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MSTEC: Molten Salt Thermophysical Examination Capability

June 2024

Toni Y Karlsson, Stephen A Warmann, Carson W Stronks, David D Tolman

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Idaho National Laboratory

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MSTEC

Molten Salt Thermophysical Examination Capability

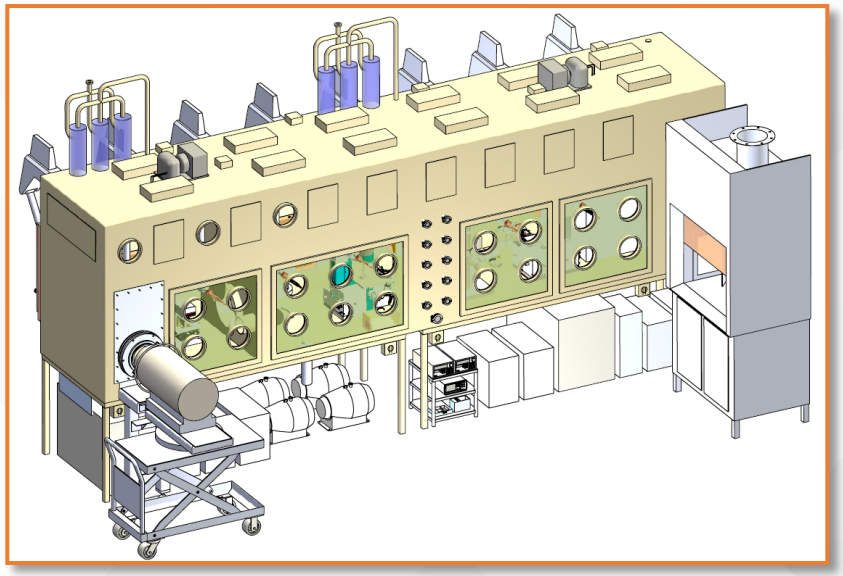
Toni Karlsson (PI/TPOC), Steve Warmann and Carson Stronks (PM's)

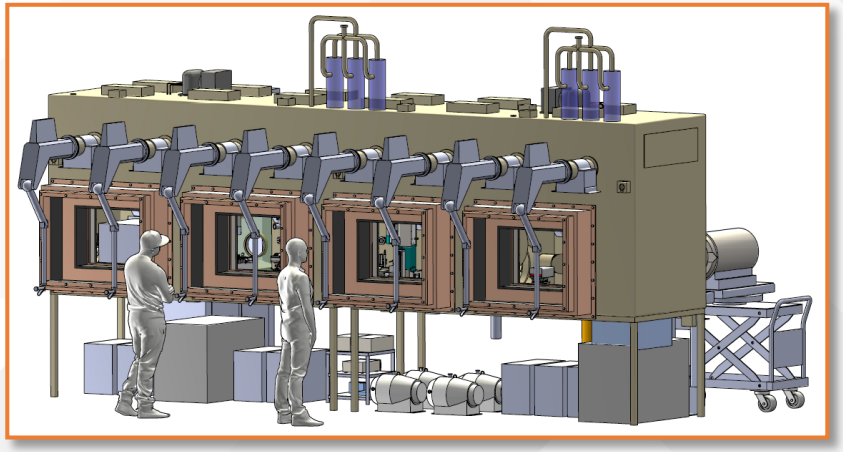
Presenter: David Tolman

MIS-24-78495

Overview

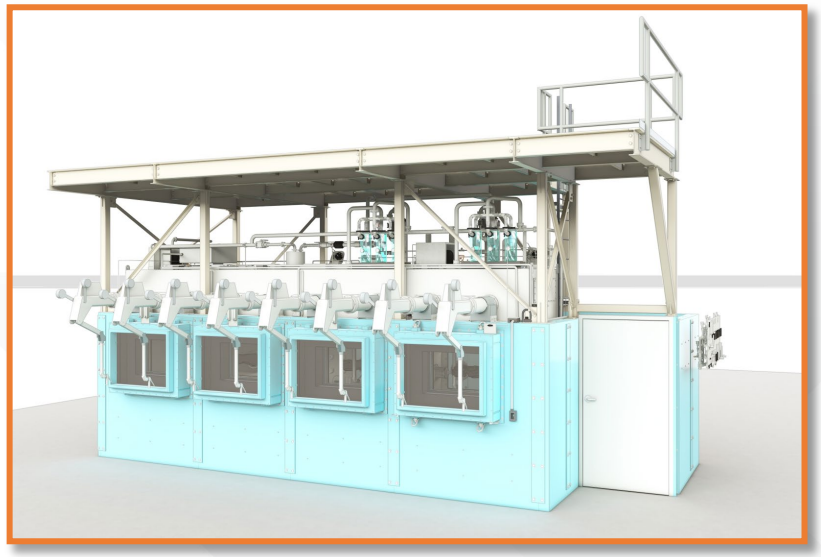
- Description – shielded modular hotcell with an inert argon atmosphere, housing characterization equipment for determining thermophysical and thermochemical properties of high temperature liquids not limited to but focusing on TRU and irradiated fuel salts
- Location – MFC, FCF, rm 35
- Compatible Materials:
  - Chloride, fluoride salts
  - Fresh fuel salts and irradiated fuel salts
  - Pyrophoric material - U, Pu metal
  - Gases – H_2, HCl, Cl_2, HF, F_2, NF_3
  - Beryllium containing salts
  - Many others





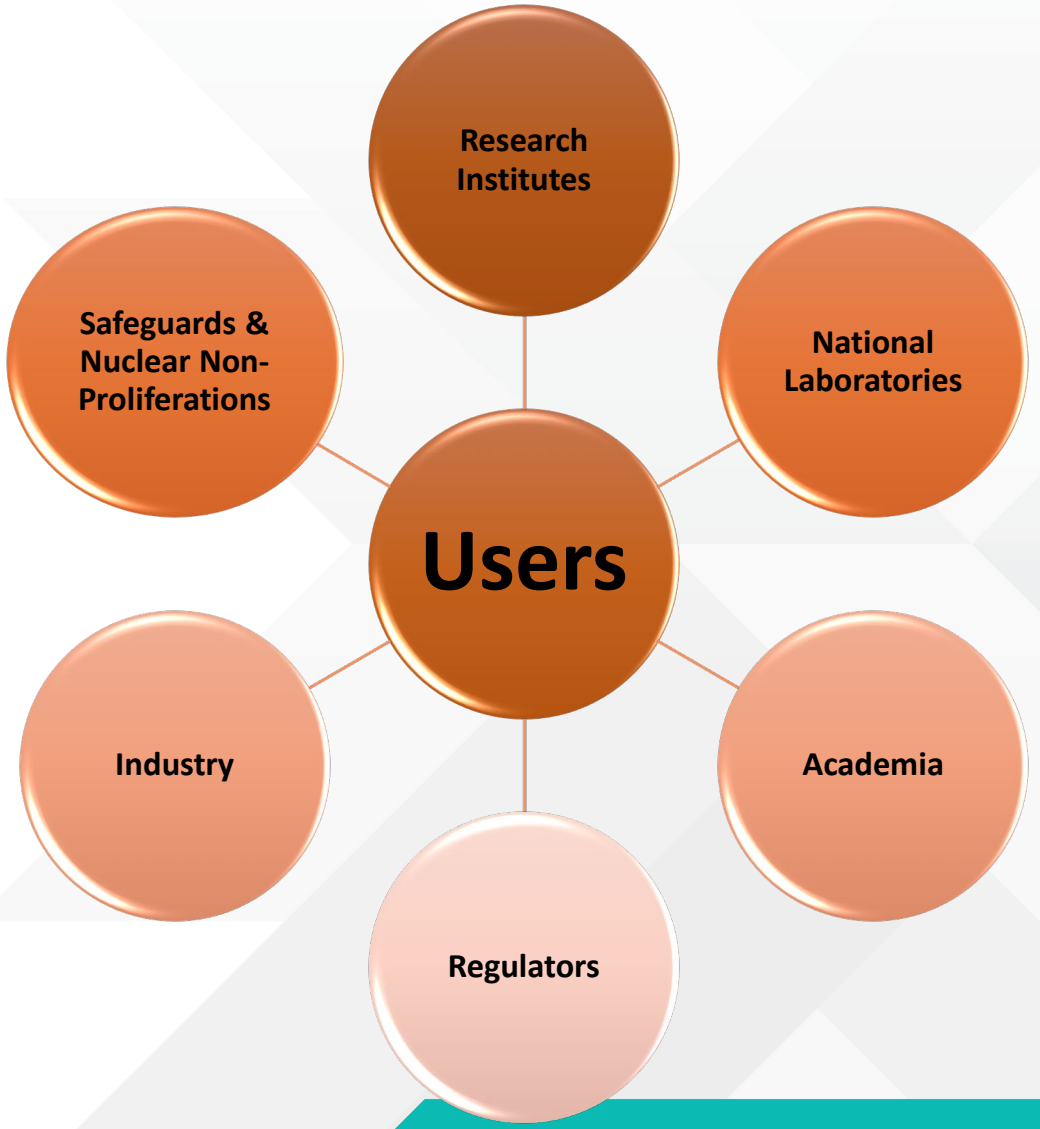
Overview

- Experimental examination facility focused on high temperature chemistry
  - Half glovebox, half hot cell
  - Capability for irradiated, actinide, minor actinide, and Be bearing salts
  - State-of-the-art, versatile workspace
- Infrastructure to address technology gaps
  - Includes universal furnace (electrochemistry, salt synthesis), DSC, STA, TMA, rheometer, thermal hotwire, pycnometer, densitometer
  - Instrumentation (≥ 1000°C)
- Opportunity to utilize new infrastructure for lab scale demonstrations



Purpose

- Provide **users** with characterization equipment, infrastructure, and technical staff necessary to produce critical data needed to design, demonstrate, license, and operate an MSR.
  - Deliver reliable data sets on properties including viscosity, density, heat capacity, thermal conductivity, melt temperature, vapor pressure, redox chemistry, and salt purification methods
  - Offers versatile space for users to setup one-of-a-kind experiments and to perform small-scale exotic salt fabrication



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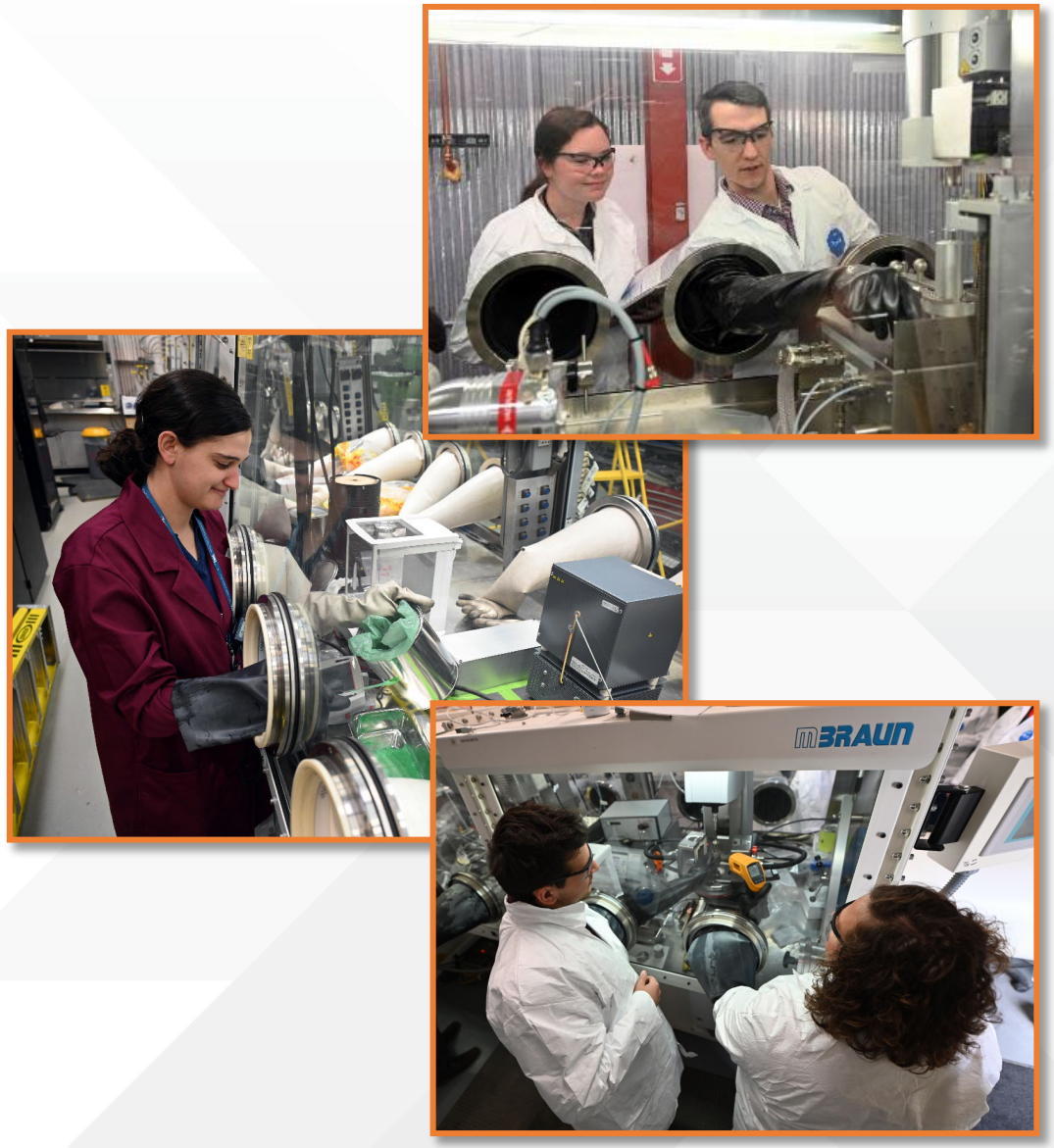
Progress

- **FY20** – Design requirements for glovebox completed, purchased characterization equipment
- **FY21** – Issued PO for glovebox, installed characterization equipment (temporary)
- **FY22/23** – Facility D&D, glovebox build, scientist development on characterization equipment
- **FY23/24** – Installation of MSTEC glovebox, shielding, and characterization equipment
- **FY25** – Commission and readiness assessment
- **Online in 2025**

Progress

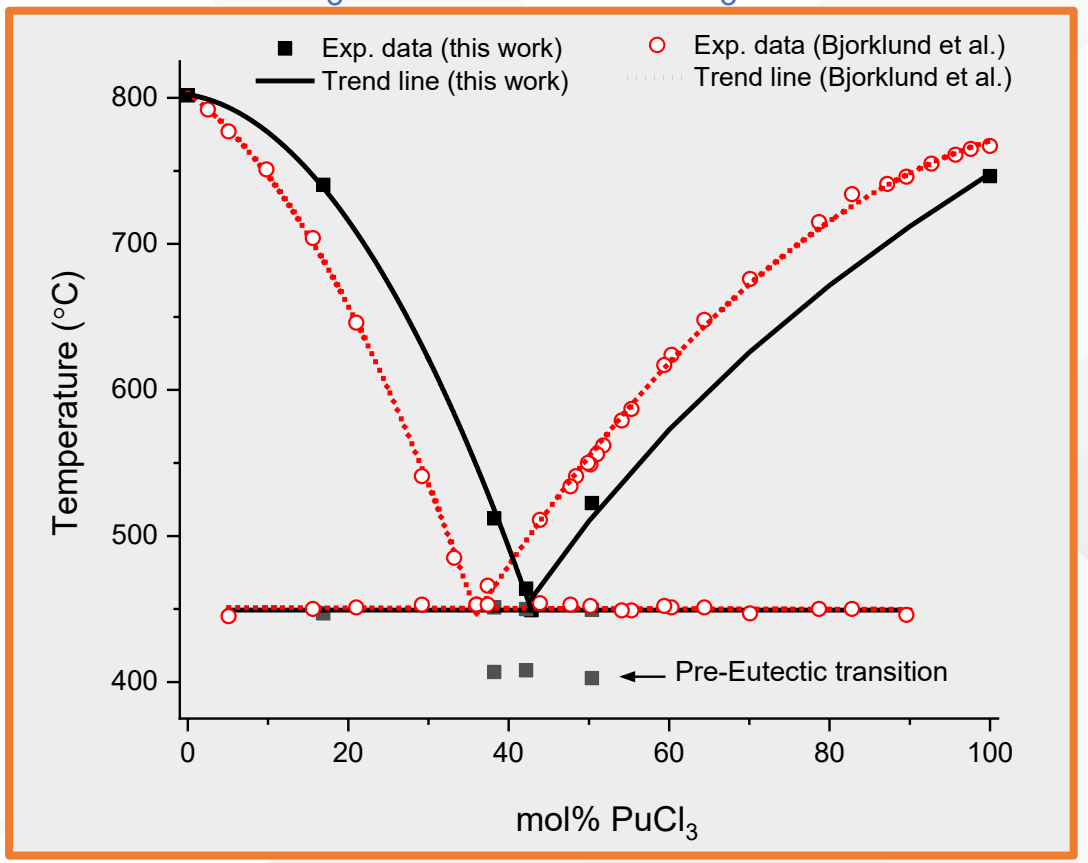
- Work force development
  - Developing our human capability while building the physical capability
- We are not sitting idle!
  - Instrumentation installed in non-radiological gloveboxes, allowing scientists to develop methods during construction of MSTEC
  - Scientists are already performing research with actinide bearing salt for pyrochemical reprocessing and MSR fuel cycle studies



Capabilities

- Instrument scientists performing measurements on “fresh” actinide fuel salts
  - Synthesis
  - Elemental/Isotopic Analysis
  - Thermal and chemical properties
  - Phase diagram development
- Changes in chemical state or salt composition (impurities) can affect the liquidus temperature of salt systems

$PuCl_3$-NaCl vs Pu-$PuCl_3$-NaCl

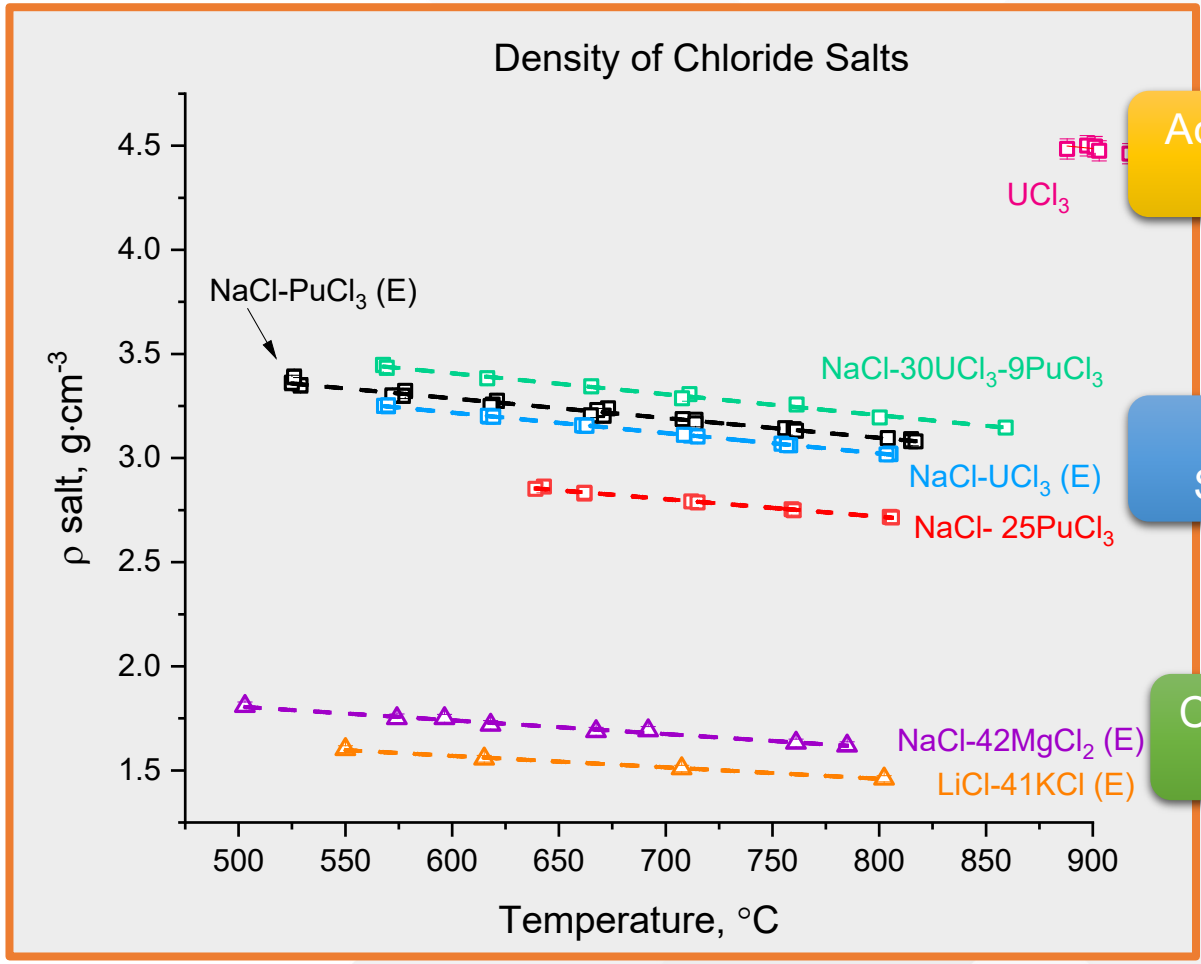


1. T. Karlsson, C. Adkins, R. Gakhar, J. Newman, S. Monk, S. Warmann. “Phase Behavior of the Ternary NaCl-$PuCl_3$-Pu Molten Salt” JNFCWT Vol.21, No.1 (March; 2023)
2. Bjorklund, C. W., Reavis, J. G., Leary, J. A., Walsh, K. A. “Phase Equilibria in the Binary Systems $PuCl_3$-NaCl and $PuCl_3$-LiCl” 1959

Capabilities

- Other capabilities not shown include viscosity, heat capacity, solid state density, stability, surface tension, moisture analysis, and purifications
- Currently investigating or working on publications for several salt systems
  - LiCl-KCl
  - NaCl-$MgCl_2$
  - NaF-KF-UF_4
  - NaCl-UCl_3
  - Moisture effects
  - Insoluble FP (particle additions)
  - Irradiated NaCl-UCl_3

1. Karlsson, T. Middlemas, S., Nguyen, M-T., et al. “Synthesis and thermophysical property determination of NaCl-PuCl3 salts,” Journal of Molecular Liquids, Volume 387, 2023 (https://doi.org/10.1016/j.molliq.2023.122636)
2. Duemmler, K. et al. “Evaluation of thermophysical properties of the LiCl-KCl system via ab initio and experimental methods.” Journal of Nuclear Materials (2021)



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Next Steps

- Major activities remaining
  - FY24
    - DOE review/approval of SAR/TSR revision
    - Construction contract, phase II, MSTEC installation
    - Installation of characterization equipment into MSTEC
  - FY25
    - FCF SAR/TSR implementation
    - MSTEC management self assessment
    - MSTEC contractor readiness assessment
    - MSTEC DOE readiness assessment and final commissioning
    - Online!

Next Steps

- First experiments already underway for MSTEC
  - Irradiate molten fissile material-bearing chloride salt with salt-facing materials relevant to MSR development
  - Salt sample: 0.66UCl_3-NaCl (93wt% 235-U), 40g, 13 cm^3
  - Irradiated in NRAD, removed from reactor on June 3rd 2024
    - Will perform “Rapid PIE” in HFEF main cell
      - Gas analysis
      - Precision gamma scanning
      - Radiography
    - Characterization of salt in MSTEC

Executing Research in Three Primary Areas

1. Radioactive Source Term Quantification
2. Thermophysical Property Evolution
3. Salt-facing Materials Corrosion

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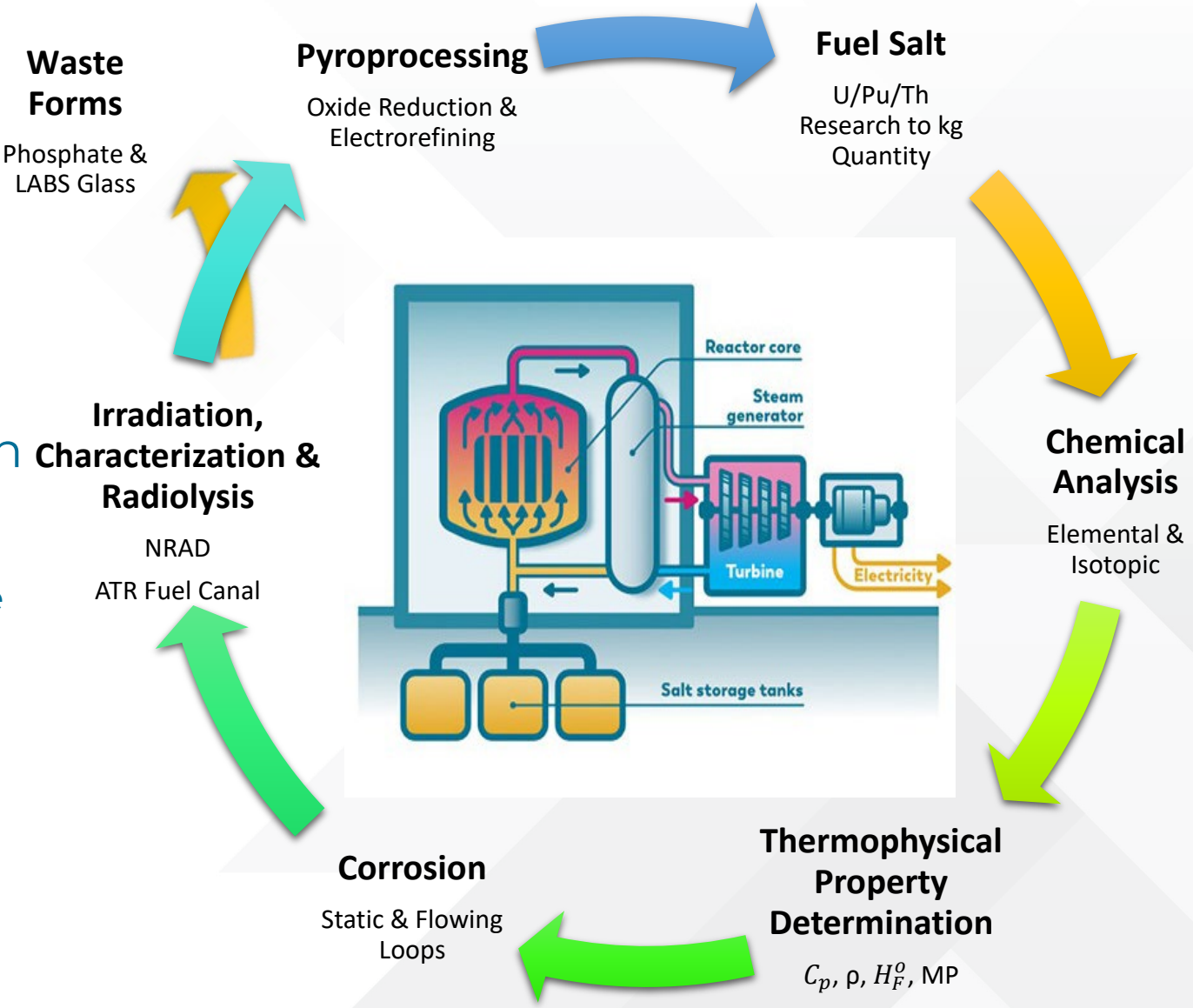
Summary

- MSTEC adds a new research capability for TRU and irradiated salts
- MSTEC leverages INLs expertise in MSR fuel cycle and pyrochemical processing of used nuclear fuel
  - Co-located on the same campus as the NRAD reactor, Analytical Research Laboratory, Irradiated Materials Characterization Laboratory
  - Easy to transfer material/samples to study the entire fuel cycle including corrosion testing
- Please reach out for more information or a detailed discussion



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Questions ?

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