CLOSE THE LOOP: IN-SPACE MANUFACTURING OF PURE PLASTIC FROM WASTE

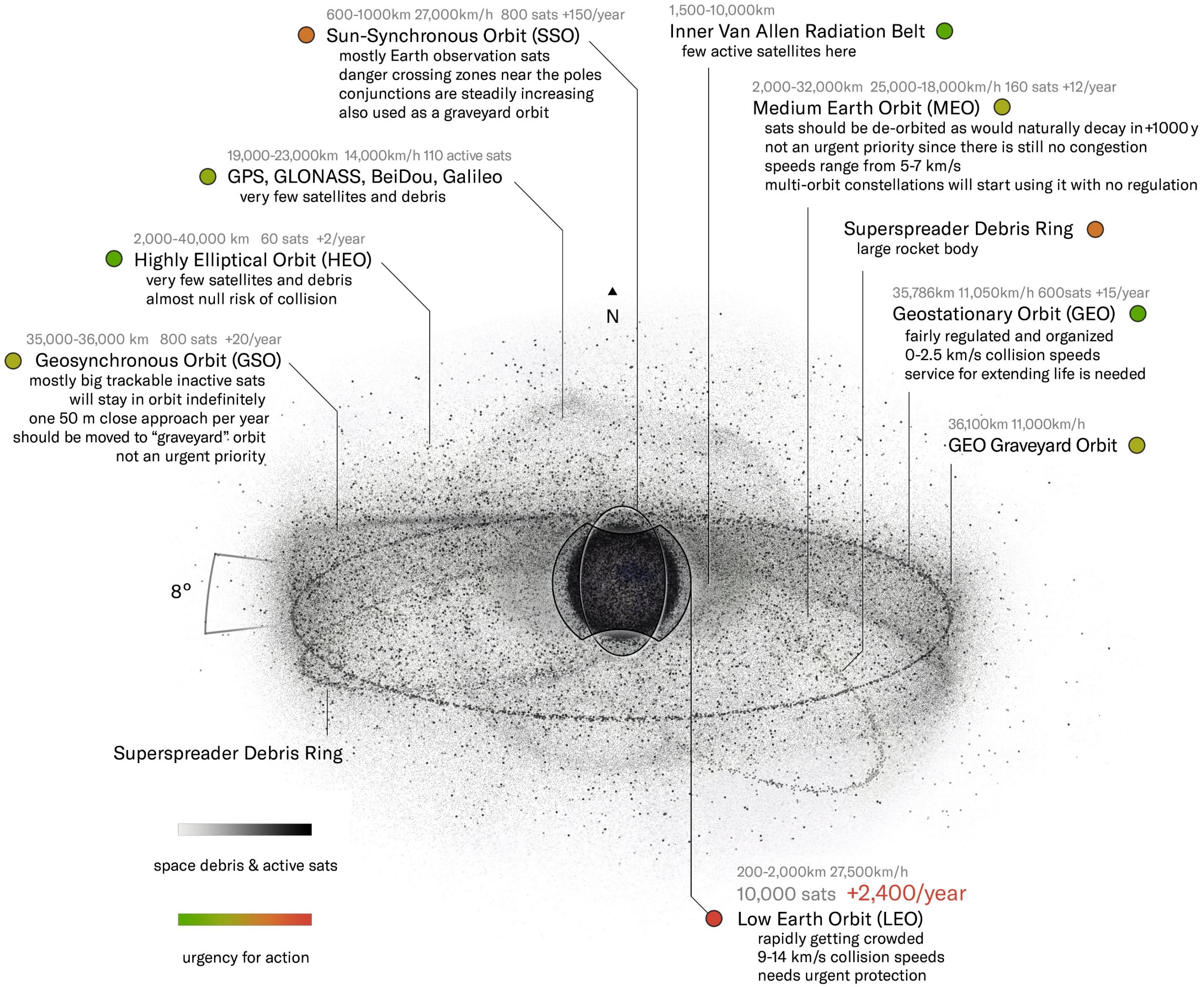
F. D. Gaertner, E. Bar-Ziv, F. Long

THE WASTE STREAMS OF SPACE

Orbital Debris [1]

Estimates of ~7000 tonnes of orbital debris

- Based on launches from 1959-2000
- **~30%** of payload compositions are polymerics, composites, and ceramics



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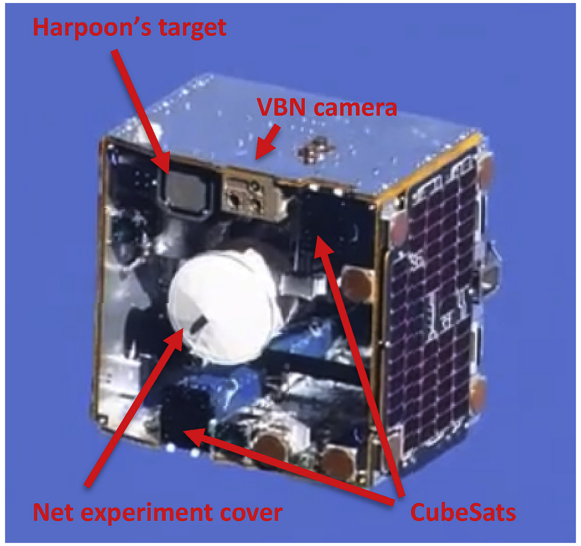
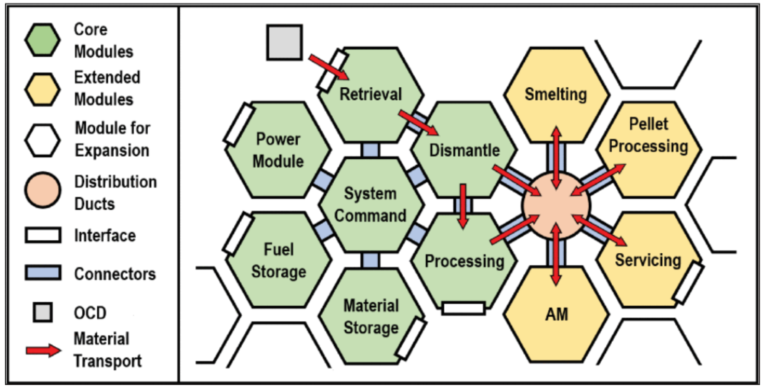
ORBITAL DEBRIS COLLECTION



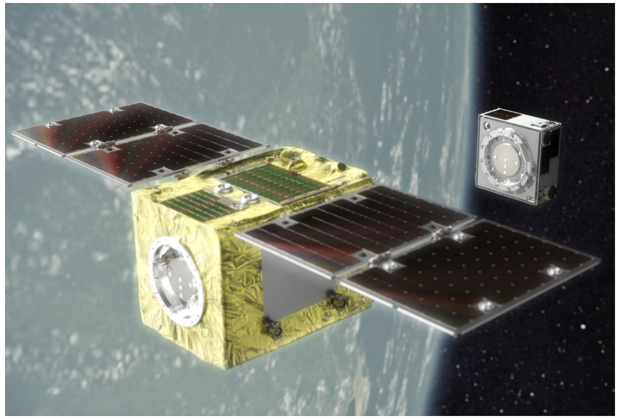
RemoveDEBRIS [3]

- Demonstration of debris removal operations
  - Net, VBN, harpoon, and dragsail



Space JANITOR [4]

- Architecture for the retrieval and processing of orbital debris



ELSA-d [5]

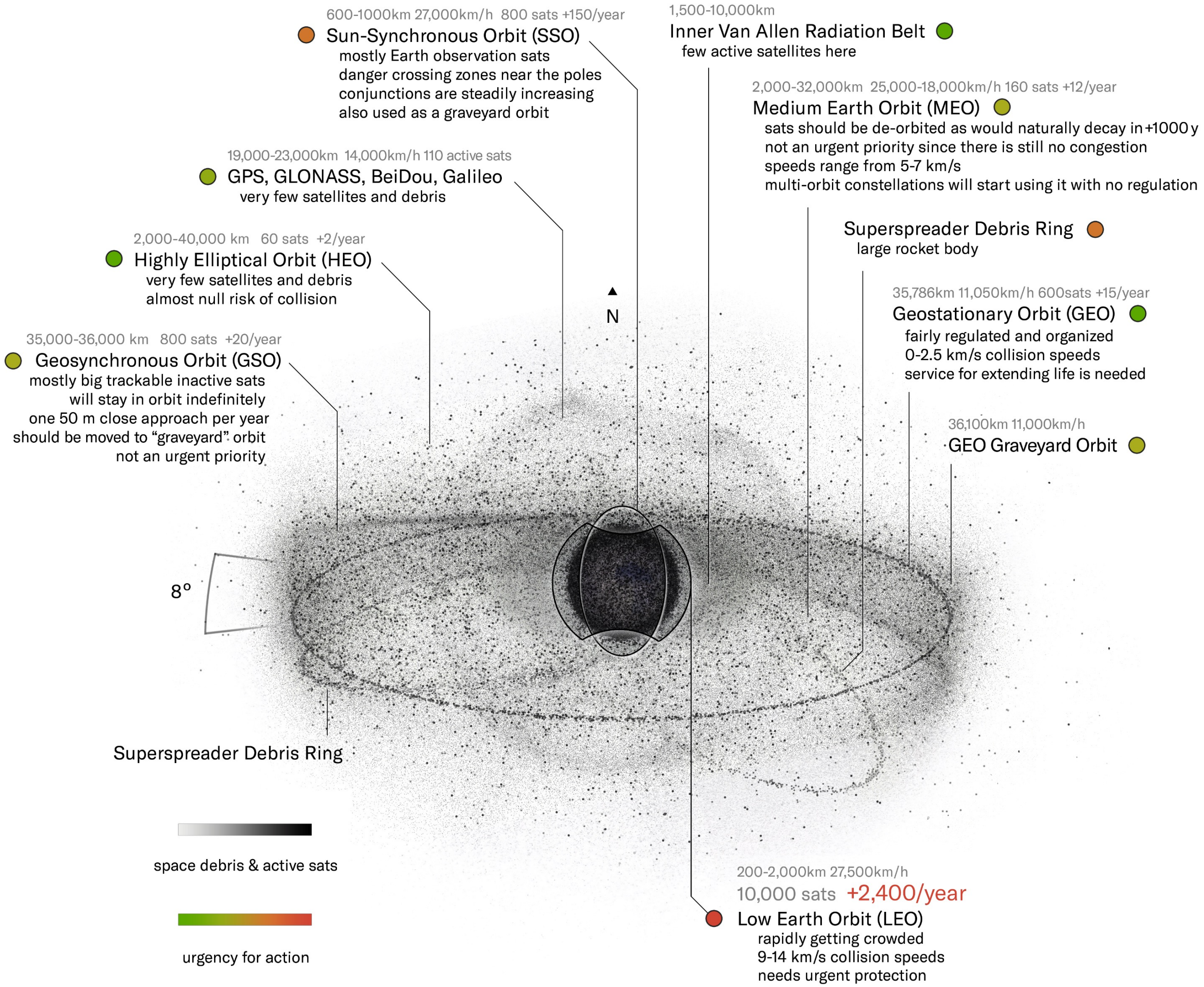
- Demonstration of technologies needed for debris docking and removal
  - Magnetic docking mechanism
  - ELSA-M in development

THE WASTE STREAMS OF SPACE

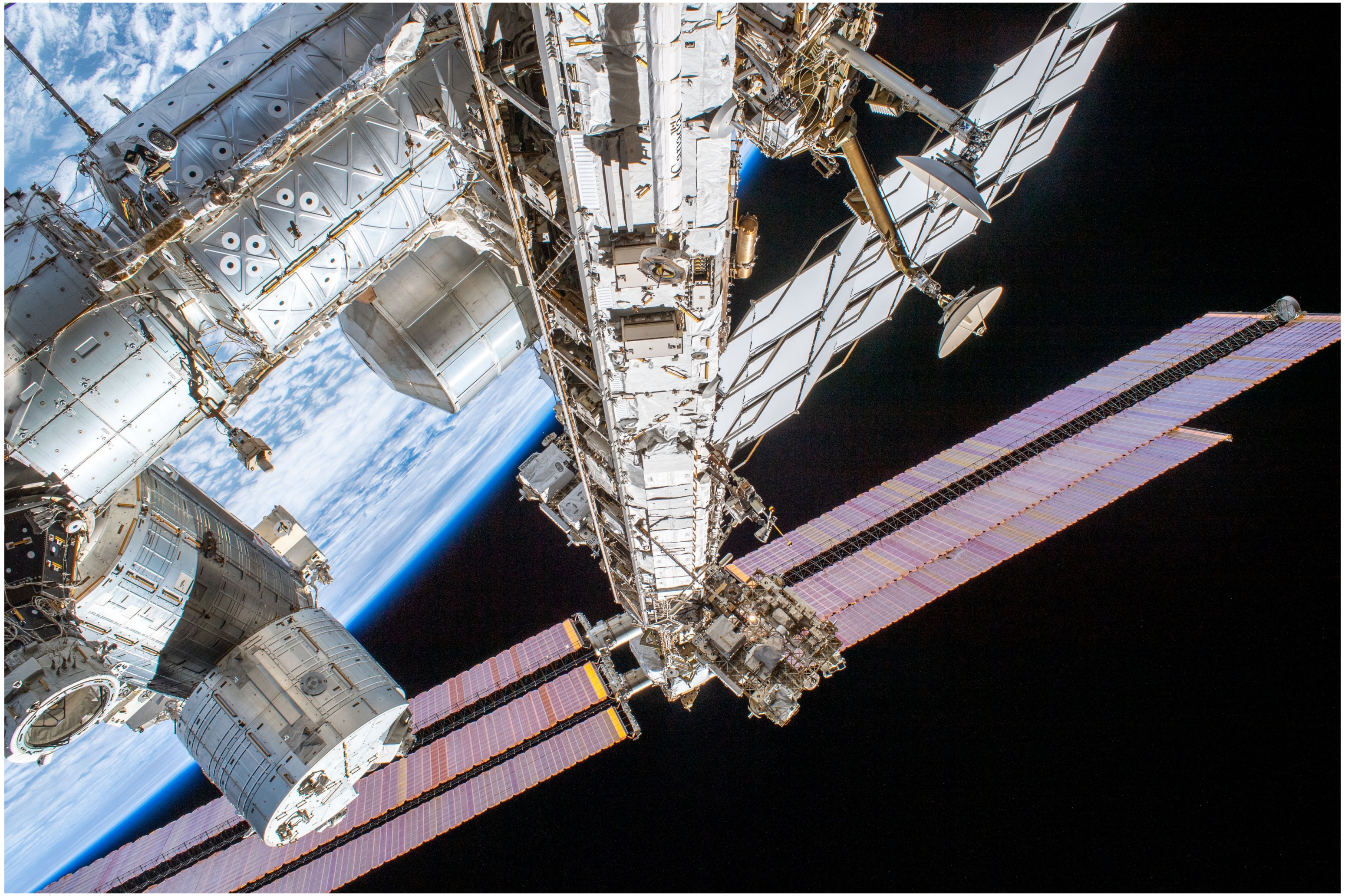
Orbital Debris [1]

Estimates of ~7000 tonnes of orbital debris

- Based on launches from 1959-2000
- **~30%** of payload compositions are polymerics, composites, and ceramics
    - Difficult to characterize compositions
    - Exposed to extreme climate for years



THE WASTE STREAMS OF SPACE



International Space Station [2]

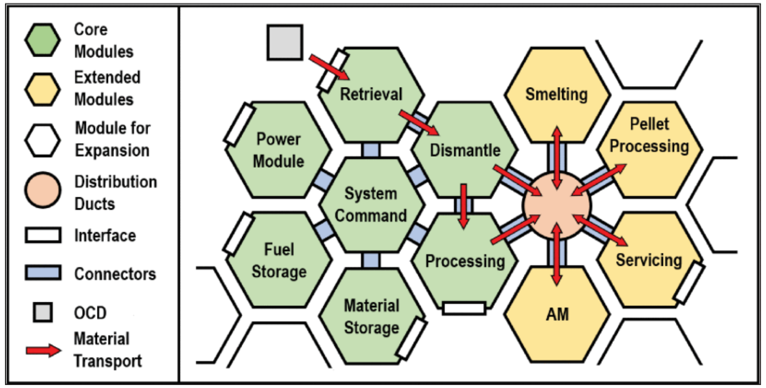
Waste disposed of manually

- Trash returned to Earth or incinerated in atmosphere
  - **Predominantly plastics**
- Occupy valuable space and pose unnecessary health hazards to the crew

IN-SITU RECYCLING DISCUSSIONS

Capability Assessment of Plastic Waste use for Deep-Space AM [2]

- Thorough assessment on current recycling and AM technology
- Discussion on logistics and knowledge gaps



Space JANITOR [4]

- Architecture for the retrieval and processing of orbital debris

Composite Materials from Beverage Packaging [6]

- Comprehensive mechanical and thermal property analysis
  - Successful filament creation

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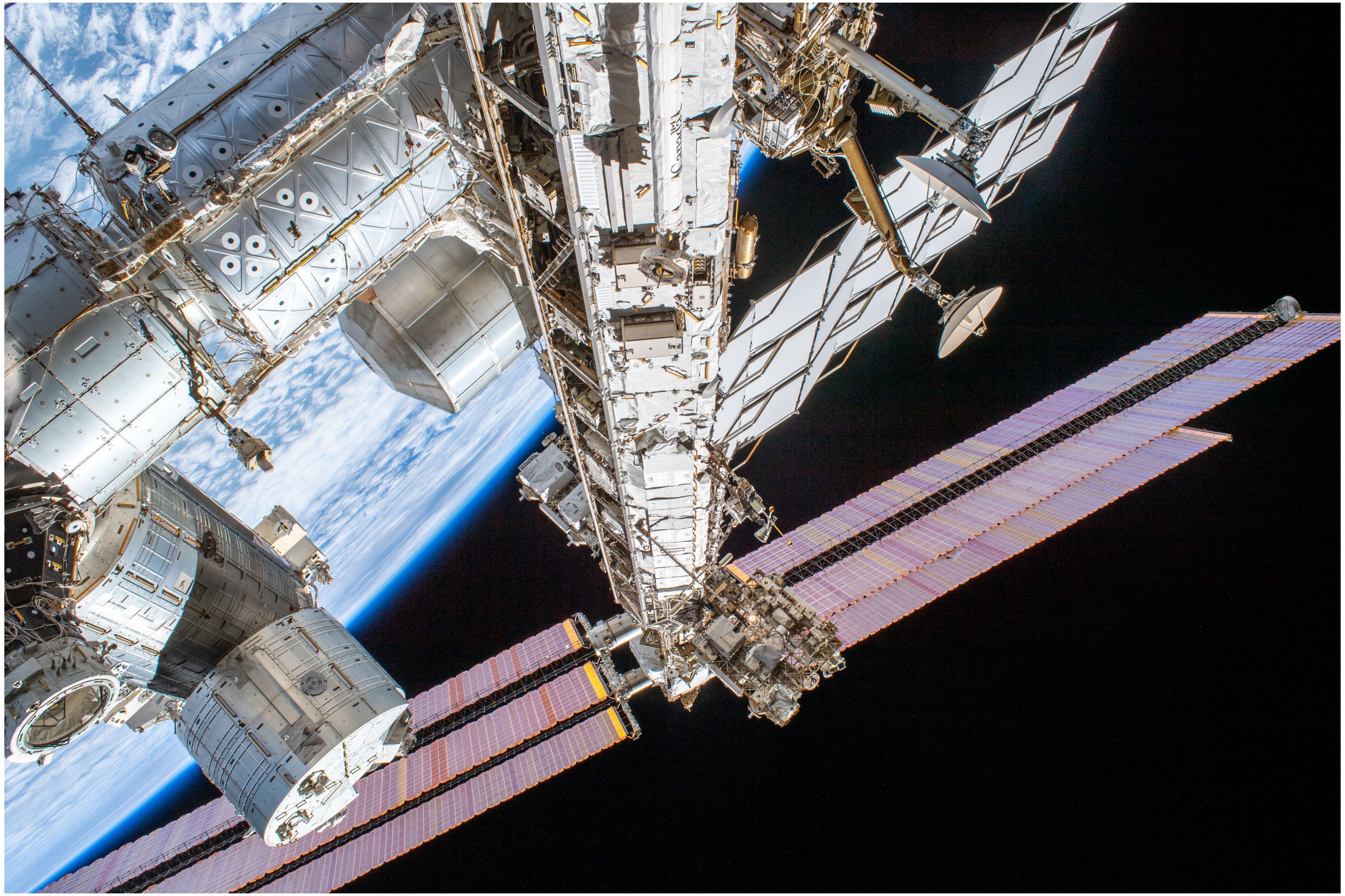
THE WASTE STREAMS OF SPACE



International Space Station [2]

Waste disposed of manually

- Trash returned to Earth or incinerated in atmosphere
  - **Predominantly plastics**
- Occupy valuable space and pose unnecessary health hazards to the crew
  - **Recycling knowledge gap**

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WHAT GOES INTO PLASTIC RECYCLING?

Image Credit: RawPixel, via Flickr

WHAT GOES INTO PLASTIC RECYCLING?

Using either of these methods requires a trade-off in recovered plastic quality and overall manufacturing and energy costs

Mechanical

- Grinding, shredding, or melting down plastic waste
- Loss in polymer quality
- Not applicable to complex plastics [2],[7]

Chemical

- Breaking down covalent bonds in polymers
- Significant amount of processing energy [7]

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Image Credit: RawPixel, via Flickr

WHAT GOES INTO PLASTIC RECYCLING?

Physical

Solvent-Targeted Recovery and Precipitation (STRAP)

- Uses a compatible solvent for polymer dissolution and precipitation [8]
- Produce high-quality resin with low cost and energy [9]

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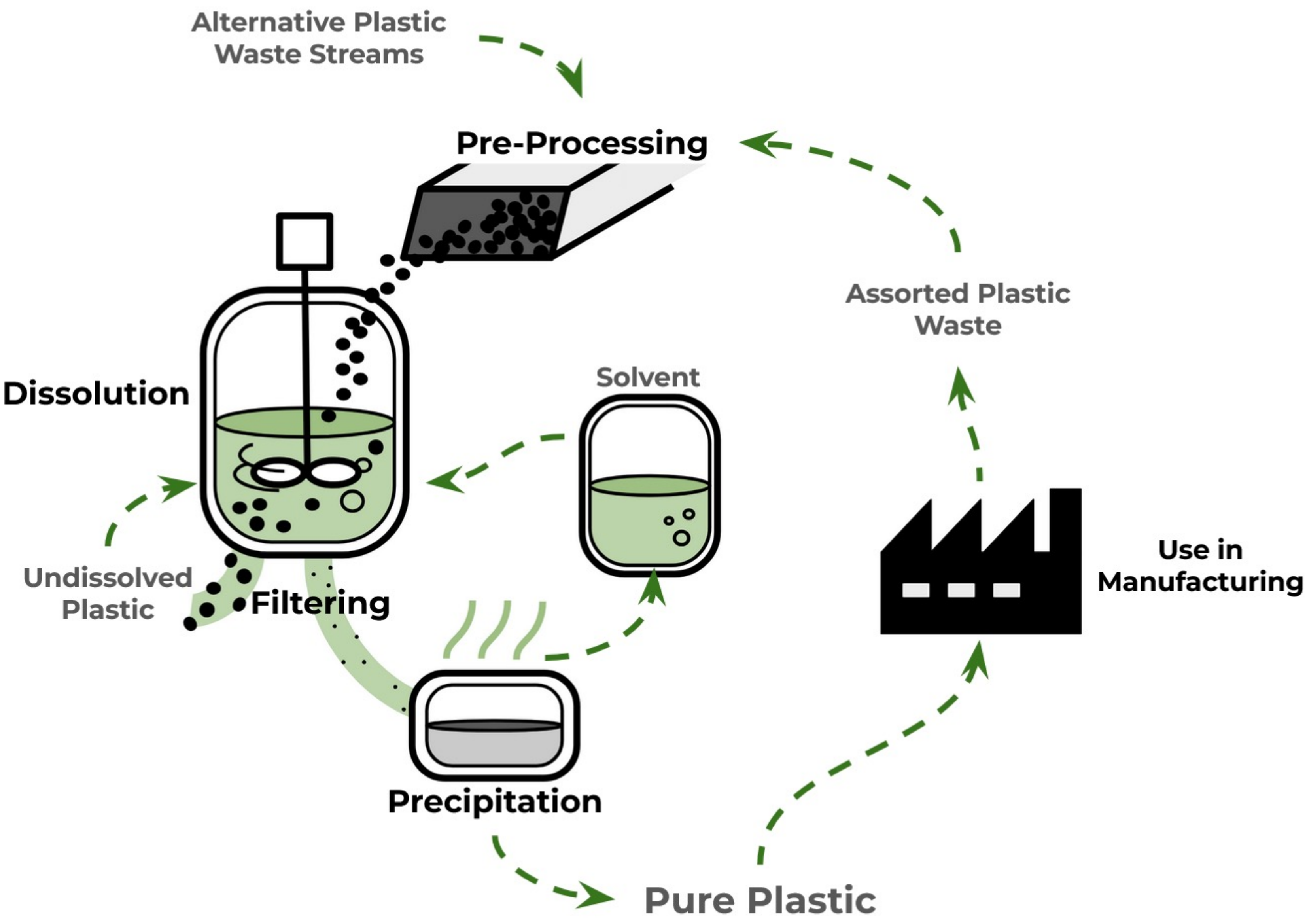
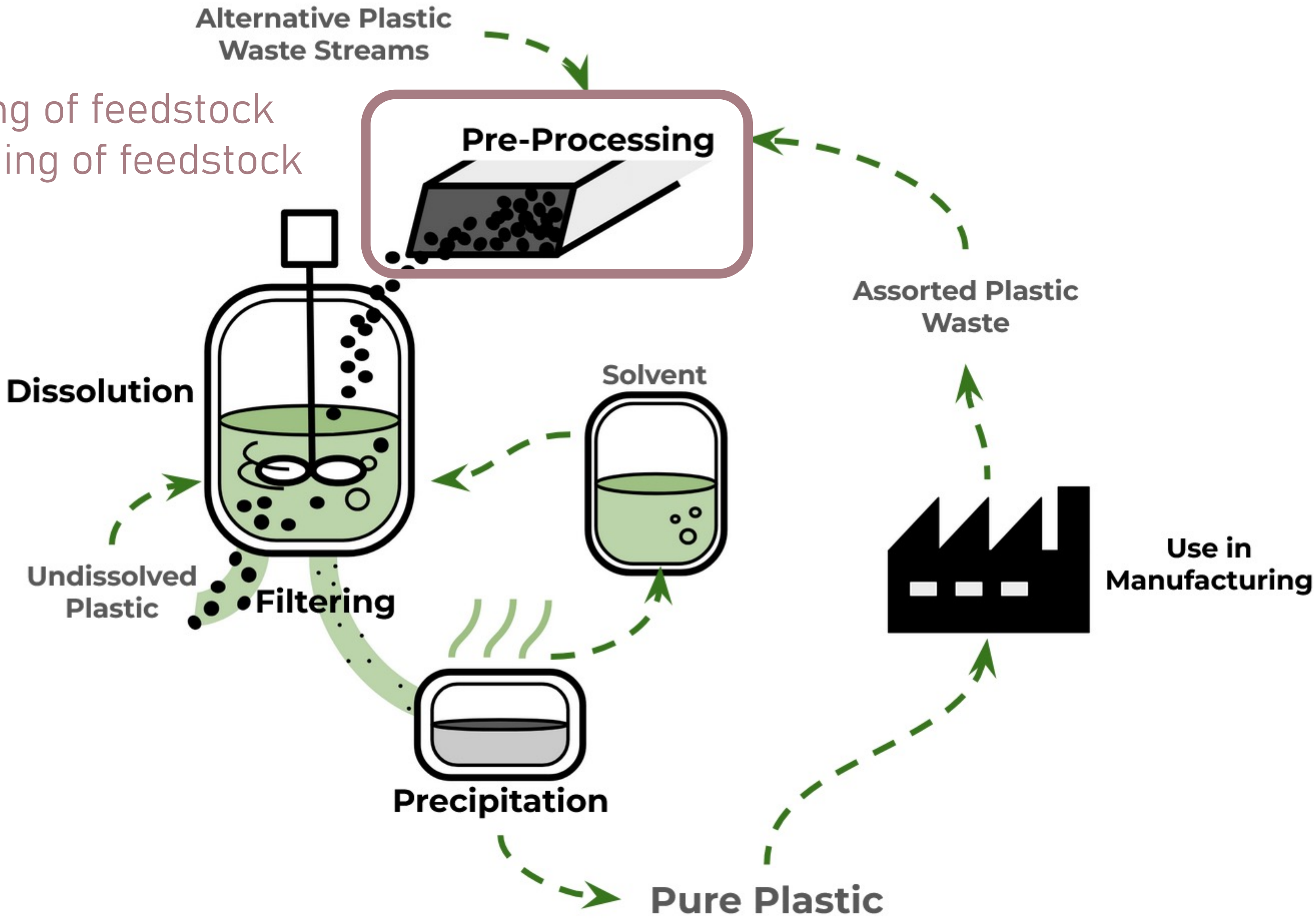
SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)

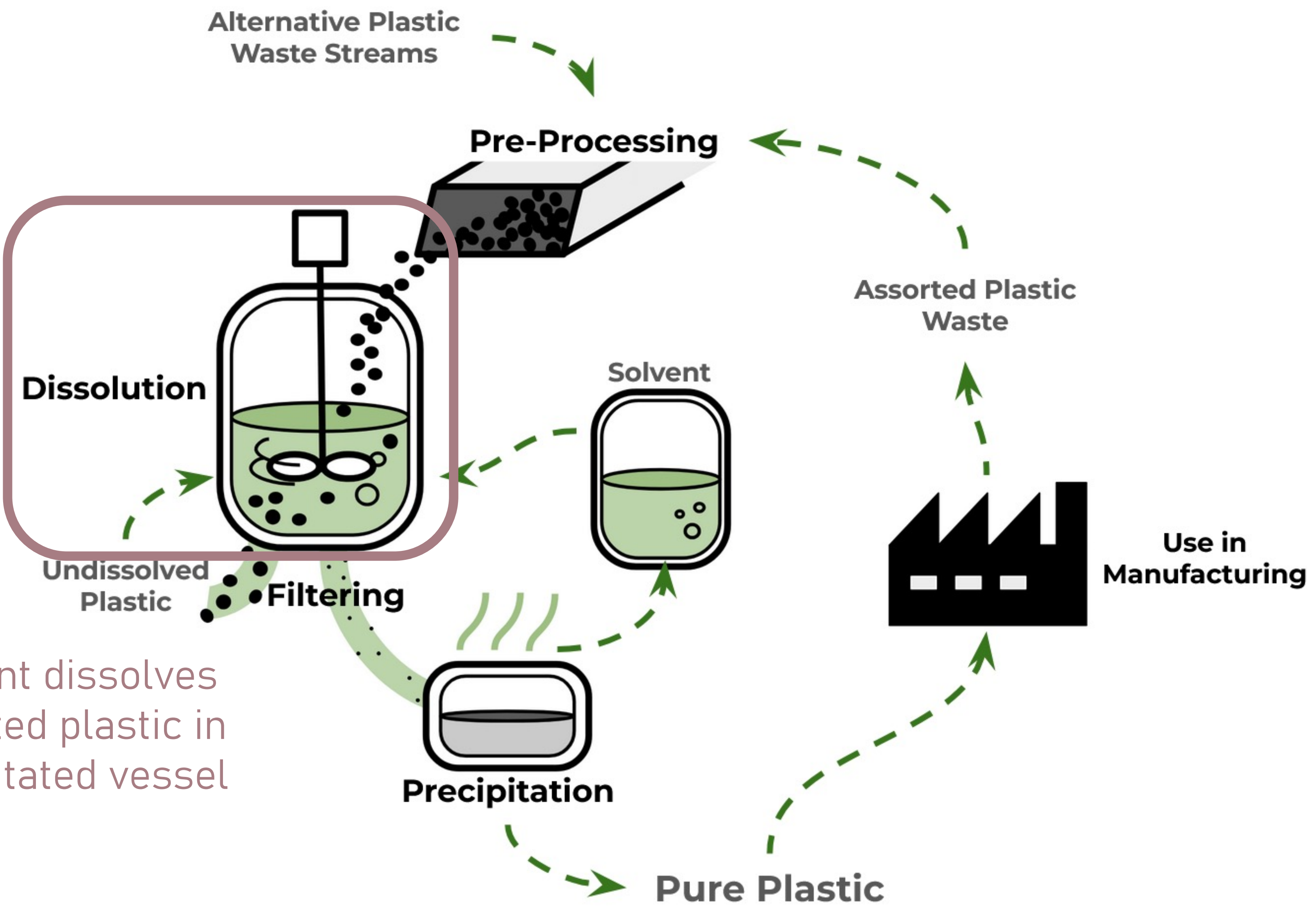


SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)

- Cleaning of feedstock
- Shredding of feedstock

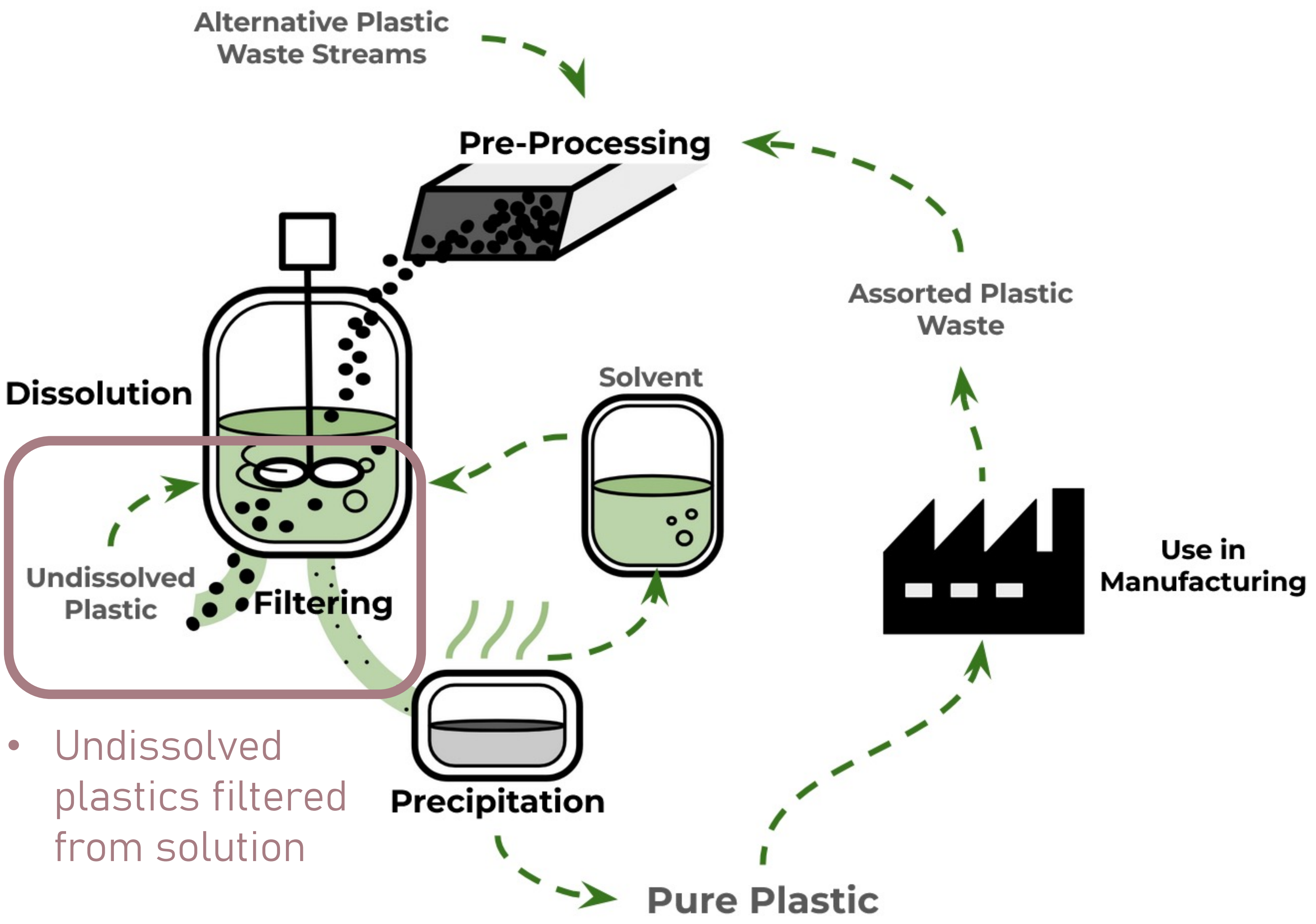


SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)



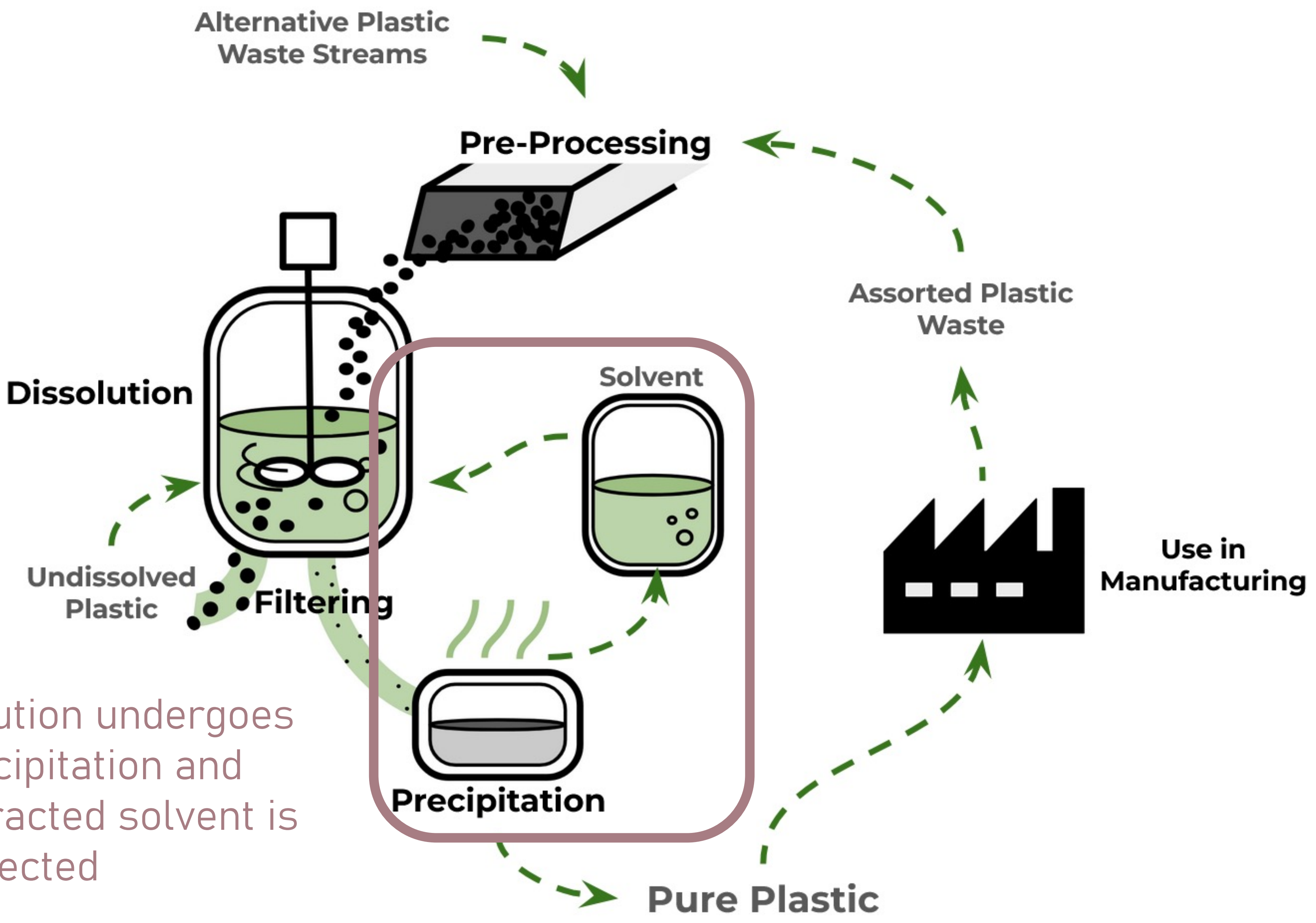
- Solvent dissolves targeted plastic in an agitated vessel

SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)



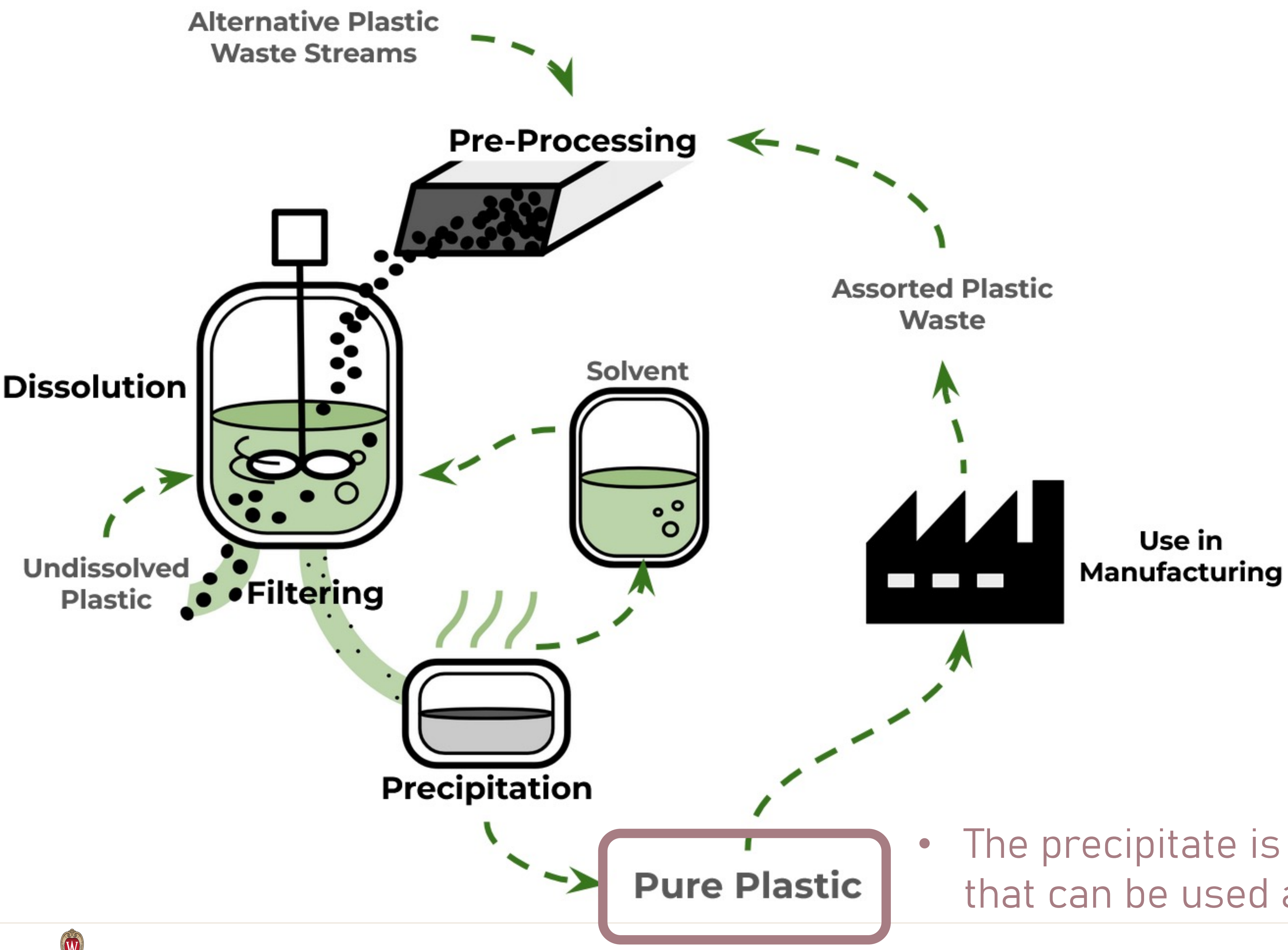
- Undissolved plastics filtered from solution

SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)



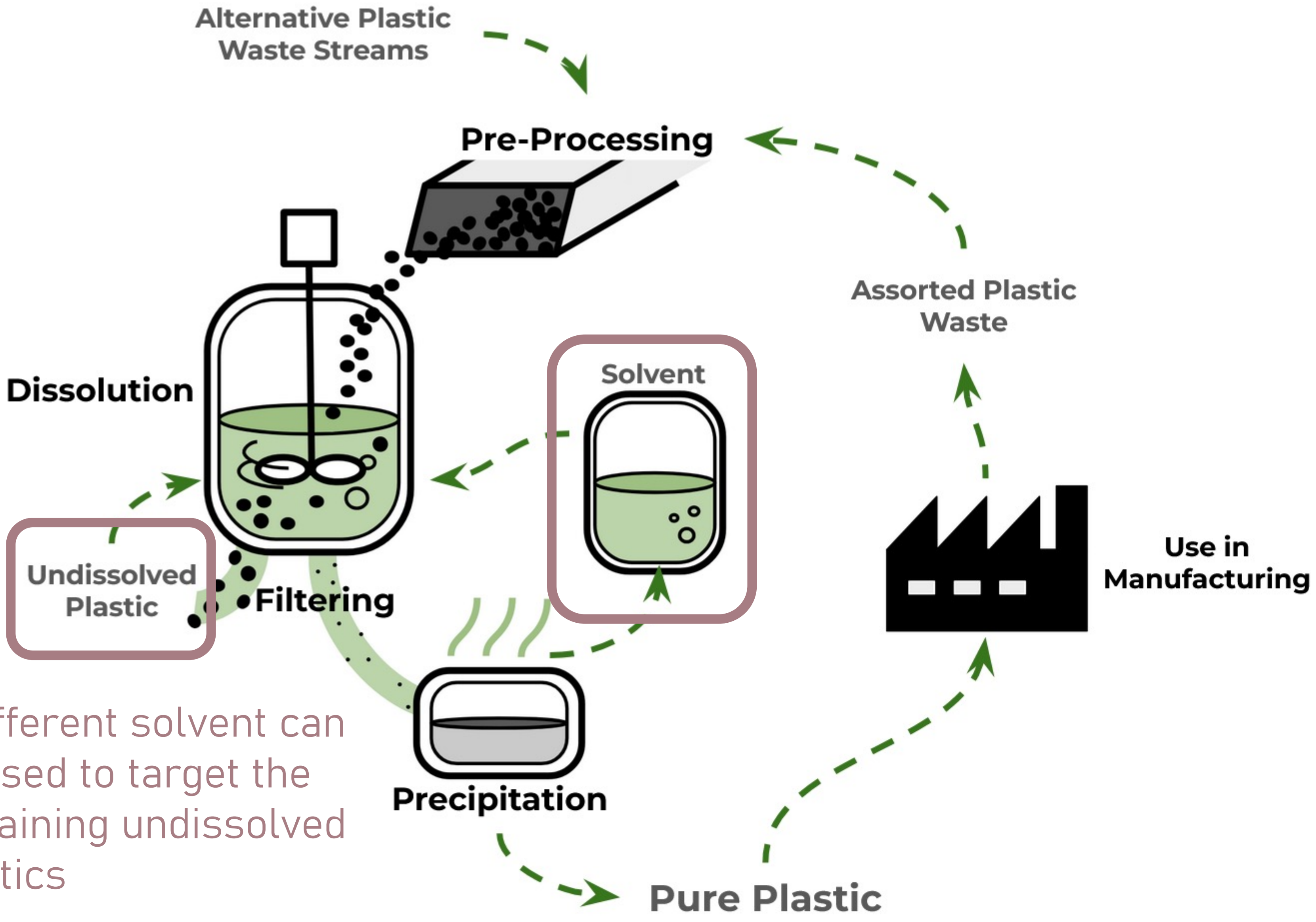
- Solution undergoes precipitation and extracted solvent is collected

SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)



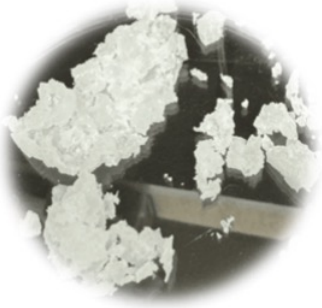
- The precipitate is pure plastic that can be used as desired

SOLVENT-TARGETED RECOVERY AND PRECIPITATION (STRAP)



- A different solvent can be used to target the remaining undissolved plastics

VERIFICATION AT LAB SCALE





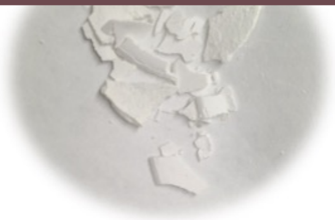

VERIFICATION AT LAB SCALE

PE and EVOH [10]

Single use pharmaceutical waste

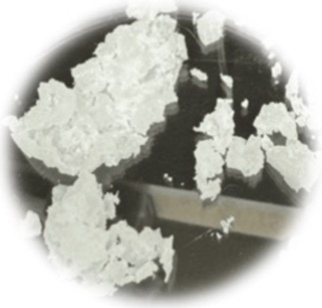
VERIFICATION AT LAB SCALE

Super sack fabric



PP

VERIFICATION AT LAB SCALE



Single use Keurig cups

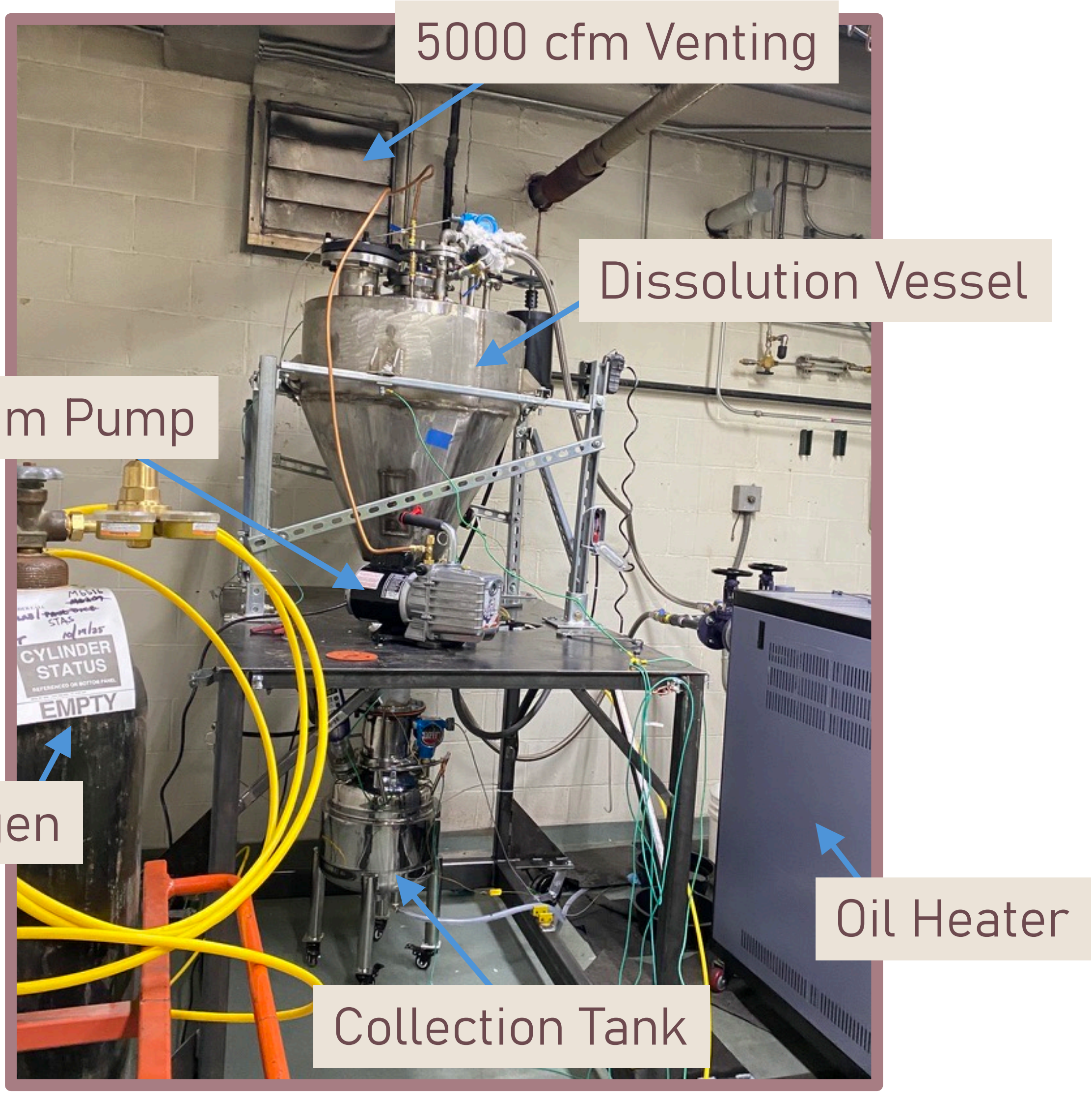

PS and PP

VERIFICATION AT LAB SCALE

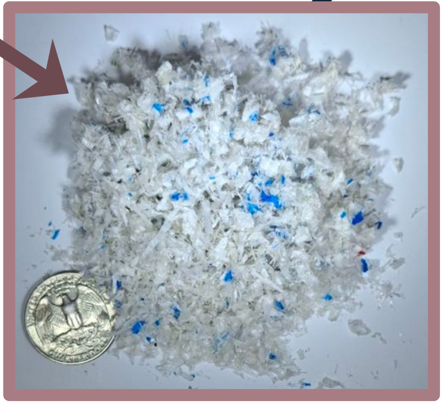
Multilayer films

PE [11]

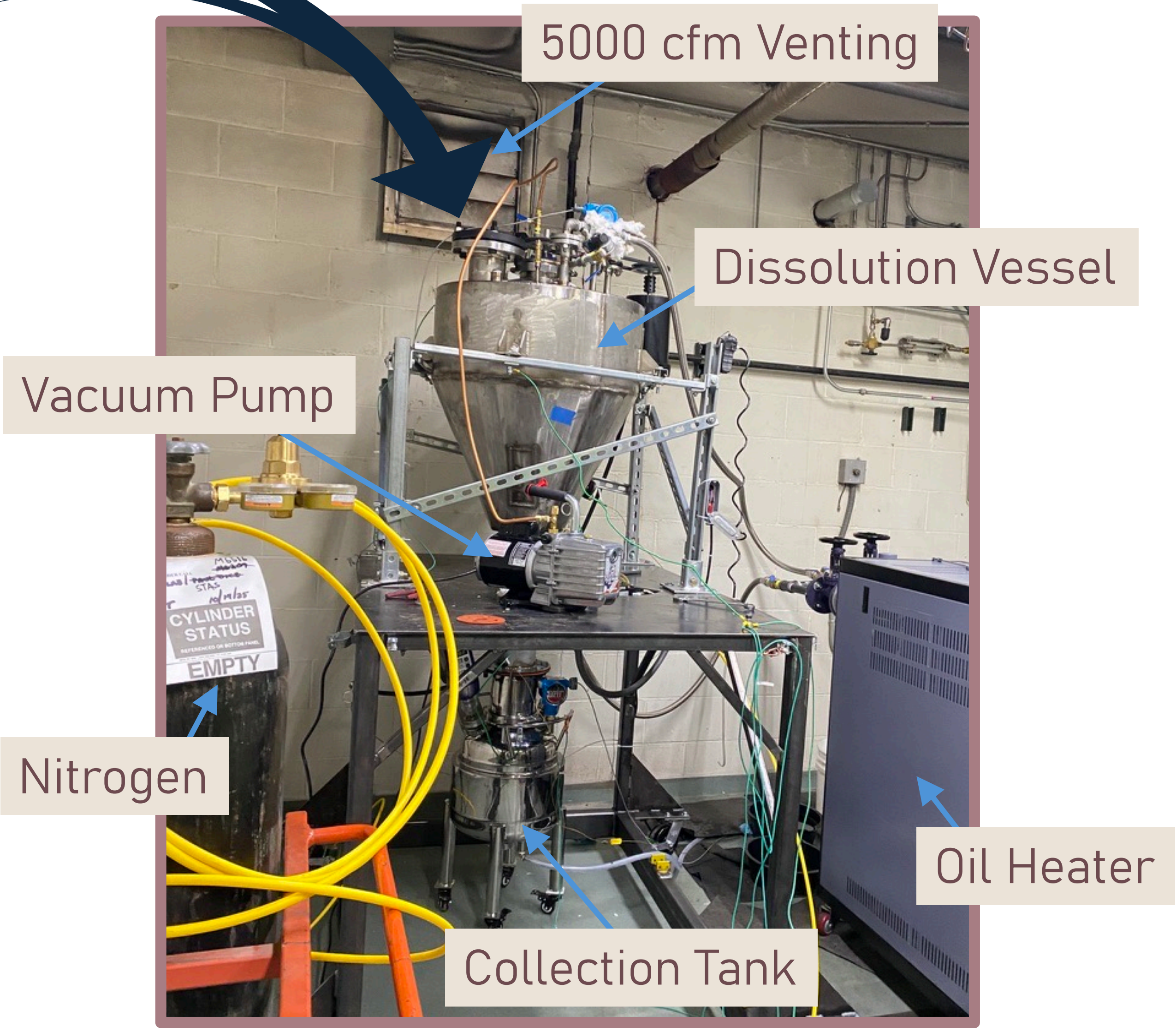
PROGRESSING TOWARDS PILOT SCALE



PROGRESSING TOWARDS PILOT SCALE



Xylene



PROGRESSING TOWARDS PILOT SCALE

PP after dissolution

PROGRESSING TOWARDS PILOT SCALE

PP separation setup

PROGRESSING TOWARDS PILOT SCALE

Solvent removal via pressure

PROGRESSING TOWARDS PILOT SCALE

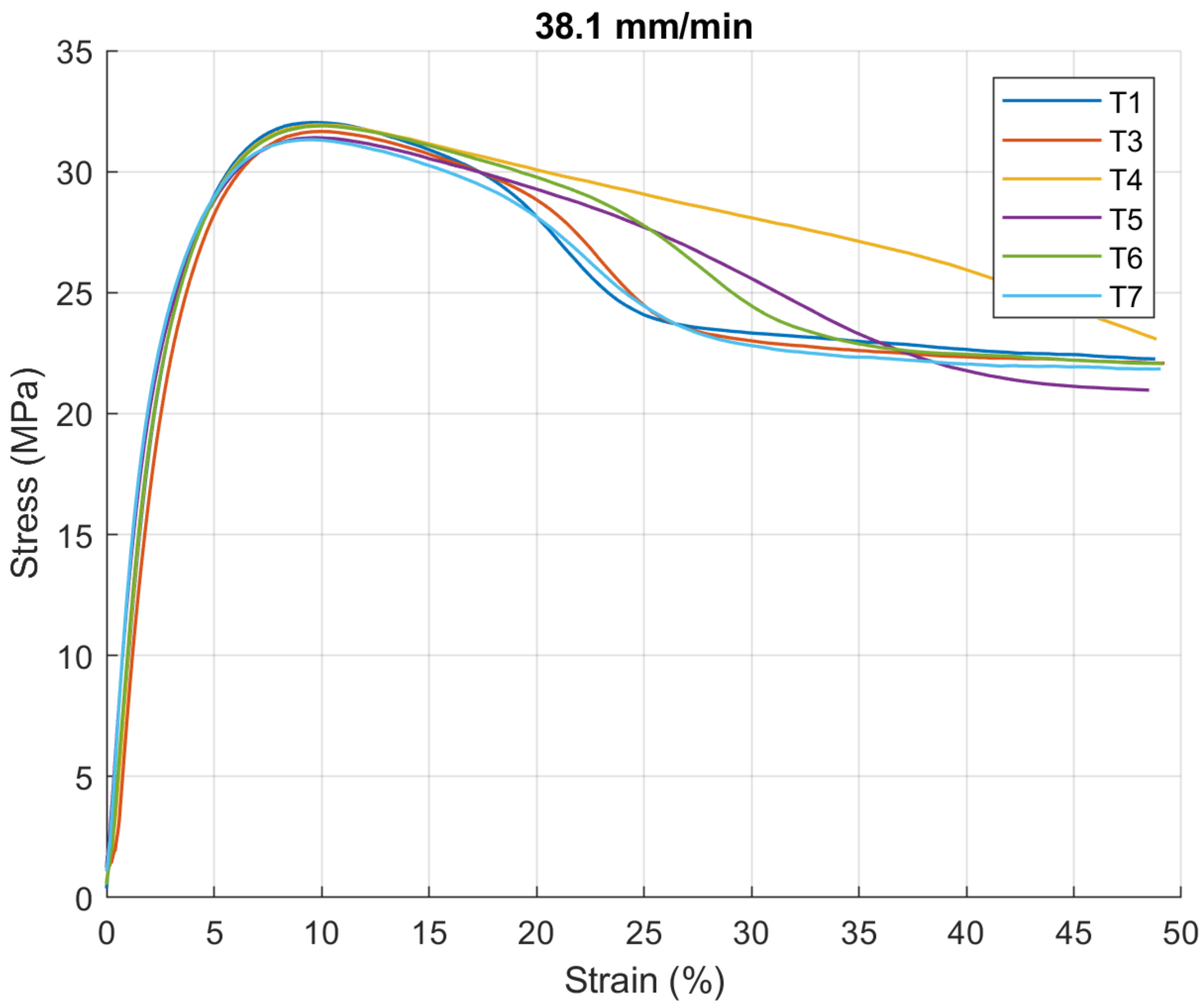
Recovered PP before vacuum drying

Recovered solvent

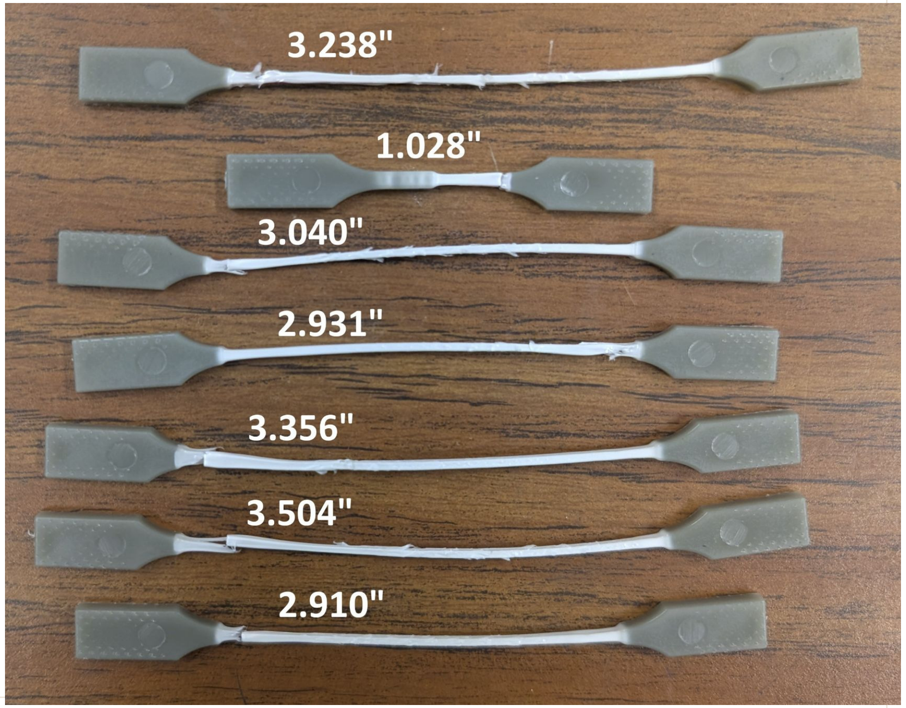
PROGRESSING TOWARDS PILOT SCALE

Recovered PP after vacuum drying

PROGRESSING TOWARDS PILOT SCALE



PP	Elastic Modulus (GPa)	Tensile Strength (MPa)
Typical Properties [1]	1.5-2.0	20-40
STRAP Processed	~1.0	~31.7



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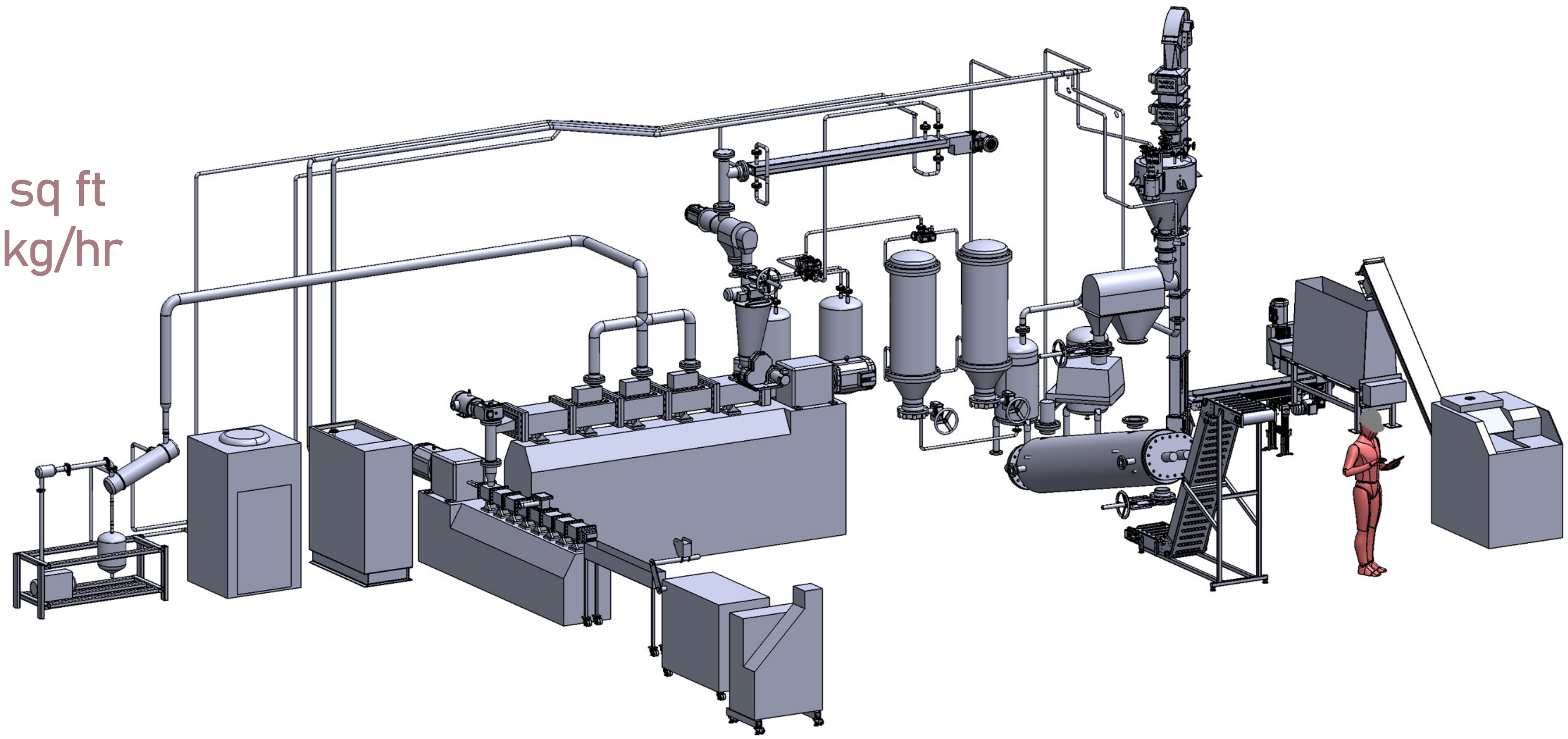
VERIFICATION AT PILOT SCALE

~1500 sq ft
20-50 kg/hr

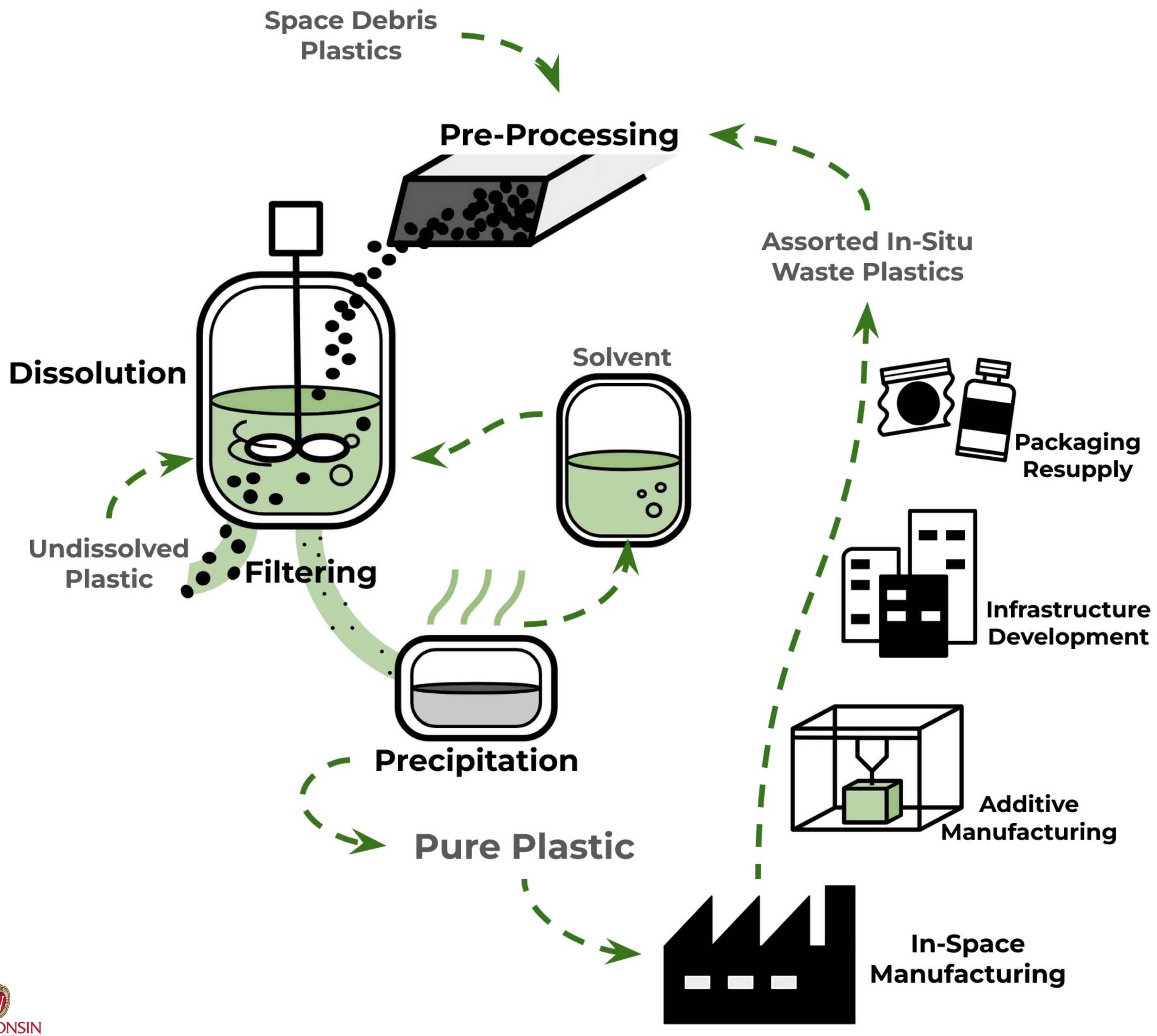


Objectives

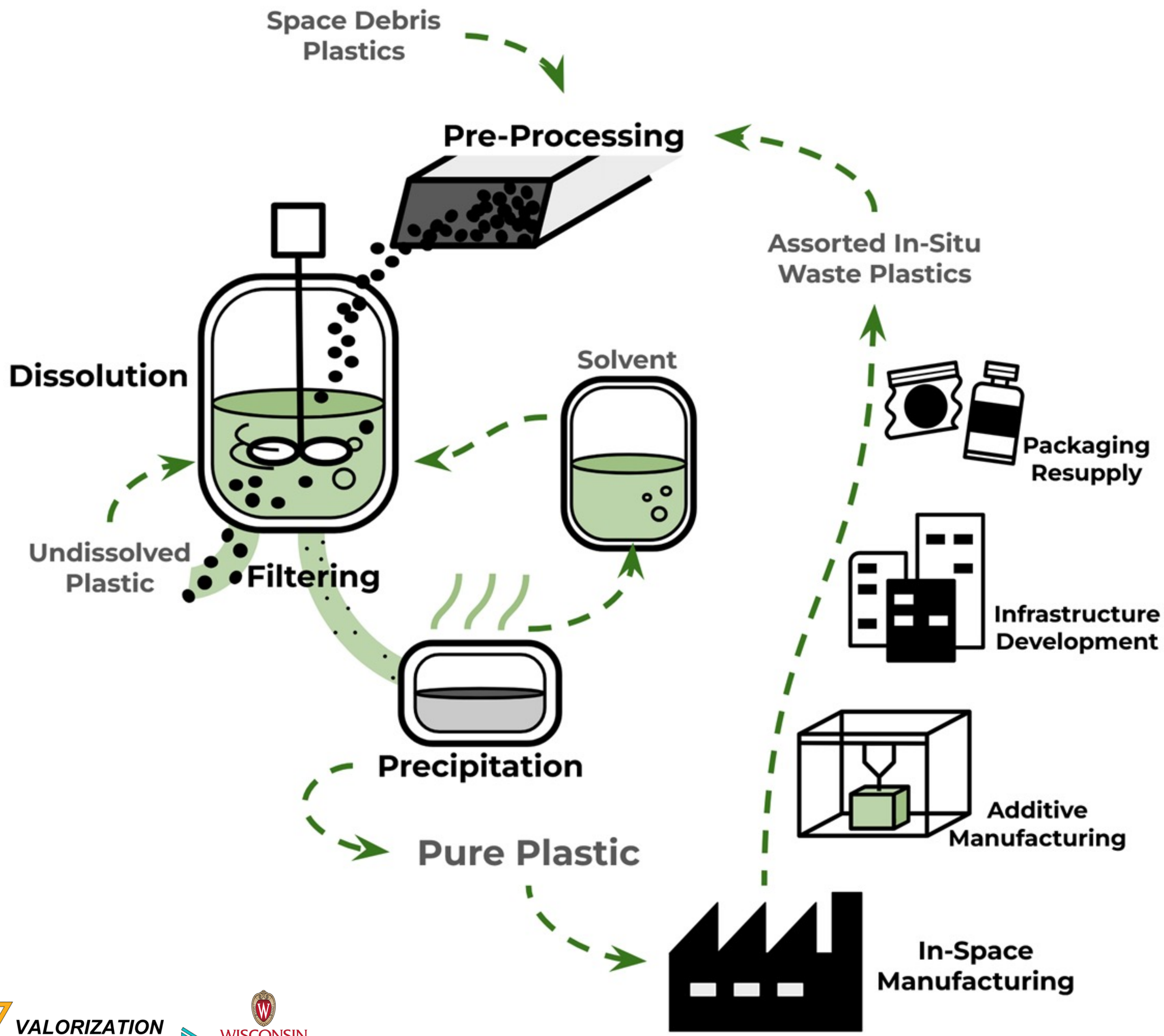
- Prove scale-up feasibility for industry purposes
  - Determine large-scale process flow
  - Characterize large batch polymers
  - Test equipment and processing limits

How can STRAP be applied to in-space manufacturing?

IN-SPACE MANUFACTURING APPLICATION



IN-SPACE MANUFACTURING APPLICATION



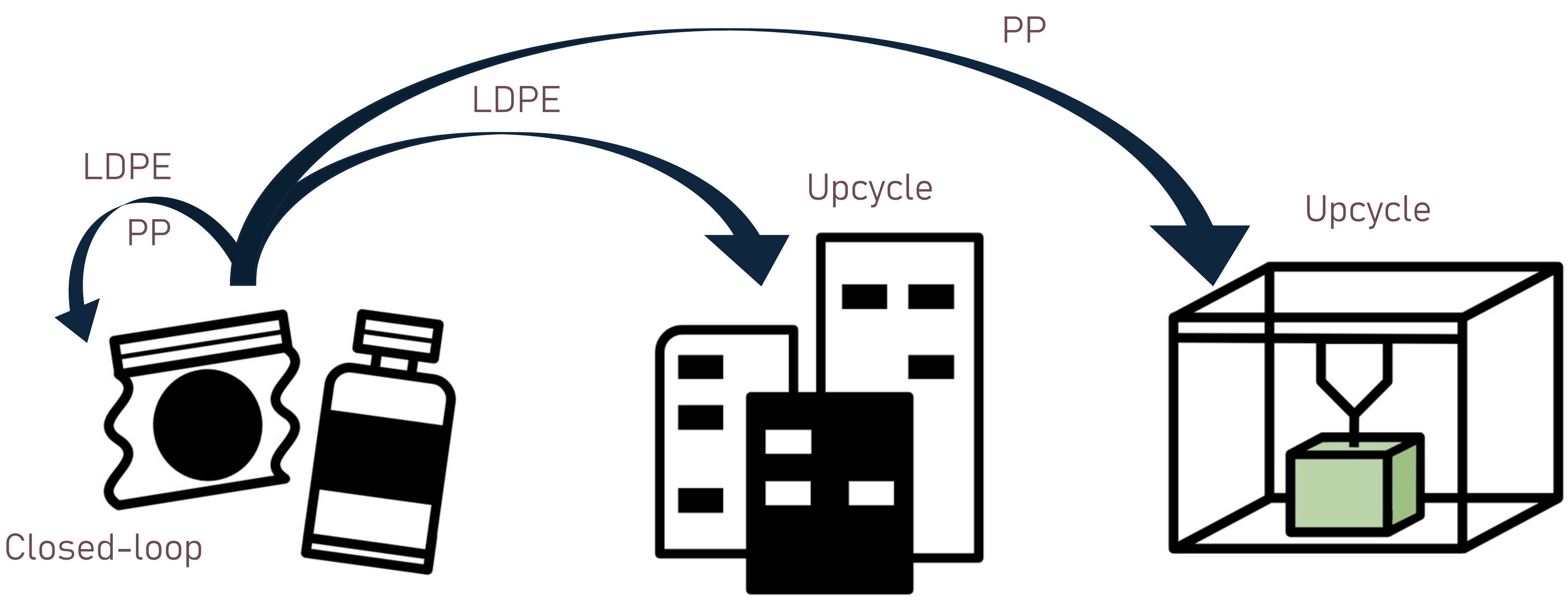
Lunar Surface Advantages

- Requires an oxygen free environment
- Vacuum conditions lower the thermal cycle temperatures

STRAP Benefits

- Decrease in resupply missions
- High quality plastic feedstock
- Supports recycling complex plastics for ISM

FEEDSTOCK USE CASES



Packaging

- Beverage Packaging: LLDPE and LDPE [6]
- Super sacks: Nylon and PP

Infrastructure Development

- Road construction or masonry bricks [12]

Additive Manufacturing

- Chemical-resistant and flexible filament for printing

THANK YOU FOR YOUR TIME

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CITATIONS

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