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Development of a deployable plastic sorting and decontamination system

Idaho National Laboratory

DARPA ReSource Program

- Military logistic support has a large human cost in contested environments with no ability to create valuable materials when and where needed.
- DARPA's ReSource program aims to revolutionize how the military procures critical supplies on the battlefield by engineering self-contained, integrated systems that rapidly produce large quantities of supplies from feedstock collected on-site.
- Products include lubricants, adhesives, tactical fibers, potable water, and edible macronutrients.
- Developed technologies will function simply, reliably, and needing limited servicing in isolated environments.
- Warfighters will be able to turn forage wastes into lubricants and nutrition, supporting independent expeditionary units and Humanitarian Assistance and Disaster Relief (HADR) stabilization operations.
- https://www.darpa.mil/program/resource

Military Applications for Technology

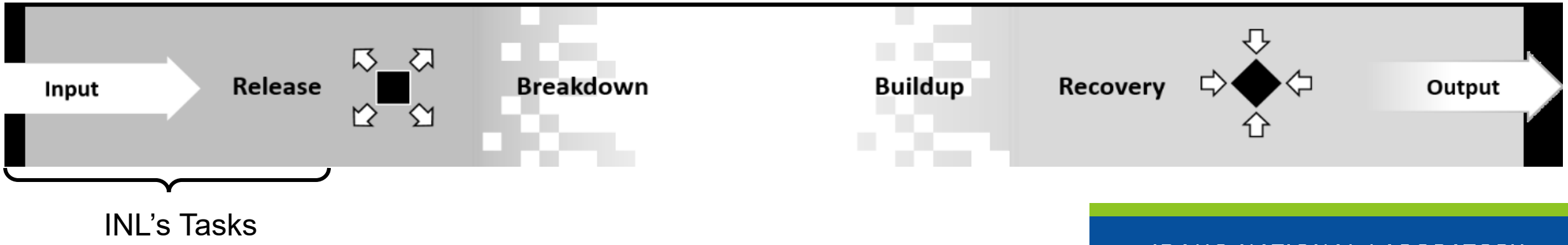
- Expeditionary Scenario
  - Soldiers need supplies and generate waste
  - New supplies need to be delivered and waste needs to be transported out
    - Risk to personnel and equipment in hostile environments
    - Expeditions can be limited by ability to receive new supplies
- Disaster Recovery/Stabilization Scenario
  - Response to a natural disaster such as a hurricane, tornado, earthquake, etc.
  - Waste is everywhere, but it is all unusable

Current Waste Management Strategy

- MSW is a highly heterogenous feedstock
  - Variable dependent upon location, residential/industrial, season, MRF/no MRF, etc.
- Disaster Recovery/Stabilization Scenario
  - Landfill
  - Incineration
- Expeditionary/Special Operations Scenario
  - Transport in new, transport waste out
  - Roadside dumps, incineration
- Challenges/limitations
  - Wasteful
  - Environmental harm
  - Detection/tracking

Project Objectives

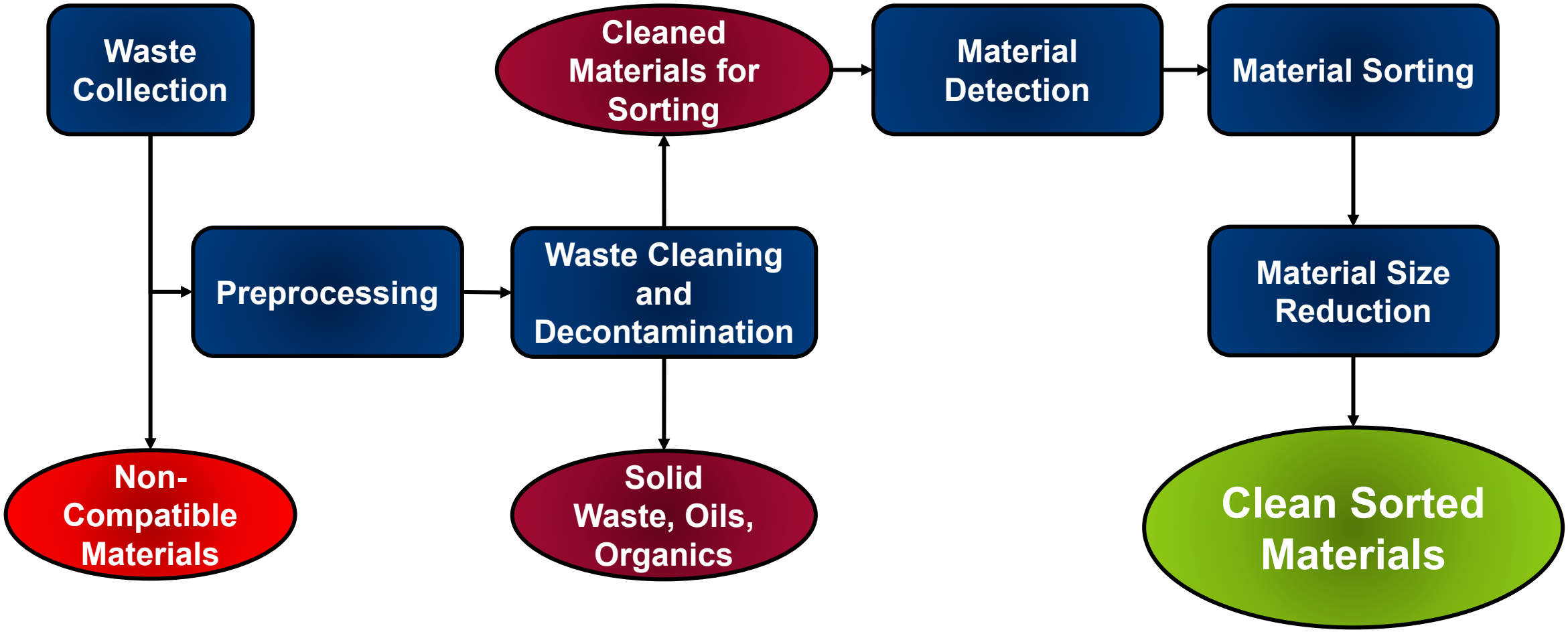
- INL's Objectives
  - Phase 1: Build one system to support Stabilization/Expeditionary scenarios
  - Make clean, on-spec feedstocks
  - Decontaminate and purify waste into usable feedstocks
  - Sort waste into compatible bins
  - Feedstock specs determined by downstream conversion performers
  - Meet strict size, weight, and power requirements



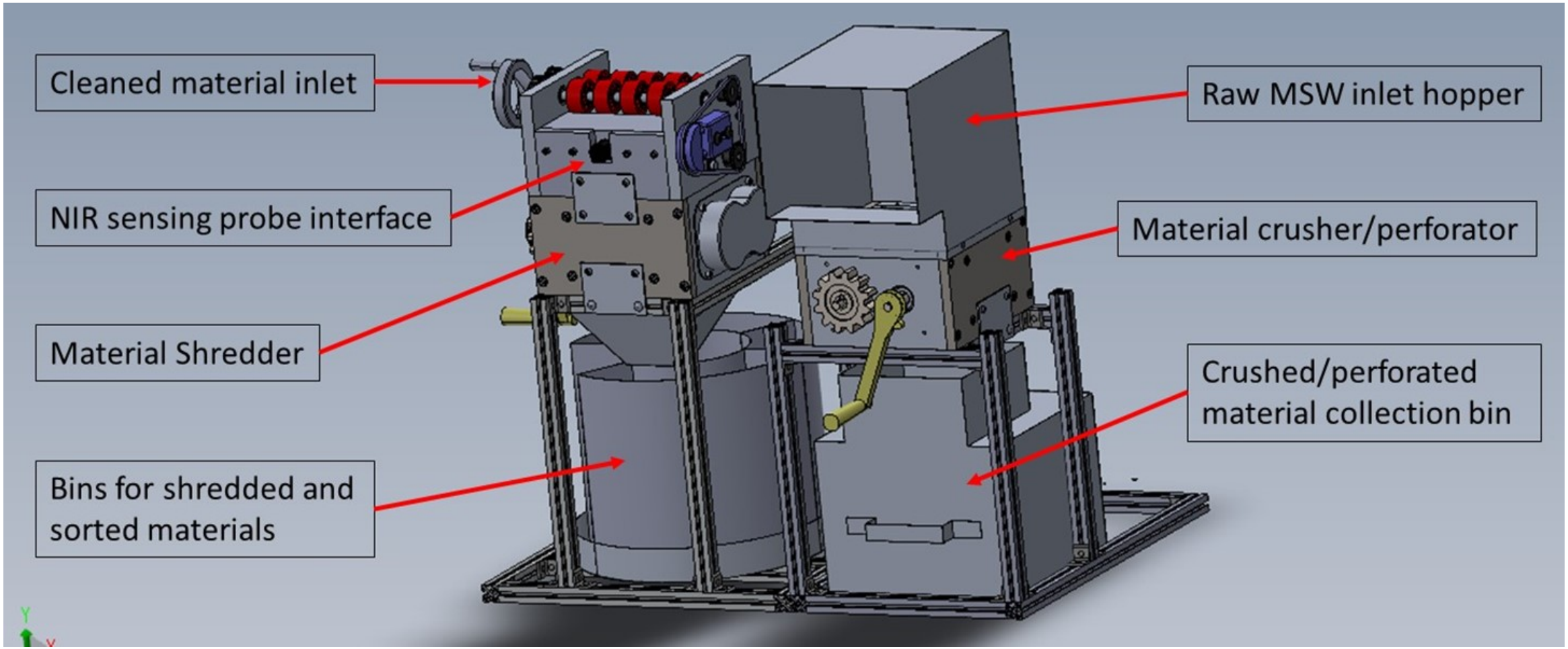
Research Plan Overview

- **Primary Goal: Produce on-spec feedstocks for performers completing conversion/upcycling tasks**
  - Manage feedstock variability
  - “One-pot” pretreatment and decontamination
    - Solvent extraction to remove contaminants, inks, plasticizers, organics
    - Clean and modify?
    - Back-up/supplementary aqueous washing system
  - Automated sorting of clean polymers
    - By plastic type (1-6) and paper
    - Size reduction of sorted polymers

Sorting and Decontamination System Process Flow



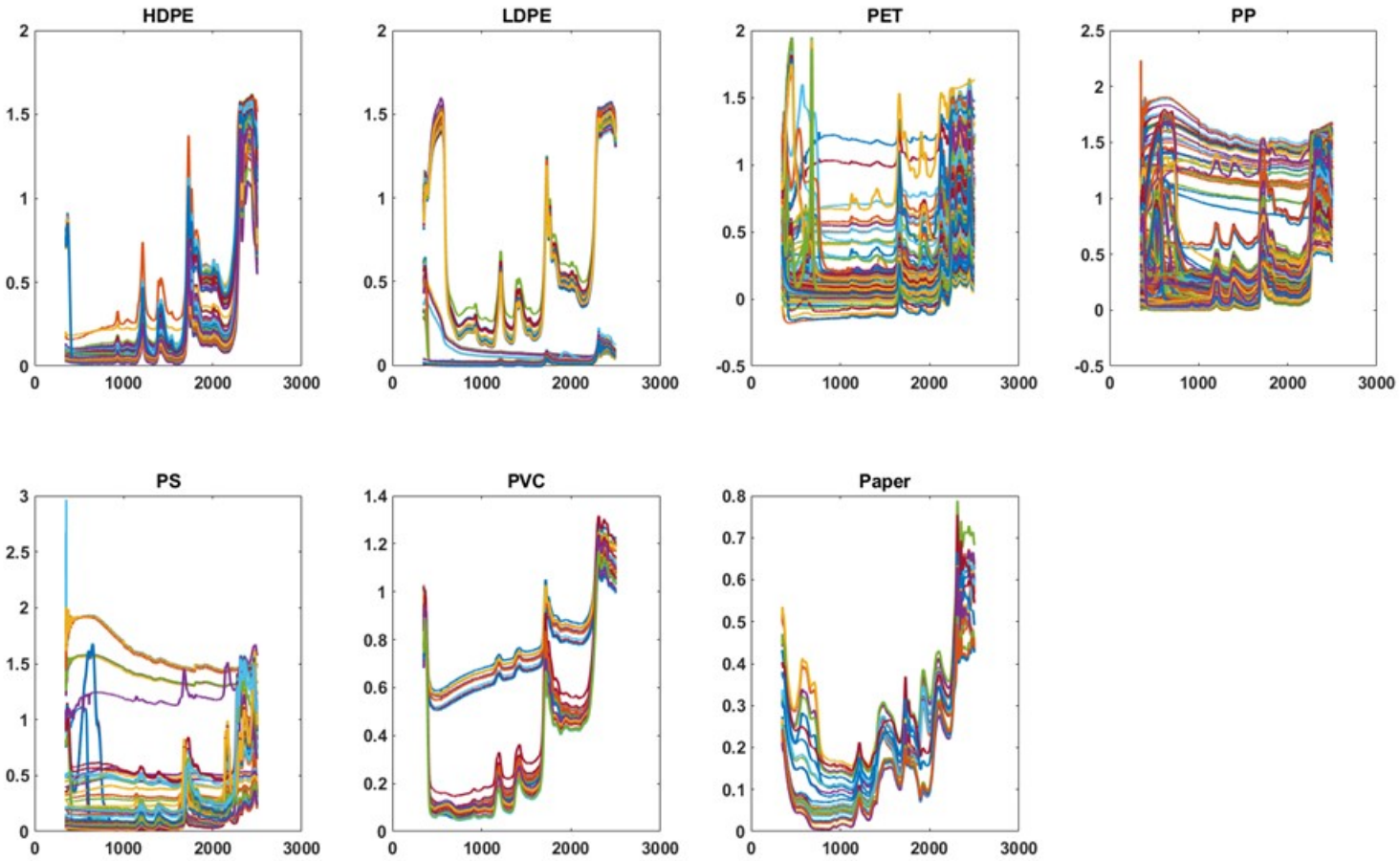
Preprocessing and Sorting System Design



Preprocessing and sorting system rendering with covers removed

Raw Data for NIR Model Development

- Training and validation datasets generated
- Clean MSW used
  - #1 PET
  - #2 HDPE
  - #3 PVC
  - #4 LDPE
  - #5 PP
  - #6 PS
  - Paper
- 1775 datasets generated
- 1st derivative data used for model development
- Variability seen between and within sample types



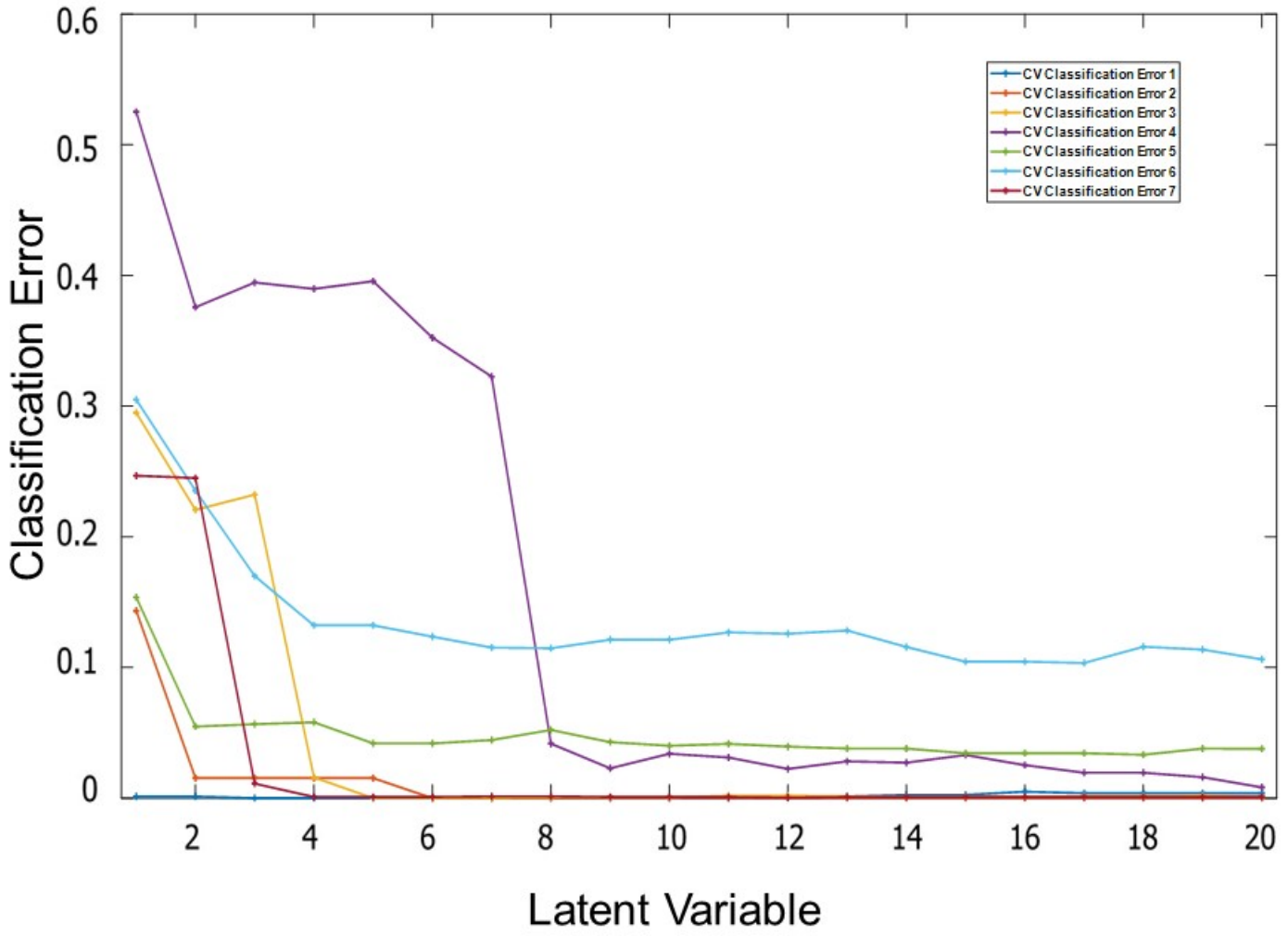
Spectral Data (log10(1/R)) of paper and plastics #1-6

Plastic Identification by NIR Model

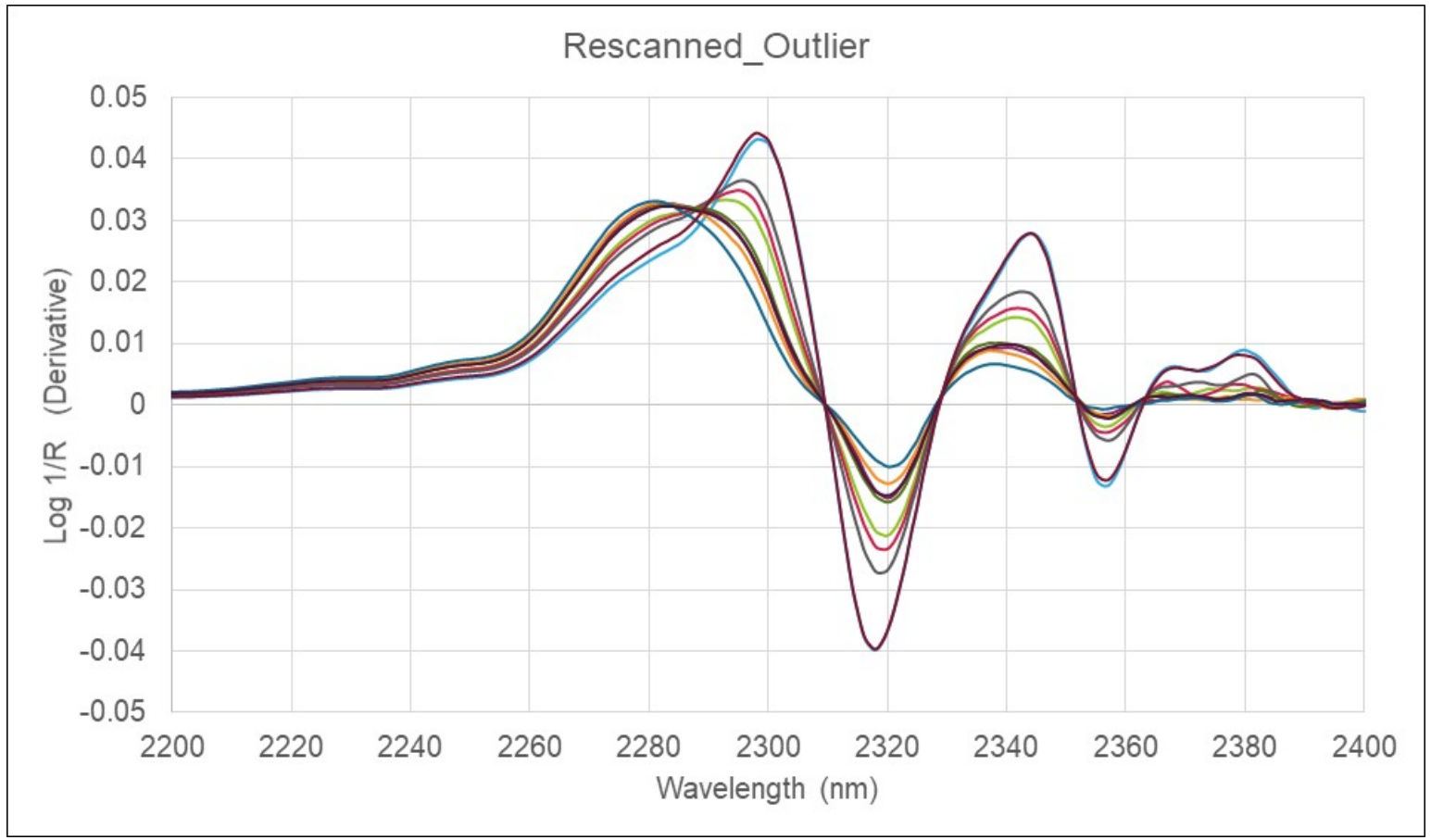
- Model type: PLSDA
- Included Wavelengths: 751-2500 nm
- Preprocessing: First Derivative and Autoscale

- Result: 8 Latent Variables needed

- Plastics identifiable with 4 LVs
- #4 LDPE, #5 PP, #6 PS, show higher error rates
  - Model is continually being refined

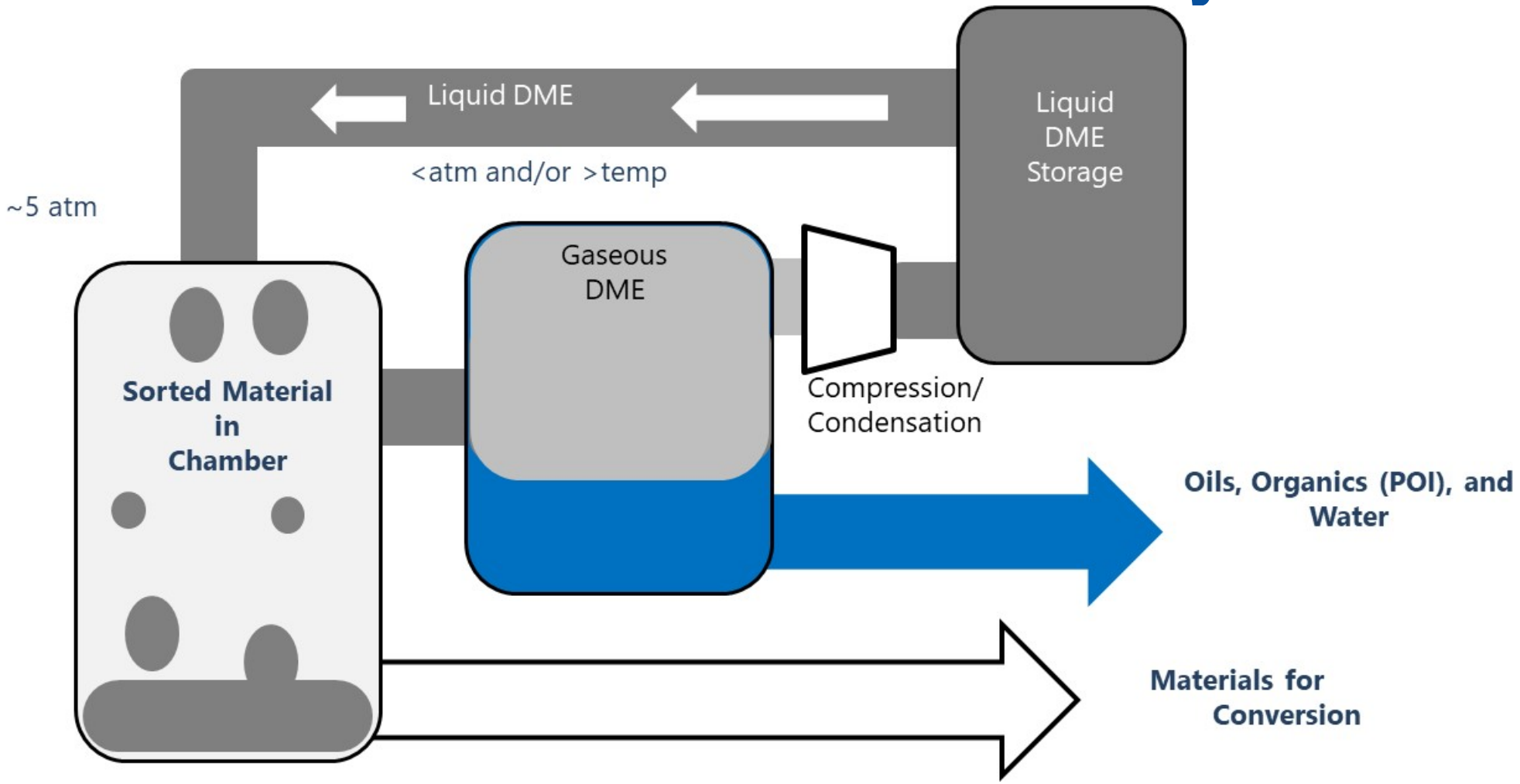


Problematic Outliers



- Multiple spectra taken from different locations on this HDPE juice bottle.
- The spectra indicate that the material is non-homogenous.
- In the current model this sample would be rejected as “unknown”.

Dewater, Drying, Extraction Process Being Adapted for Pretreatment and Decontamination System

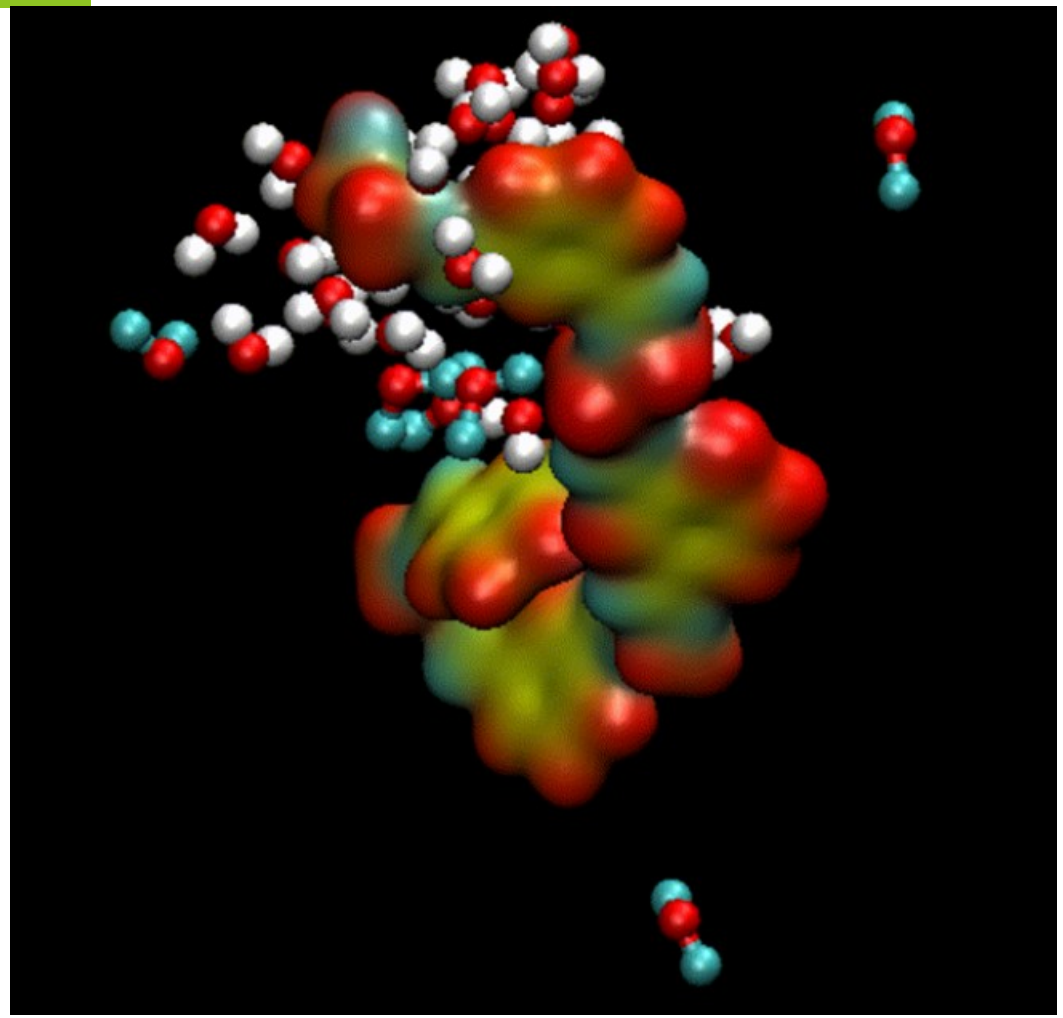


Pretreatment and Decontamination System

10L solvent extraction system

- Commercial Modular L-S Solvent Extraction Platform
  - Compressible solvent (refrigerant)
    - Dimethyl ether (DME) will be the starting solvent
  - 100+ cycles per solvent charge
  - Avoid carrying recharge solvents in field
  - Easily modified and scalable
- System will clean, decontaminate, and possibly modify waste materials

Molecular Dynamics Model of DME Interactions



Screenshot of MD animation of interaction between PET (large molecule), DME (red/green), and water (red/white)

- Developing molecular dynamics model of DME interactions
  - This will allow us to virtually test a variety of reaction conditions before entering the lab
  - Enable the evaluation of many other solvents or modifiers
- Preparing animation of MS simulation of PET/DME/water
  - Large molecule is PET
  - Red/white molecule is water
  - Red/green molecule is DME

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Artificial Neural Network (ANN) for MSW Characterization

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Subtopic 2a
Control Number 2203-1827

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Problem Statement

- MSW represents a valuable and plentiful source of low-cost feedstock, but its heterogeneity and variability are significant barriers to the application of state-of-the-art mechanical sorting devices.
- Each energy conversion pathway has different critical material attribute requirements for desired MSW feedstock.
- Sorting operations cannot manage MSW heterogeneity, variety, value, and contamination if they cannot measure it, which is why we are proposing to digitize the waste stream.

Project Innovation

- Develop an ANN that can identify and characterize, in real time, the organic and plastic constituents of the municipal solid waste (MSW) stream diverted to landfill.
- **Inputs:** AMP's current vision-based ANN, near-infrared camera, mid-wave infrared, X-ray fluorescence, 3D/depth imaging, and Ramen spectrometer.
- **Output:** We will develop a new neural network architecture that fuses these sensor signals as a multimodal ANN.
- Identify the plastic and organic MSW categories at 95% purity or greater, and characterize CMAs at 80% accuracy or greater.

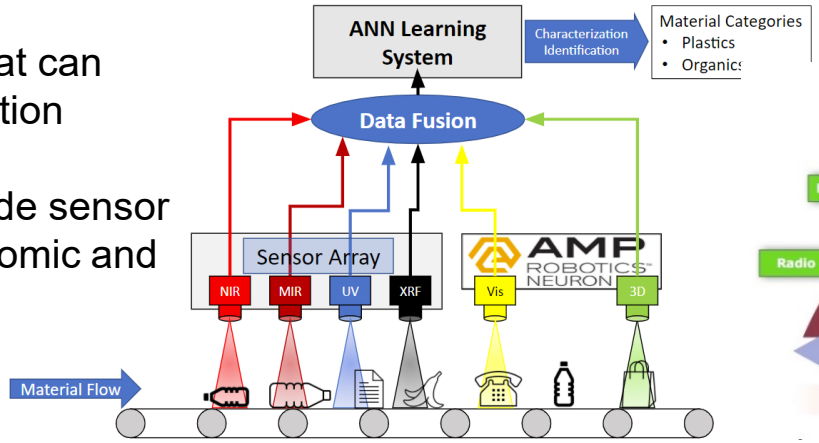
Project Impact

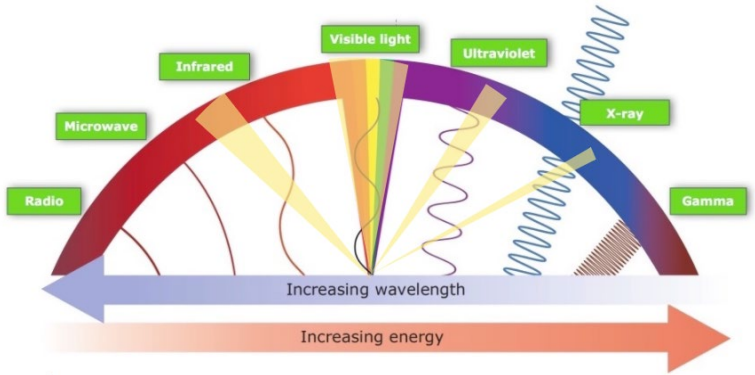
Project Goals/Objectives:

- Demonstrate a multimodal ANN-based technique that can identify MSW material categories at >95% classification accuracy.
- Identify reduced sensor and spectrum ranges to guide sensor cost reduction efforts to achieve BETO techno-economic and life cycle objectives.

AMP ROBOTICS

Project Approach





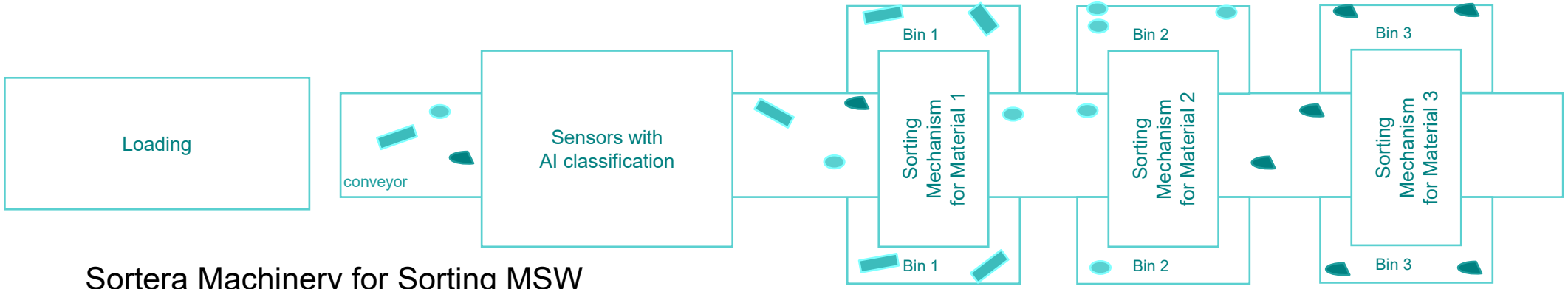
Advanced Sensing for Characterization and Sorting of Non-Recyclable Plastics Using Sensor Fusion with Artificial Intelligence

Objectives

1. Develop multi-sensor “fingerprint” for waste plastic
2. Develop novel classification system for waste plastics, including layered plastics
3. Use sorted materials in catalytic pyrolysis to identify high performing fractions

Sensors to be used: Visible, NIR, XRF

Sortera’s Automated Modular Sorters



Sortera Machinery for Sorting MSW

SORTERA ALLOYS

https://recyclepowernow.weebly.com/getting-involved.html
https://mcgrathgroup.co.uk/services/recycling/sorting/
https://www.pri.org/stories/2018-01-01/mountains-us-recycling-pile-china-restricts-imports

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