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Isotope Production R&D and Re-establishing Domestic Stable Isotope Production

2nd Federal Workshop on Isotope Demand and Supply
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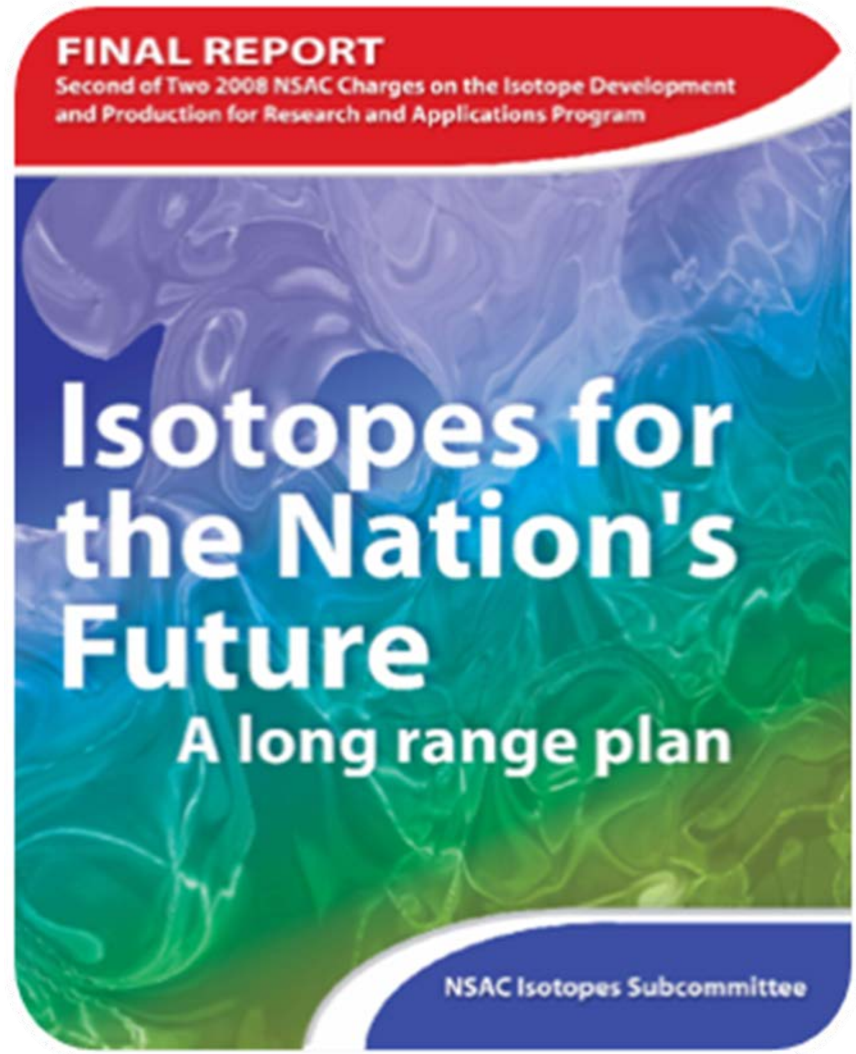
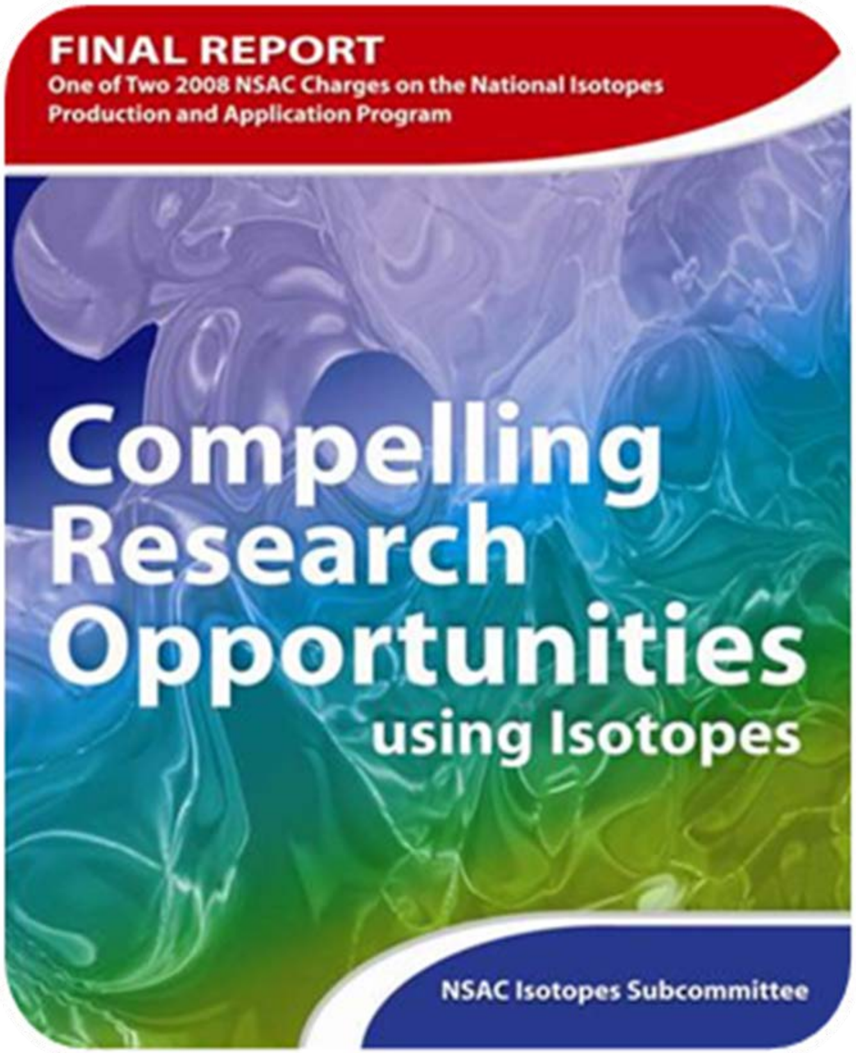
Nuclear Sciences Advisory Committee on Isotopes

- Charge 2: Develop a long range plan outlining the Nation's future isotope needs
- Recommendations
  1. Devise process for enhanced communication and outreach
  2. Coordinate production capabilities and research among existing facilities
  3. Support research program in base budget to enhance IP capabilities
  4. Encourage isotope use in research with reliable supply and affordability
  5. Increase robustness and agility of transportation of isotopes
  6. Invest in workforce development
  7. Construct and operate isotope separator facility
  8. Construct and operate a dedicated multiparticle accelerator production facility



Nuclear Sciences Advisory Committee on Isotopes

- Charge 1: Prioritize near term compelling opportunities for Isotope Research
- Recommendations
  1. New approaches for production of therapeutic alpha-emitting isotopes
  2. Coordinate production capabilities and research among existing facilities
  3. Create plan and make investments in isotope production to meet needs in heavy element research
  4. R&D to address new or increased production of He-3
  5. R&D to re-establish a domestic source of mass separated stable and radioactive research isotopes
  6. Robust investment into education and training in isotope production



R&D Related Investments

- Solicitations: $28.3M total Invested since 2009
  - FOA 09-14 (*R&D on Alternative Isotope Production Techniques*)
    - FY 2009 – FY 2010 56 Program Funds/ARRA: ~$16.4M
      - 56 proposals, $50.4M Requested
      - Awards: 13 Laboratory, 9 University, 1 Industrial
  - FOA 11-448 (*Research, Development, and Training in Isotope Production*)
    - FY 2011 – FY 2012 Program Funds: $5.8M
      - 35 Proposals, $40.5M Requested
      - Awards: 3 Laboratory, 4 University,1 Industrial
  - FOA 13-743 (*Research, Development, and Training in Isotope Production*)
    - FY 2013 – FY 2014 Program Funds: ~$6.1M
      - 46 Proposals, $42 M Requested
      - Peer review completed February 21-22, 2013
      - Awards: 7 Laboratory, 2 University
- Core R&D Support: ~$1.5M annually

Supported Activities

- Therapeutic alpha emitters (*At-211*, Ac-225, Th-229, Ac-227/Ra-223)
- *New radioisotope extraction/separations technologies*
- *Accelerator and reactor isotope production targetry*
- Isotopes for positron emission tomography (*Se-72/As-72*, Cu-62, Cu-64, Y-86, Zr-89)
- Heavy elements (Cf-252, Bk-249, Am-243, Cf-251, *Optimization of the use of Cm feed-stocks in heavy element production*)
- Nuclear Forensics, Environmental Research (U-233/Th-229, Si-32, *Np-236/Pu-236*)
- Therapeutic beta-emitters (*Cu-67, As-77,* Re-186, Rh-105, Pr-143)
- *Workforce development* (Most grants and core R&D)
- Stable isotope enrichment (EMIS/*ESIPF*, Puerto Rico Project, *Li-7*)
- Isotope harvesting at rare ion beam facility

ORNL Isotope Enrichment Project

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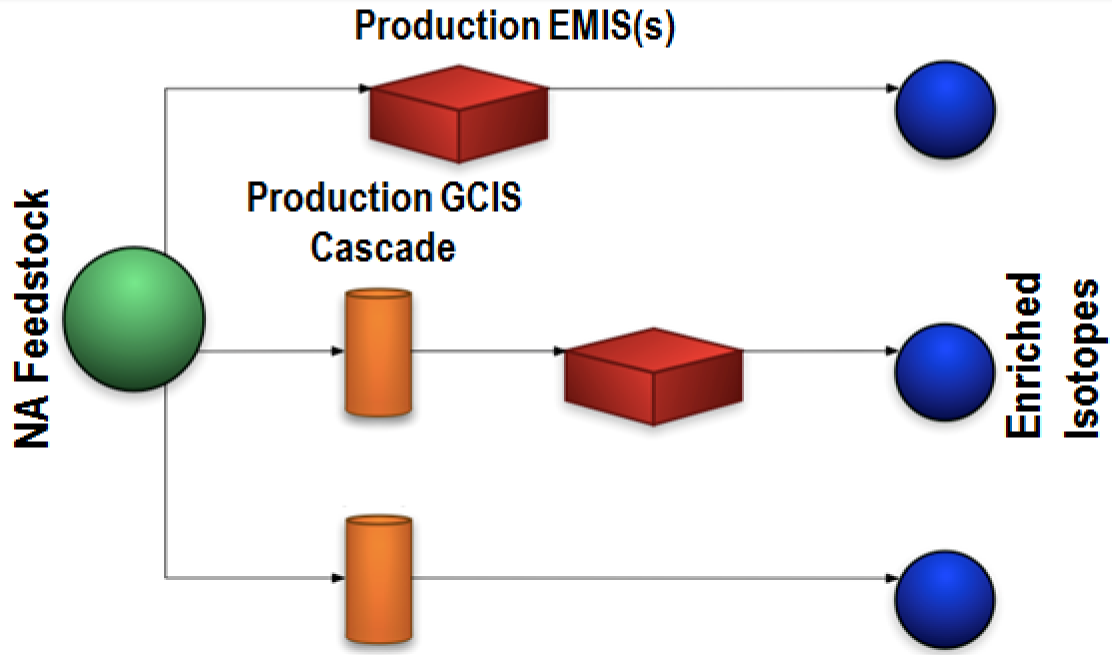
ORNL's Concept

Enriched isotopes can be produced in 10's of g quantities by Electromagnetic Isotope Separators (EMIS), Gas Centrifuge Isotope Separators (GCIS) and using a combined method where GCIS is used to pre-enrich feedstock for final enrichment on EMIS



ORNL submitted proposal "Integration of Centrifuge and Electromagnetic Separation for the Preparation of Stable Isotopes", in response to SC Program Announcement LAB 09-14; May 2009

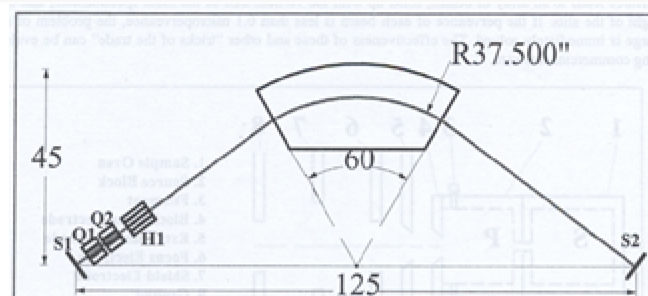
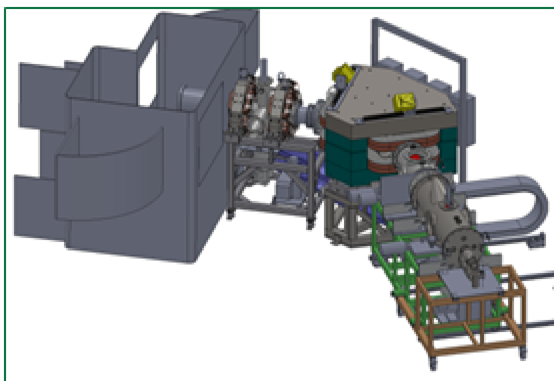


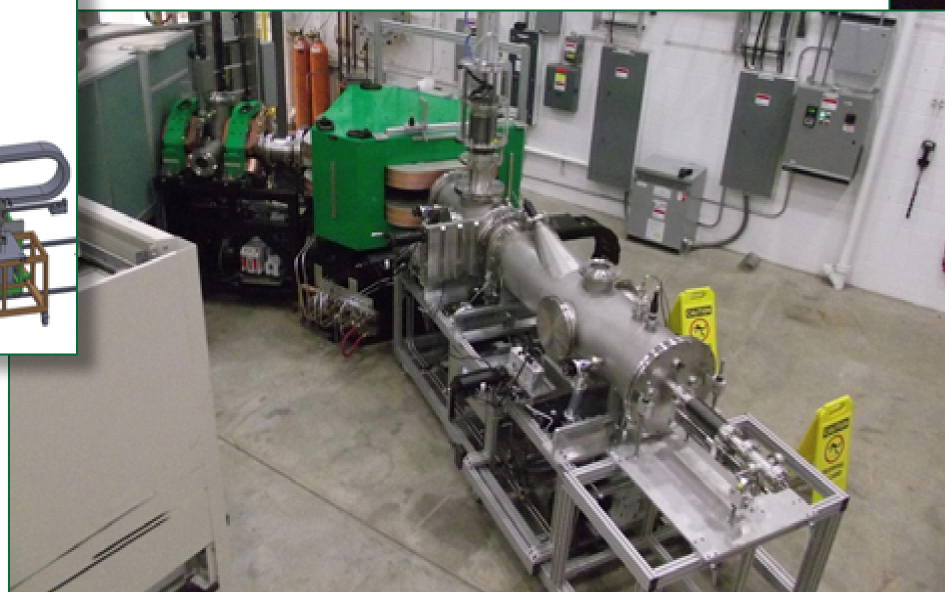
Figure 3. Ion optics of the Electromagnetic Separation Device. Ions enter the mass analyzer via S1 at kinetic energy between 10 and 20keV, tranit electrostatic quads Q1 and Q2, hexapole Q1, to the laminated core magnet, were targets isotope ions are transmitted onto collectors behind slit S2. A 60° sector angle gives minimal geometric aberrations. The quadrupoles are used to adjust the 1st order focus of the beam, the hexapoles to adjust slit image curvature, i.e., aberrations. Dimensions are in inches.

ORNL EMIS R&D

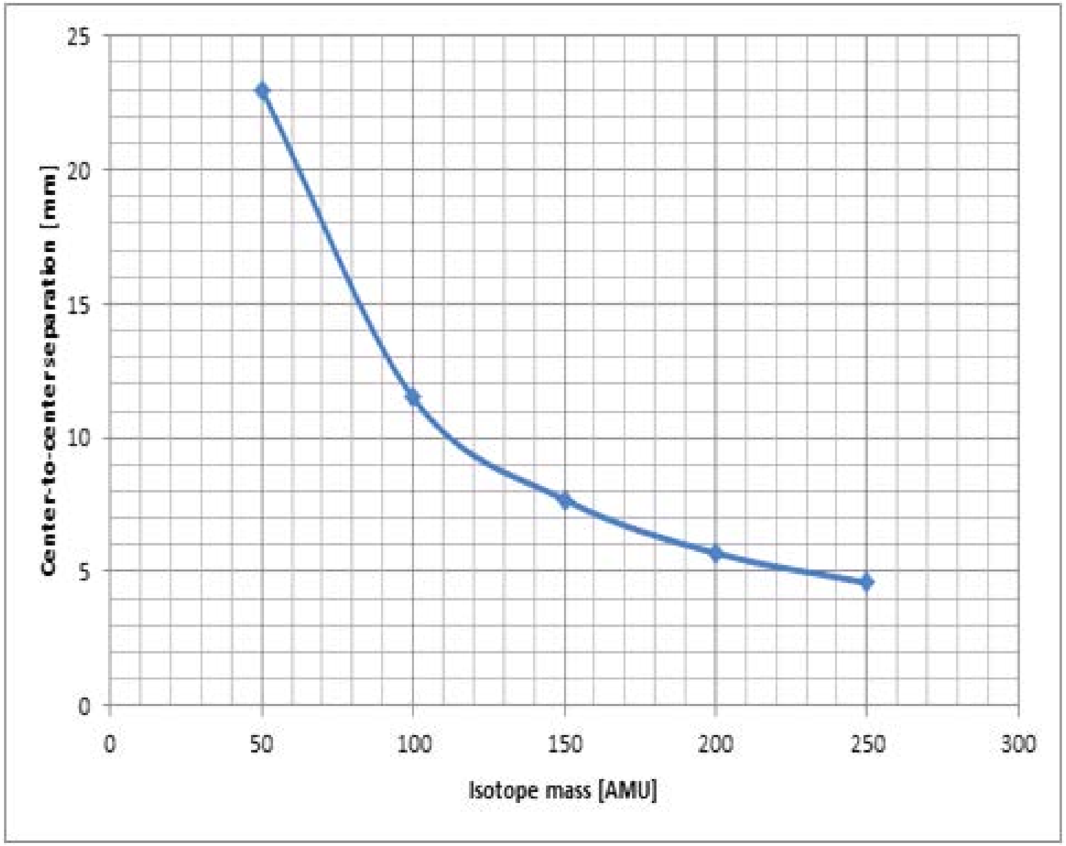
Design time and fabrication risk reduced through use of advanced 3D computer aided design and simulations tools

First enriched samples collected Feb 2012
Greater than 98% enriched molybdenum and nickel





10 mA construction completed December 2011
100 mA upgrade scheduled to be complete FY15

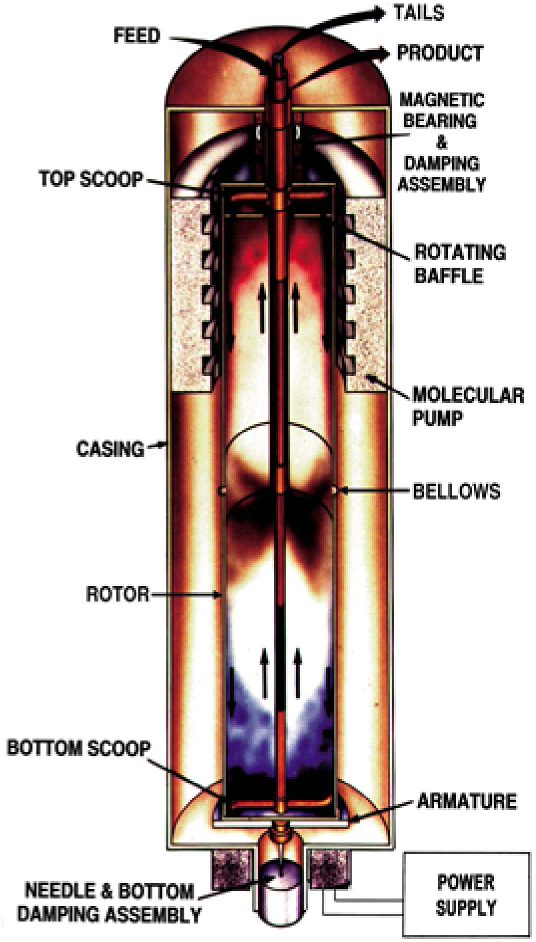


- Magnet designed for 20 amu < A < 208 amu
- Optimized for a A = 100 amu as mid-point
- Magnet capable of bending the path for A up to 450 amu
- Slight amount of distortion in the magnetic field for masses above 250
- Can make adjustments in the flight path to increase the separation for heavier isotopes

GCIS Engineering Study

The goal of this study was to examine a number of different isotope systems and centrifuge designs to determine the feasibility of using a GCIS cascade to improve stable isotope production rates using EMIS.

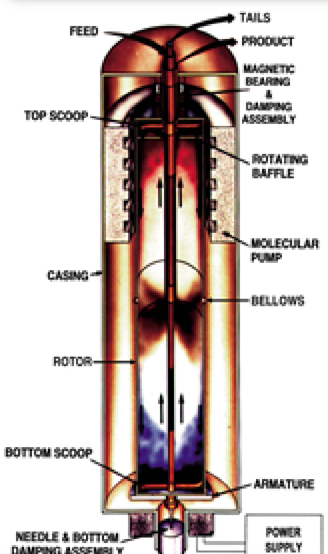
- **Studied various scenarios**
  - Four target gases: MoF_6, WF_6, GeF_4, and $Ni(PF_3)_4$
  - Single machines in series
  - Cascades of different designs (number of stages/machines)
- **All centrifuges were capable of separating all of these gases**
  - *Smaller machines* better for lower mass flows and product requirements, more flexible for range of isotopes
  - Must consider more units in a cascade or passes through a single machine
  - Machine geometry must be adjusted to make some of the machines effective for a specific gas



ESIPF Technology Development Proposal

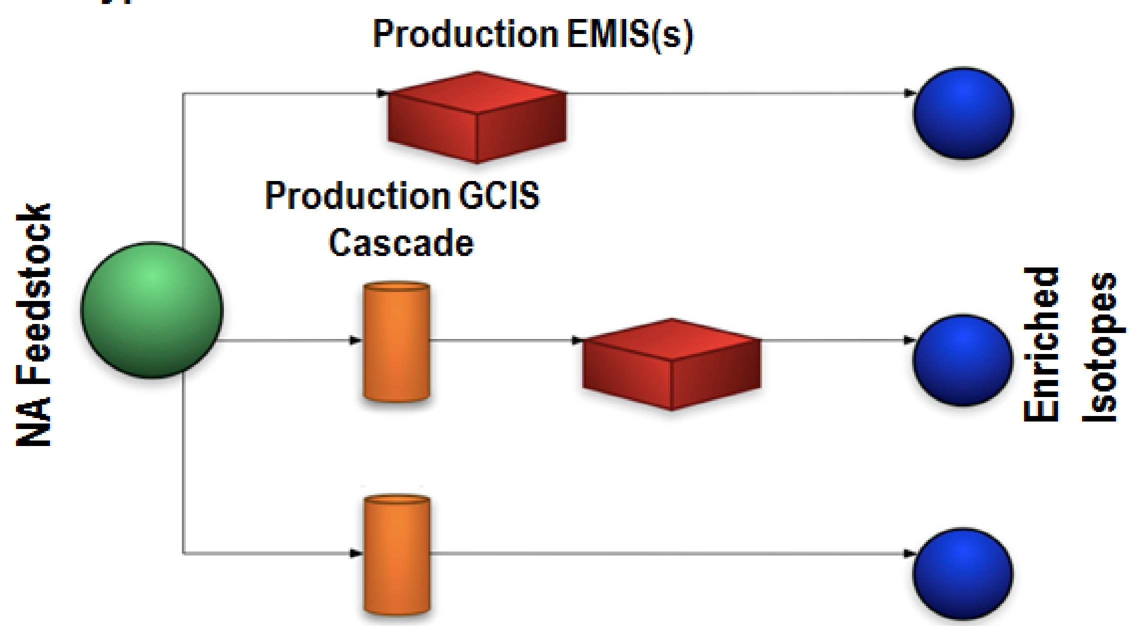
The goal of this project is to complete final reliability and automation tasks to achieve a modern, production-class electromagnetic separator and a 9-unit gas centrifuge cascade (with a 2-unit test stand), capable of producing milligram to tens of grams of enriched stable isotopes.

R&D EMIS Prototype

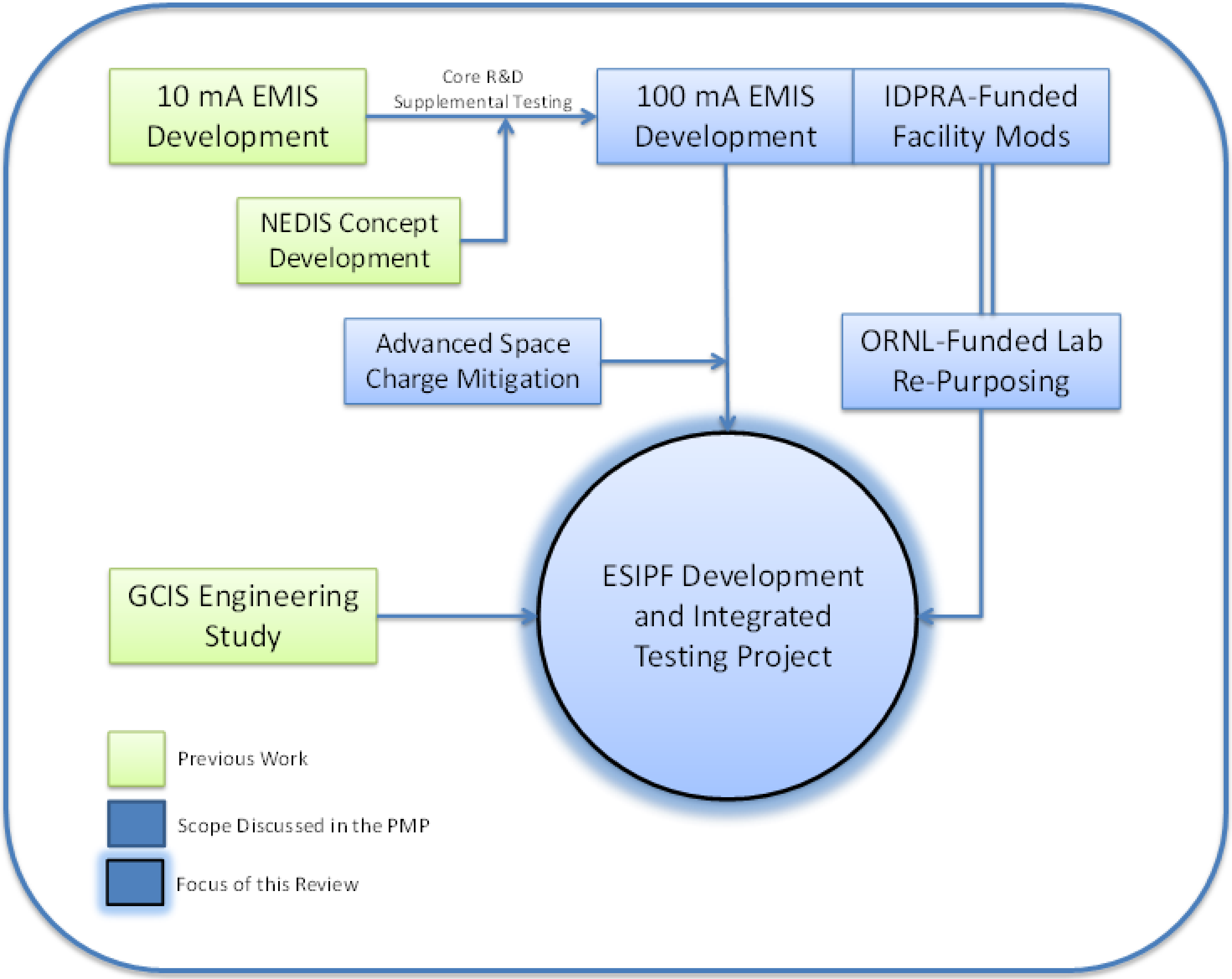


CRED Initial Design

Implementation and Performance Testing of Integrated GCIS/EMIS Concept



ESIPF Technology Development Project



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Isotopes for Super Heavy Element Research

- Production of Cf-252
  - Optimization of irradiation of curium targets at HFIR
  - Cf-252 used primarily by industry (neutron sources for oil exploration, R&D)
- Bk-249, Am-243, Cf-251
  - "Hot fusion" to produce isotopes of heavy elements 117, 115
  - New Isotopes of element 118
  - SHE factory in Dubna

Accelerator Production of Ac-225/Bi-213

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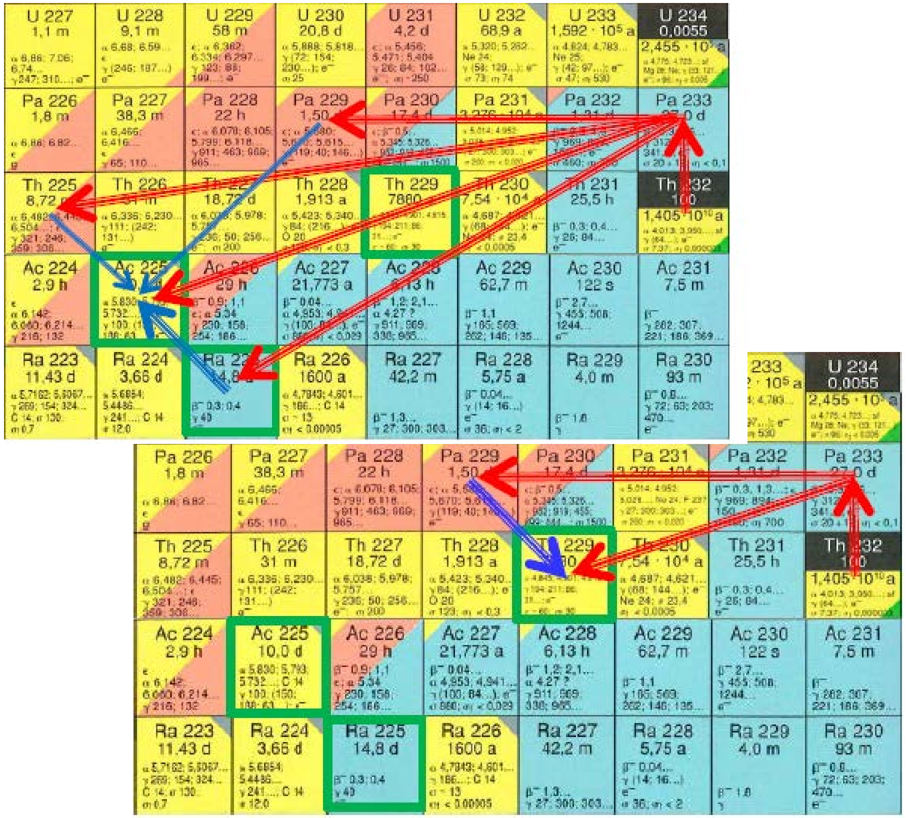

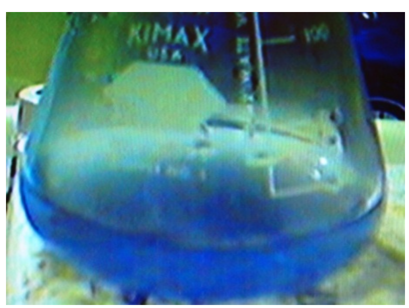

- Protons on Thorium Targets
  - High energy reactions
    - ^{232}Th(p,x)^{225}Ac
    - ^{232}Th(p,x)^{225}Th $\rightarrow$ ^{225}Ac
    - ^{232}Th(p,4n)^{229}Pa $\rightarrow$ ^{225}Ac
    - ^{232}Th(p,x)^{225}Ra $\rightarrow$ ^{225}Ac
  - Low energy reactions
    - ^{230}Th(p,2n)^{229}Pa $\rightarrow$ ^{229}Th
    - ^{232}Th(p,4n)^{229}Pa $\rightarrow$ ^{229}Th
    - ^{232}Th(p,p3n)^{229}Th
- **Processing**
  - Scale up ORNL technology
  - Develop new for scale up

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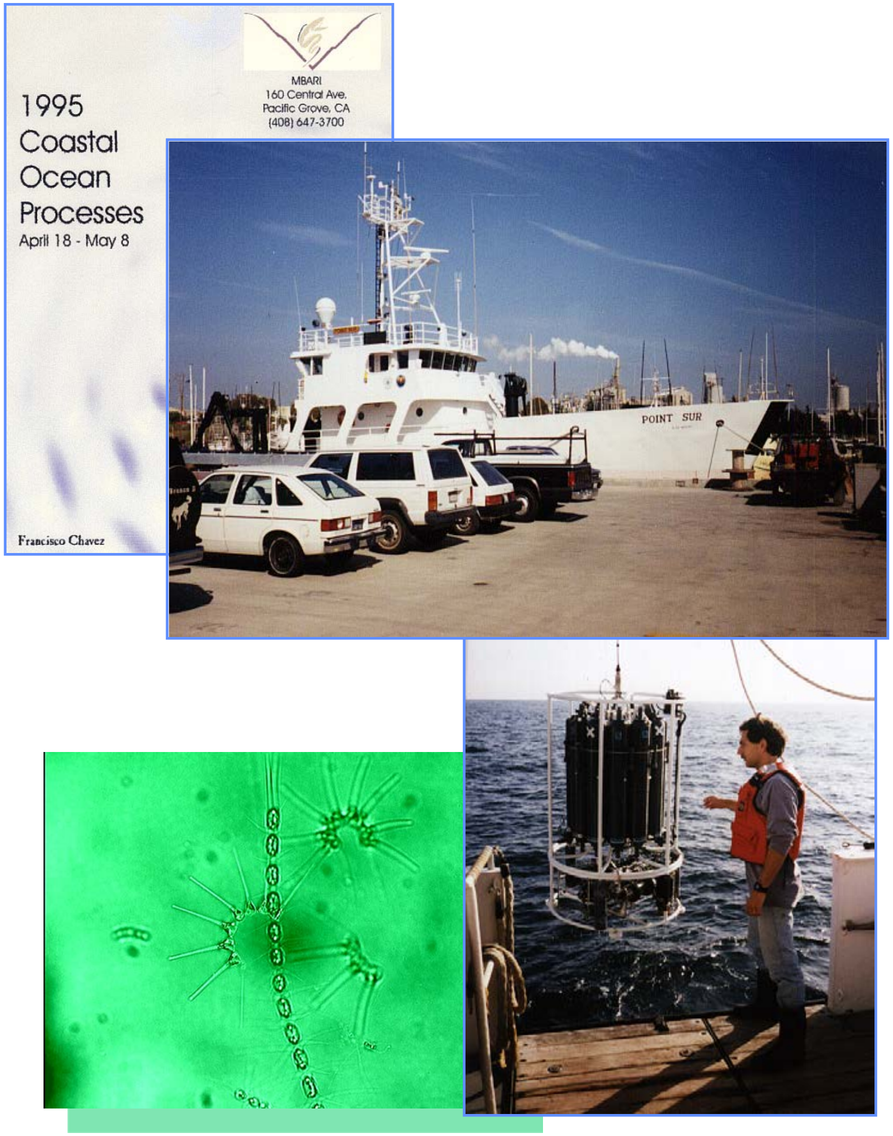
Silicon-32 Production



- Si-32 is a radioanalytical tracer to measure bloom rates of diatoms
- Rate of bloom of diatoms is a key parameter in carbon cycle
- Can only be effectively produced by spallation reactions on KCl targets
  - $KCl(p,x)^{32}Si$
  - Long irradiation
  - Complicated chemistry

Recent Investments in New Development Activities

- Recovery of high purity U-233 and Th-229
  - Collaborative effort with NNSA Office of Non-Proliferation and International Security
  - Recovered, separated Th-229, analyzed, re-packaged ~100 g of 99.9875% pure U-233; provided ~20 g of the U-233 to New Brunswick Lab for CRM
- R&D project to investigate feasibility of accelerator production of Np-236g and Pu-236 for IDMS applications in Nuclear Forensics
  - $^{238}U(p,3n) \rightarrow {}^{236m}Np \rightarrow {}^{236}Pu$
  - $^{235}U(d,n) \rightarrow {}^{236g}Np$
- R&D project to evaluate feasibility of a new process to enrich Li-7
  - Solvent extraction technology
  - Goal to demonstrate enrichment to greater than 99.9%

Discussion

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Accelerator production of $^{236m,g}Np$

Reaction	Advantages	Disadvantages
$^{238}U(p,3n)^{236m,g}Np$ LANL-IPF: 1μA of 30 MeV protons	• Target material readily available • Larger amounts of ^{236m}Np produced per irradiation: • **Estimated 1 mCi of ^{236m}Np for 1h of proton beam *or*** • **0.4 μCi of ^{236}Pu after decay**	• ^{237}Np impurity in product would require isotope separation to purify ^{236g}Np • ^{238}Np from (p,n) decays to ^{238}Pu, potentially contaminating grown-in ^{236}Pu.
$^{235}U(d,n)^{236m,g}Np$ University of Washington: 1μA of 24 MeV deuterons	• Anticipated higher radioisotopic purity of ^{236g}Np (no production of ^{237}Np) • **0.2 ng of ^{236g}Np for 1h of deuteron beam**	• Lower total cross section for deuteron-induced reactions compared to proton • Available deuteron beam currents are a factor of 5 smaller than available proton currents, reducing yields significantly