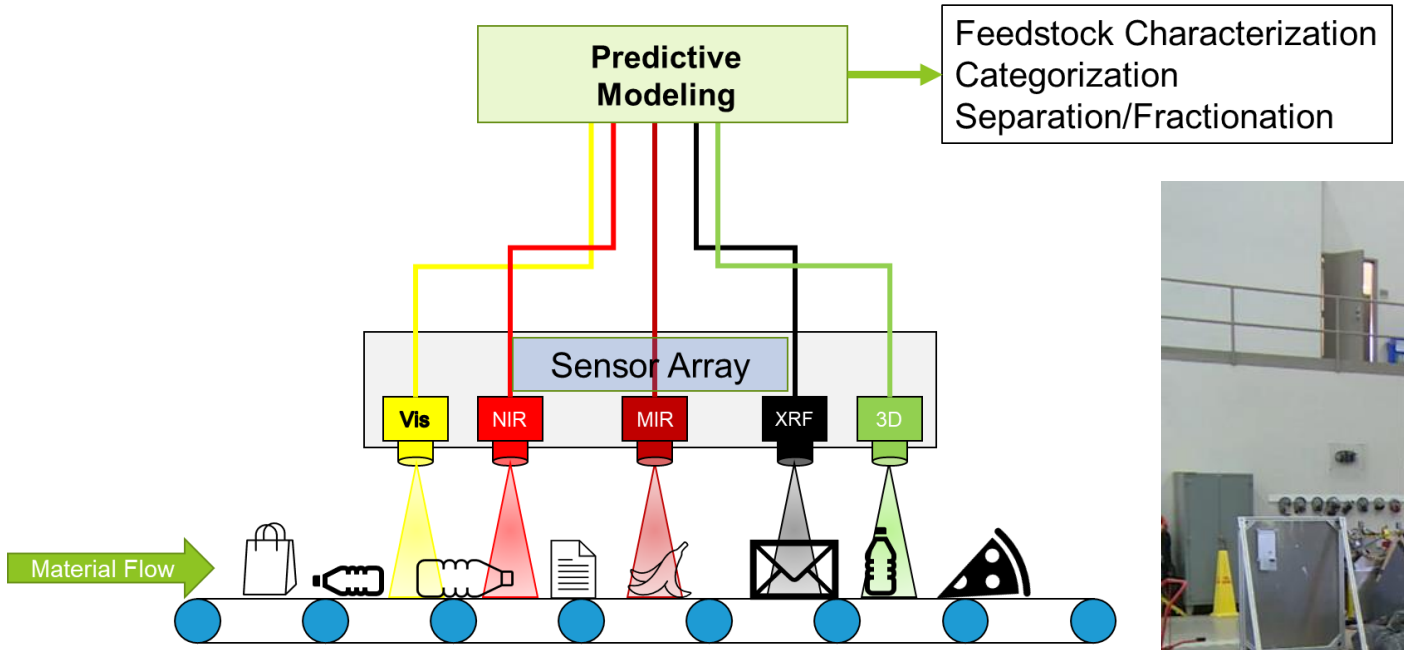
These unit operations may be used for both herbaceous, woody, and MSW separations, but often lend themselves more effectively to one or the other due to the different challenges and characteristics of each.

Not pictured: Disc screens, brush screens

# Reconfigurable Fractional Milling Loop

- Multi-stage milling and separations to manage quality
  - Removal of soil
  - Capture of at-spec fractions
  - Recycle to achieve a narrow size distribution
- Reconfiguration enables tailored fractionation for multiple feedstocks and conversion pathways

# New Spectroscopic Analysis Tools will Improve Artificially Intelligent Robotic Separations

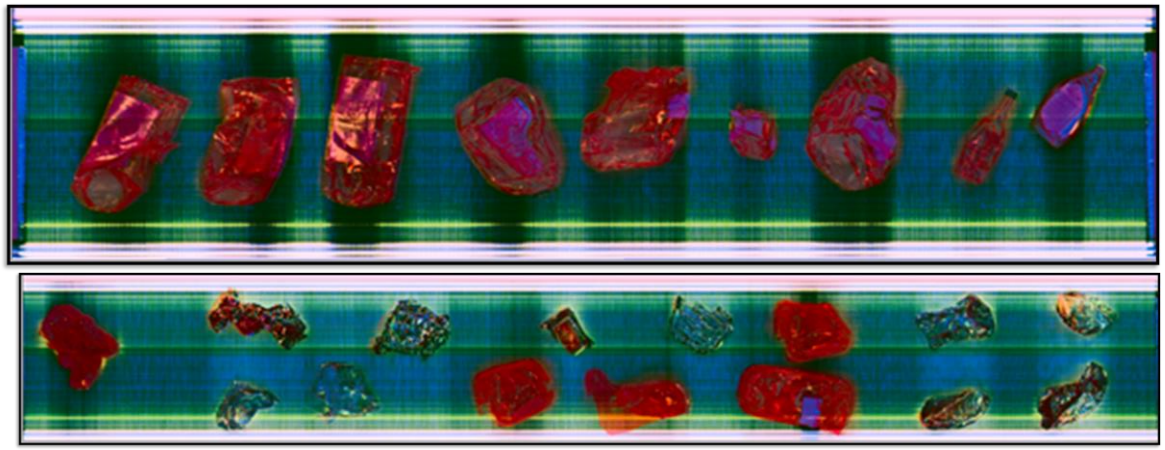




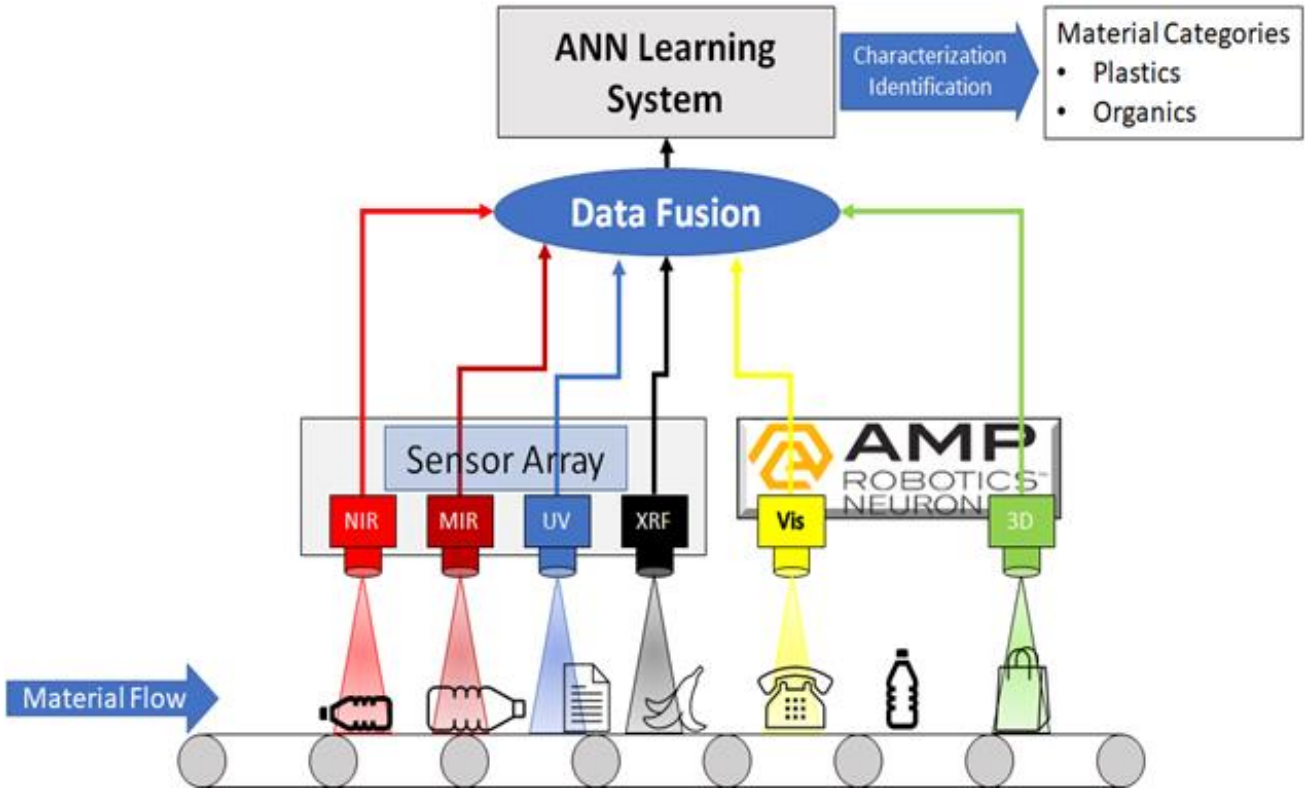
New tools, like Mid-IR, cameras will allow us to better characterize plastics in MSW for separations using artificial intelligence-based software.

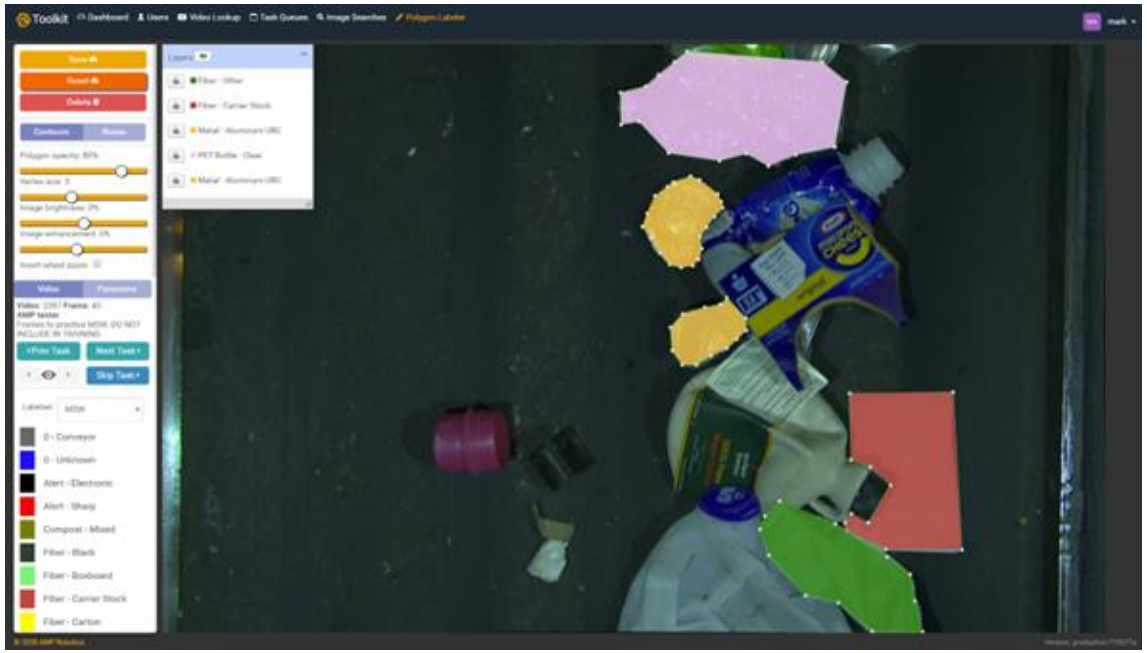
# BETO FY-20 Multi-Topic FOA - NanoRanch

- Multi-Sensor Suite
  - NIR – multiple wave ranges
  - MIR
  - XRF
- Collect hyperspectral data of MSW stream
- Train AI to identify MSW components
- Demonstrate separation



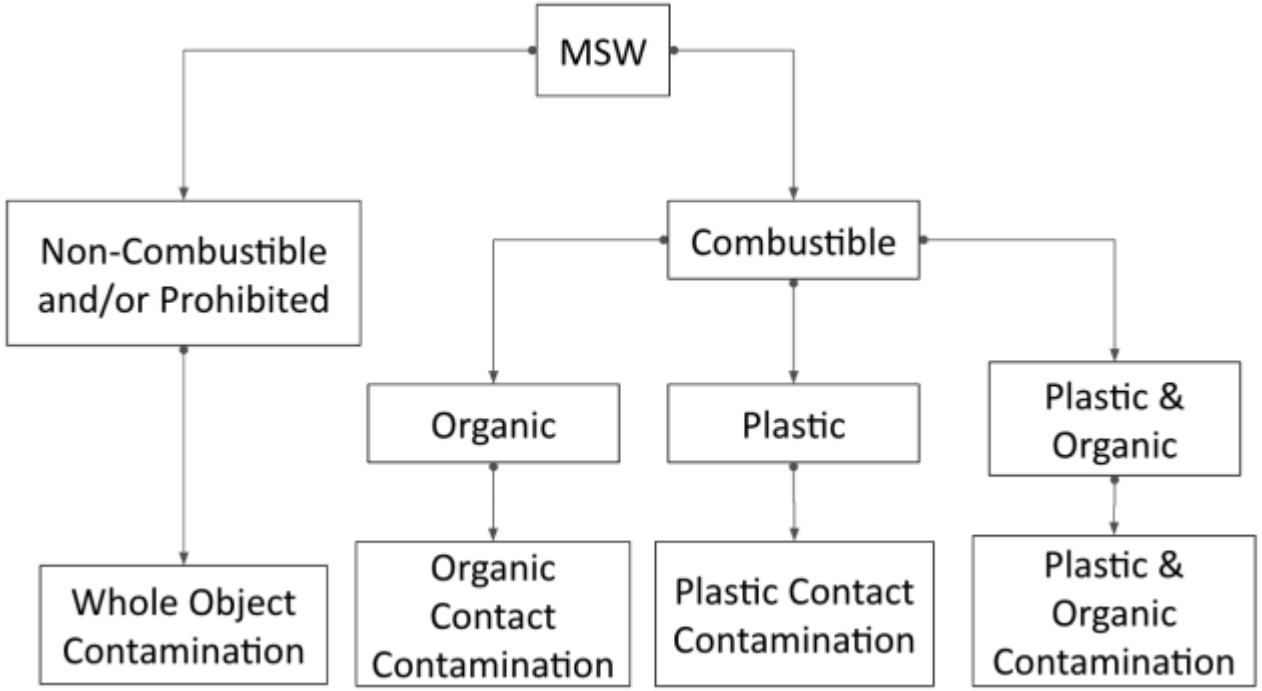
# BETO FY-20 Multi-Topic FOA – Amp Robotics



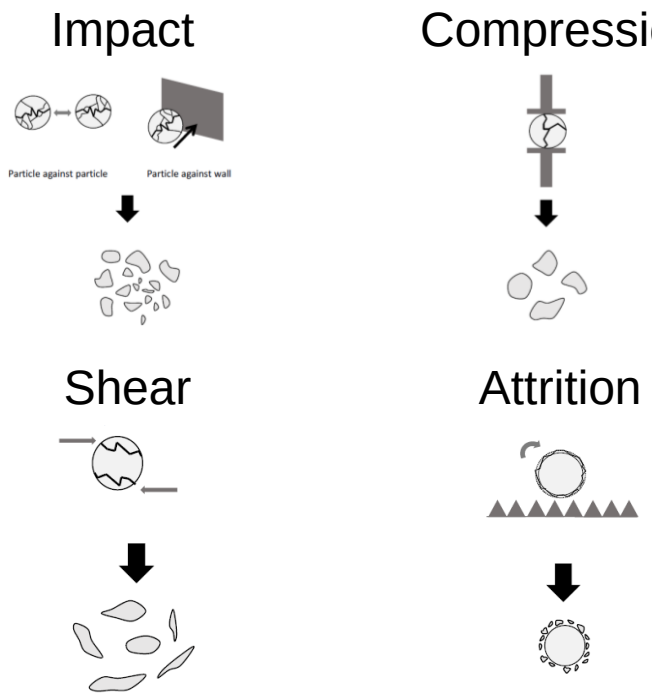



# FY21 BETO Multi-Topic FOA – Amp Robotics

- Understand impact of MSW contamination on conversion
  - Use hyperspectral sensors to identify contaminants
  - Identify impact of contaminants on pyrolysis (Michigan Tech)
  - Train AI to select MSW with best properties for pyrolysis and remove other contaminated materials
  - Route materials to appropriate applications



# Fundamental Deconstruction – Unique Capabilities




Mayer-Laigle et al., 2018

A variety of mill types allows **independent investigation of the four deconstruction mechanisms** that will ultimately impact material flowability.


A 50mm screw extruder with temperature control >200°C **is being used to compound biomass and plastics for 3D printing**

# Fundamental Deconstruction and Handling

BFNUF performs small-scale studies on deconstruction using specific tools to:

- Develop purer separation results.
- Better understand material handling challenges.
- Improve success of technology at a larger, industrial scale.

## General Capabilities

### Deconstruction Mechanisms

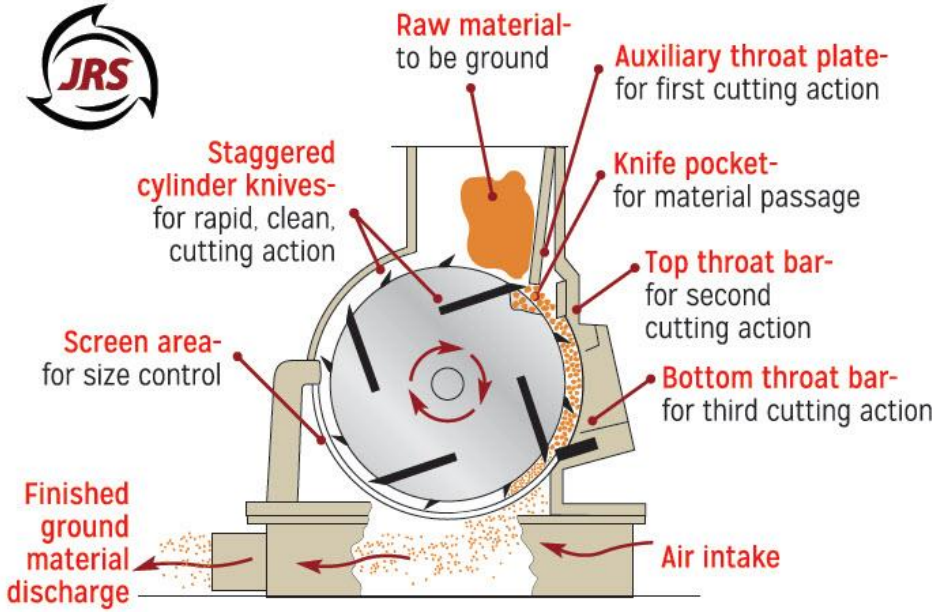
| Mill | Impact | Attrition | Shear | Compression |
|---|---|---|---|---|
| Condux | Primary | | Secondary | |
| Tornado | Primary | | | |
| Vibrating Ball | | Secondary | | Primary |
| Attrition | | Primary | Secondary | |
| PolarFit | | | | Primary |
| Disc Refiner | | | Primary | Secondary |

### Handling & Densification

Screw Extruder

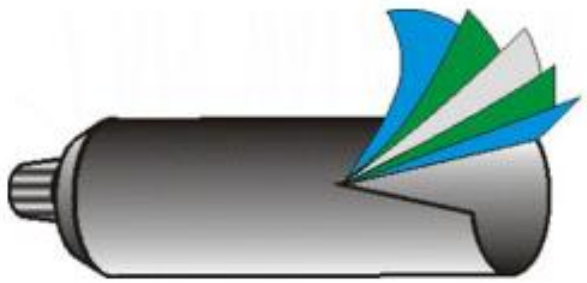
Fluidized Bed Agglomerator

# Gravity Screening




# Recycling Challenges with Multilayered Packaging

Multilayer composite materials cannot currently be recycled because they are mixtures of various plastics and metals contaminated with pigments and dyes.



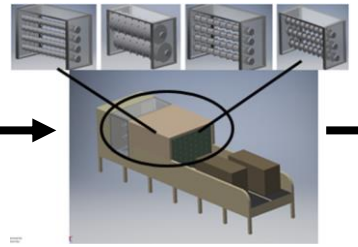
**Key:**
Blue: Polyethylene
Green: Polyethylene copolymer
Light Grey: Aluminium foil

BFNUF capabilities aim to advance recycling methods for multilayered composite material.

# BFNUF Process for Multilayer Package Recycling

**MSW Bale Acquisition**

Coarse Bale Deconstruction



Coarse Bale Separation

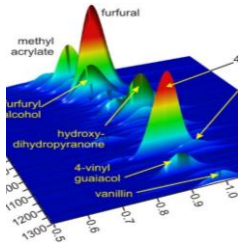
Chemical Analysis and Separation

Bench-Scale Storage Conditioning Systems

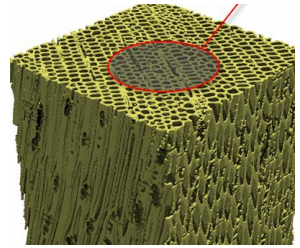
Shear, Impact, and Attrition Milling

Densification or Tempering

**Conversion-Ready Feedstock**




Reactivity Screening

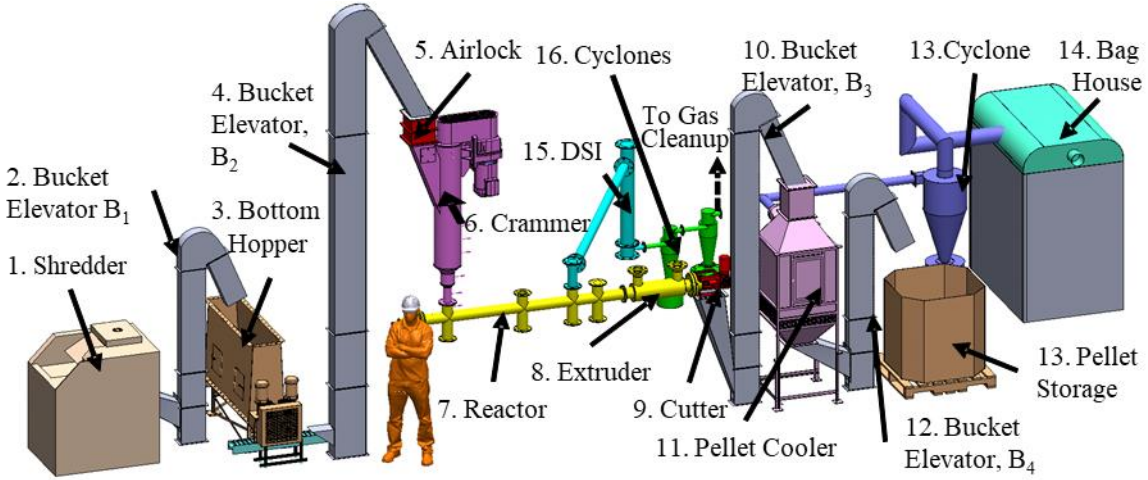


Structural Analysis

Each capability upgrade plays a role in expanding research capabilities towards enabling new feedstocks for the coming decade.

# Thermal preprocessing and mechanical reformatting

- Investigation of thermal treatment to remediate chlorine content in wastes
- Produce a more consistent solid fuel or solid feedstock
- Project with Convergen Energy and Michigan Technological University

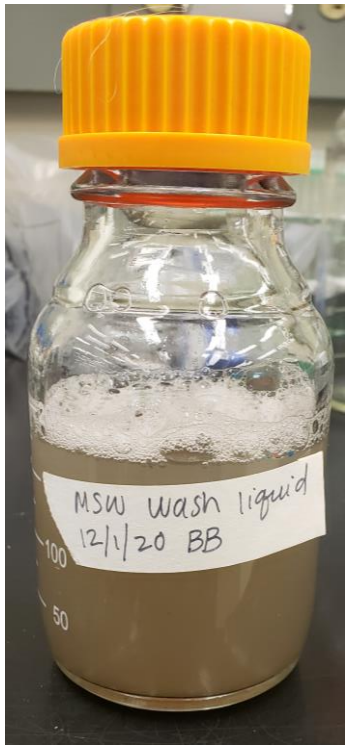




Kolapkar, Shreyas S., et al. "Integrated torrefaction-extrusion system for solid fuel pellet production from mixed fiber-plastic wastes: Techno-economic analysis and life cycle assessment." *Fuel Processing Technology* 226 (2022): 107094.

# Plastic Decontamination Studies

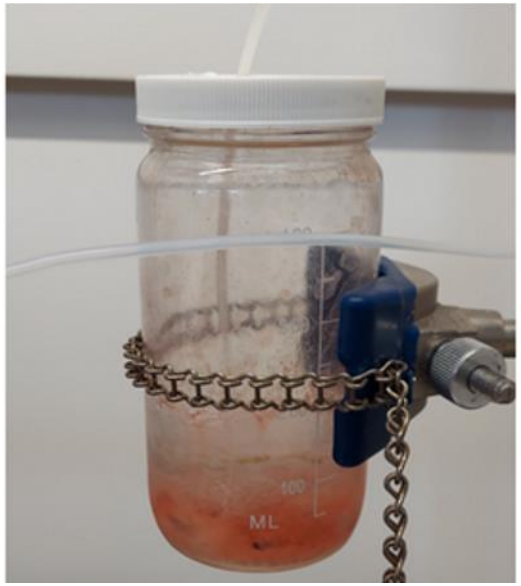
## Detergent wash

Samples washed with detergent and water




## Chemical wash

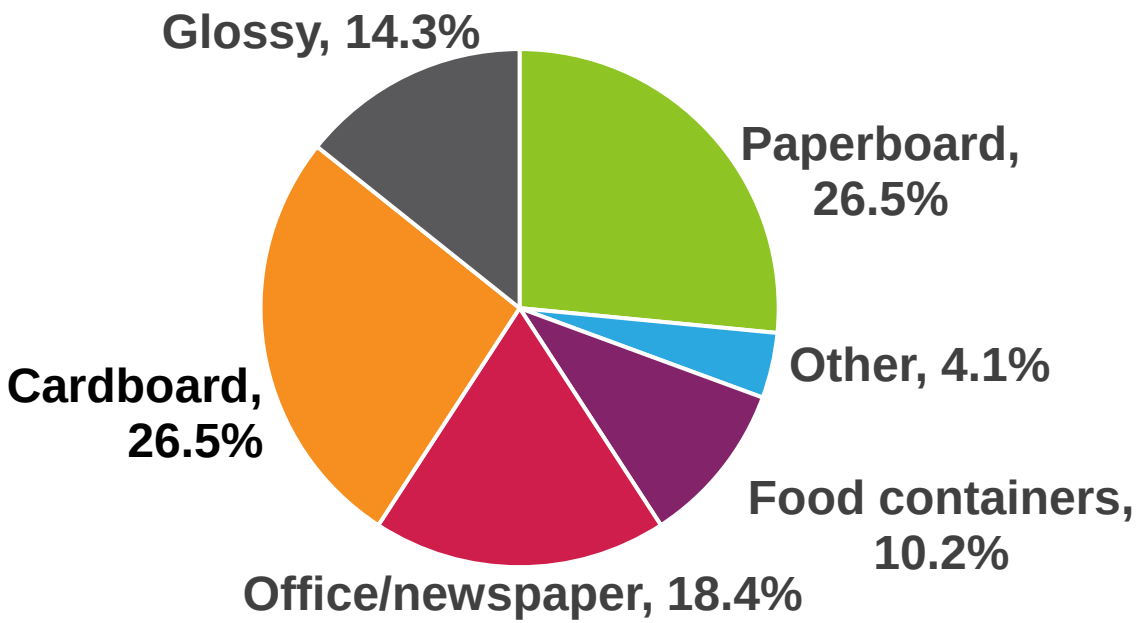
Samples washed with dimethyl ether (DME)

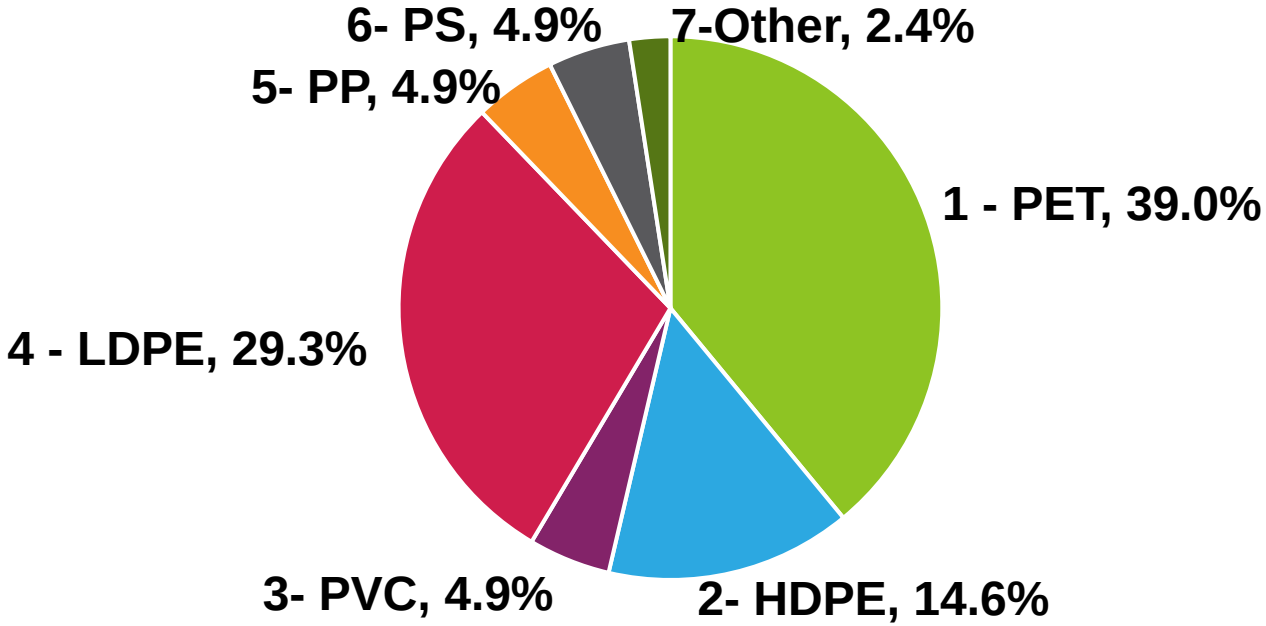



Rebecca M. Brown, Amber N. Hoover, Jordan L. Klinger, Bradley D. Wahlen, Damon Hartley, Hyeonseok Lee, Vicki S. Thompson.
*Decontamination of Municipal Solid Waste Increases Low and High Temperature Conversion Yields*
Submitted to Frontiers Energy Research

# Rural Waste

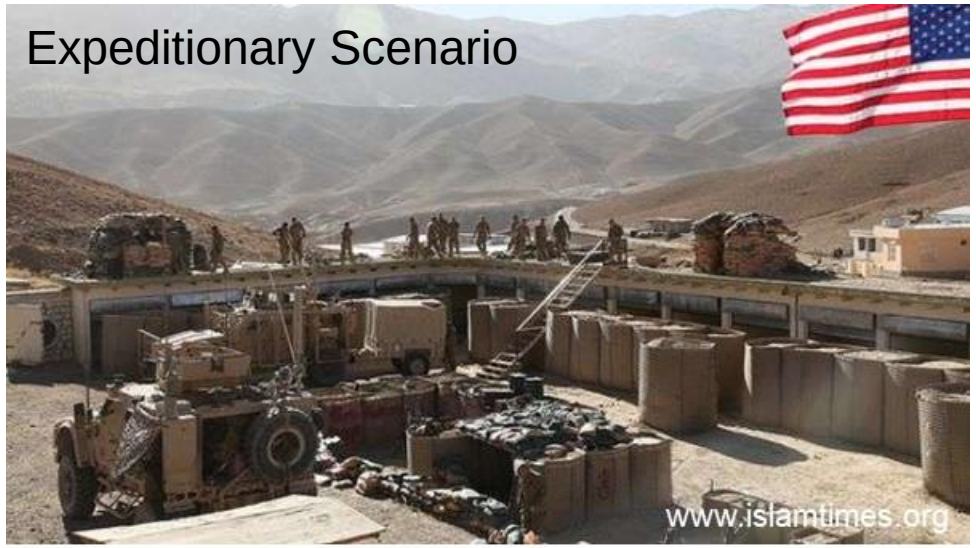
Source waste from rural community
Characterize the waste streams
Salyersville, KY pop. 1536 in Magoffin County, pop. 11,500



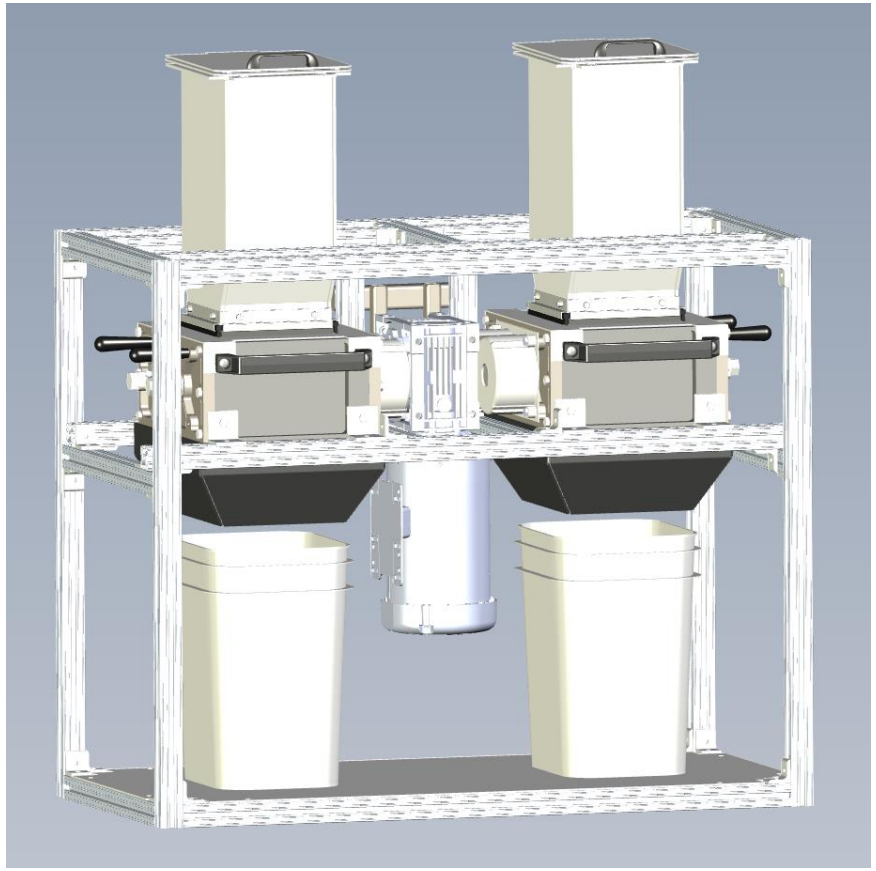



# DARPA ReSource Program: Bringing MSW Processing Systems to the Battlefield

- The military needs deployable technology to convert battlefield waste into useful products
  - Petroleum, lubricants, oils, textiles, nutrients
  - Strict size, weight, and power limitations
- INL's role is to make clean, sorted, reactive feedstocks out of battlefield waste
  - Unit operations included in system
    - Crushing and perforating for increased bulk density and enhanced cleaning
    - DME cleaning of dirty plastic and paper
    - NIR identification for automated sorting
    - Delamination of layered plastics
    - Shredding materials to < 5mm
- INL is designing/building functional systems that will be deployed to teams at MIT, Michigan Tech, and Battelle Memorial Institute in September

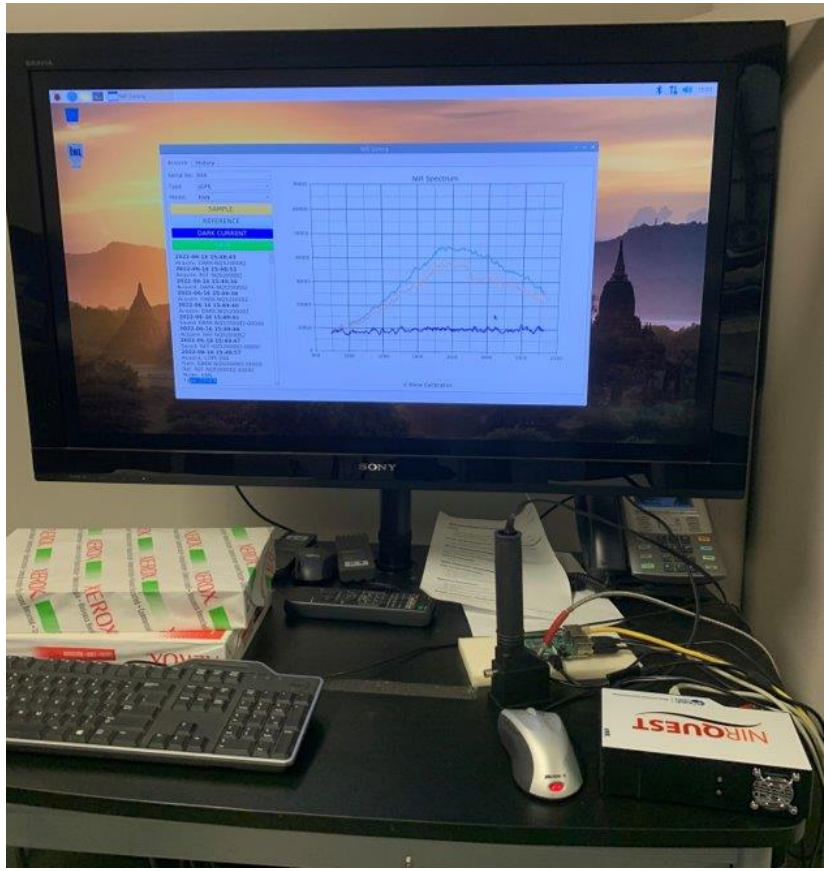



# INL's Deployable Waste Processing System: *Δ-S*



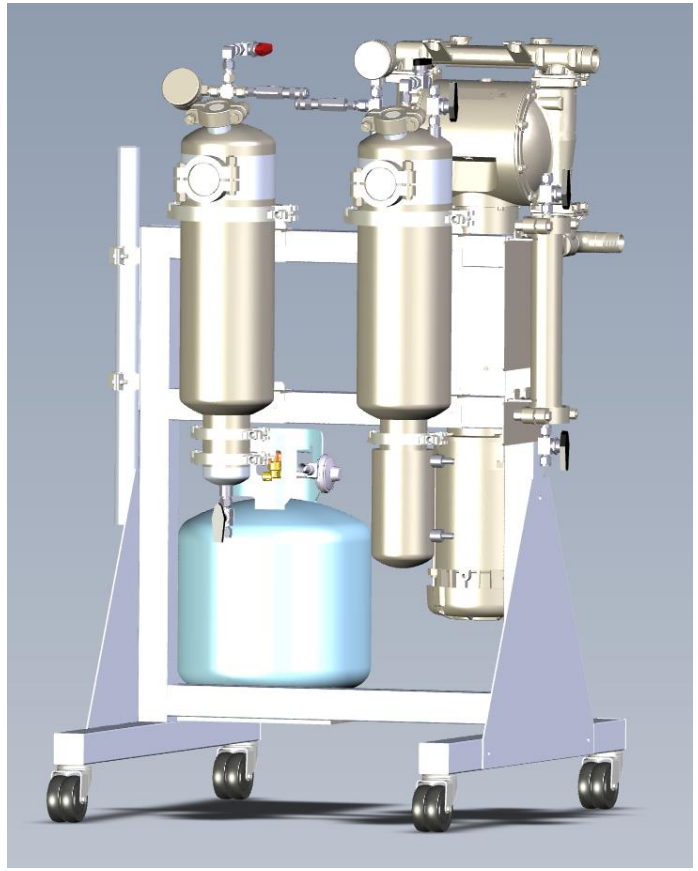
**Crusher/Perforator and Shredder**

- Collaboration with Forest Concepts
- > 20kg/day throughput
- 1.2m tall, 50 kg
- Output: 5mm particles and strips




**NIR Material Identification System**

- INL developed model and app
- Portable NIR spec and probe
- Model and app run on Raspberry Pi
- Adding new sensors for layered plastics



**MSW Solvent Cleaning System**

- DME solvent cleaning
- Integrating delamination process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