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## Nuclear Energy Enabling Technologies (NEET)

# Advanced Sensors and Instrumentation (ASI) Annual Project Review

## Micro Pocket Fission Detectors (MPFD)

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May 21-22, 2013

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# Project Overview

## Goal and Objectives

- Develop, fabricate, and evaluate the performance of prototype, high temperature, compact, multi-purpose, fast and thermal fission chambers with integral temperature sensors

## Participants


- Troy Unruh and Joy Rempe; Idaho National Laboratory
- Philip Ugorowski, Douglas McGregor, and Michael Reichenberger; Kansas State University
- Jean-François Villard; Commissariate a l'energie atomique

## DOE-R&D programs benefitting from this work

- FCRD, ATR NSUF, ARC, SMR, NGNP, LWR/Reactor Safety (new), and LWRS/ Industry Programs

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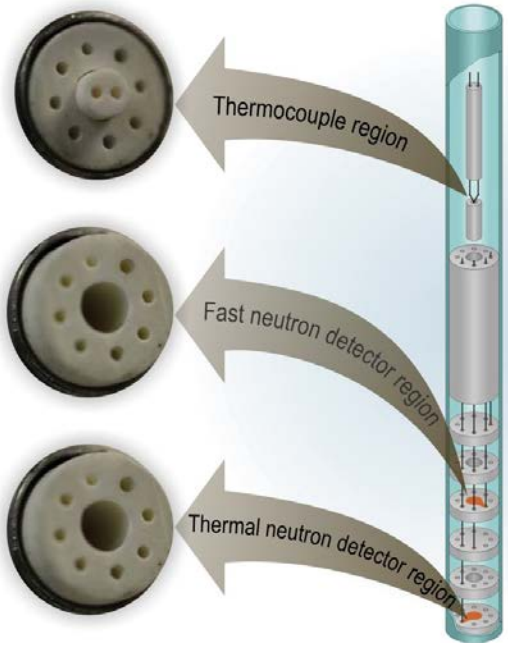
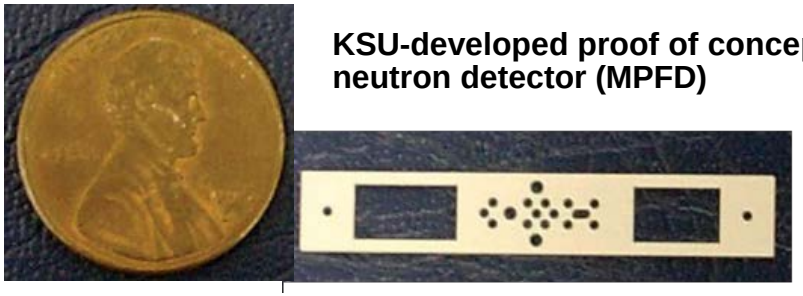
# Technology Impact




- **Robust and compact multi-purpose advanced neutron detector sorely needed to support planned DOE-NE and industry fuel and material irradiations at high temperatures and high pressures in high flux US MTRs**
- **Three-year project to yield prototype ready for DOE-NE program irradiations**



**KSU-developed proof of concept neutron detector (MPFD)**

***Although original KSU MPFD prototypes <u>not suitable</u> for high flux MTR irradiations, KSU evaluations demonstrated that concept can simultaneously detect thermal and fast neutron flux and temperature***

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# Research Plan

- **FY 2012: $375K Initial Design and Fabrication**
  - Collect input from DOE-NE programs and define sensor survivability requirements (INL)
  - MPFD redesign for HTIR-TC (INL, KSU, CEA)
  - Develop detector evaluation plan (INL, KSU, and CEA)
  - Issued "NEET Micro-Pocket Fission Detector – FY 2012 Status Report ," INL/EXT-12-27274, Milestone Number M3CT-12IN0703013 (INL, KSU)
- **FY 2013: $192K Prototype construction and initial evaluation**
  - Evaluate prototype design at HTTL (INL, KSU)
  - Initial evaluation of detectors (INL, KSU, and CEA)
  - Issue "NEET Micro-Pocket Fission Detector –FY 2013 Status Report " Sept. 2013 (INL, KSU)
  - Journal and conference papers, patents (Micro Pocket Fission Detector, IDR-2291) (INL, KSU)
- **FY 2014: $473K Final construction and evaluation/recommendations**
  - Final evaluation of detectors (INL, KSU, and CEA)
  - Build multiple MPFD string (INL, KSU)
  - Results documented in final project report Sept. 2014 (INL, KSU, CEA)

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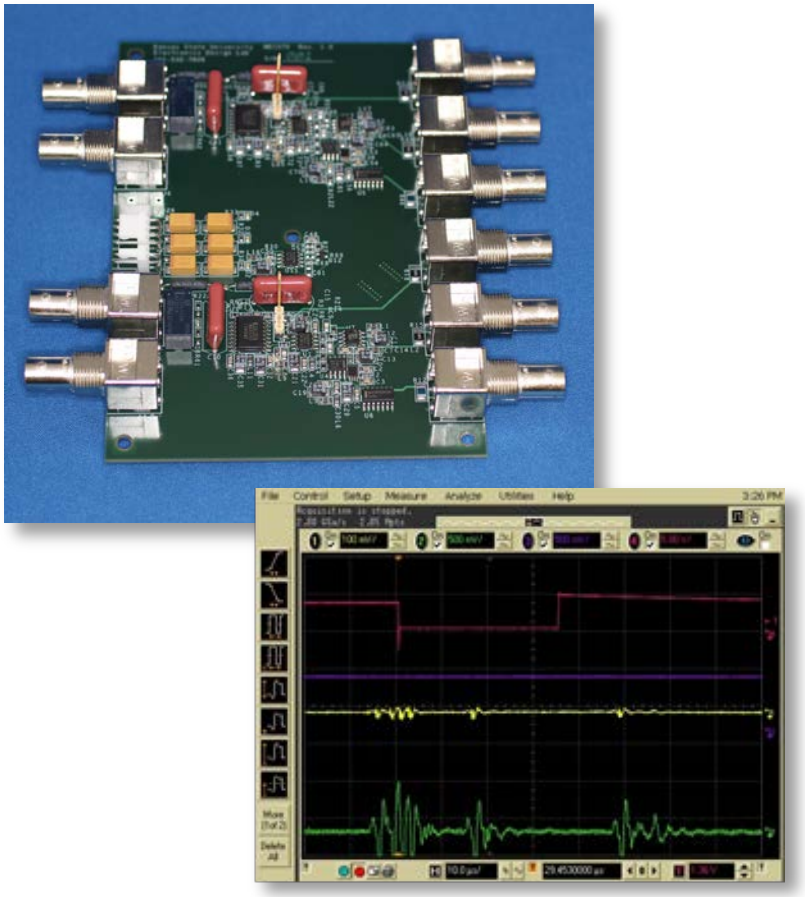
# FY 2012 Accomplishments



- **FY2012 (Completed)**
  - Developed enhanced MPFD design to accommodate INL-developed HTIR-TCs and improve robustness for higher temperature, long-duration high flux irradiations
  - Procured materials and initiated fabrication activities
  - First-generation amplifier board assembled and tested using initial KSU-designed MPFD in KSU TRIGA
  - Fissile depositions started at KSU
  - Issued “NEET Micro-Pocket Fission Detector – FY 2012 Status Report,” INL/EXT-12-27274, September 2012.

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# FY2013 Activities

- **Fabricate prototype**
  - Fissile deposit characterization
  - Refine construction techniques
- **Evaluate survivability**
  - High temperature furnaces
  - High pressure/high temperature autoclave
- **Device response**
  - Gamma irradiator
  - Reactors and neutron sources
- **Initiated INL patent paperwork**
- **Publications**
  - ICEM 2013 (ASME student sponsored)
  - NIM publication (in preparation)
- **Issue "NEET Micro-Pocket Fission Detector – FY 2013 Status Report," in Sept 2013**

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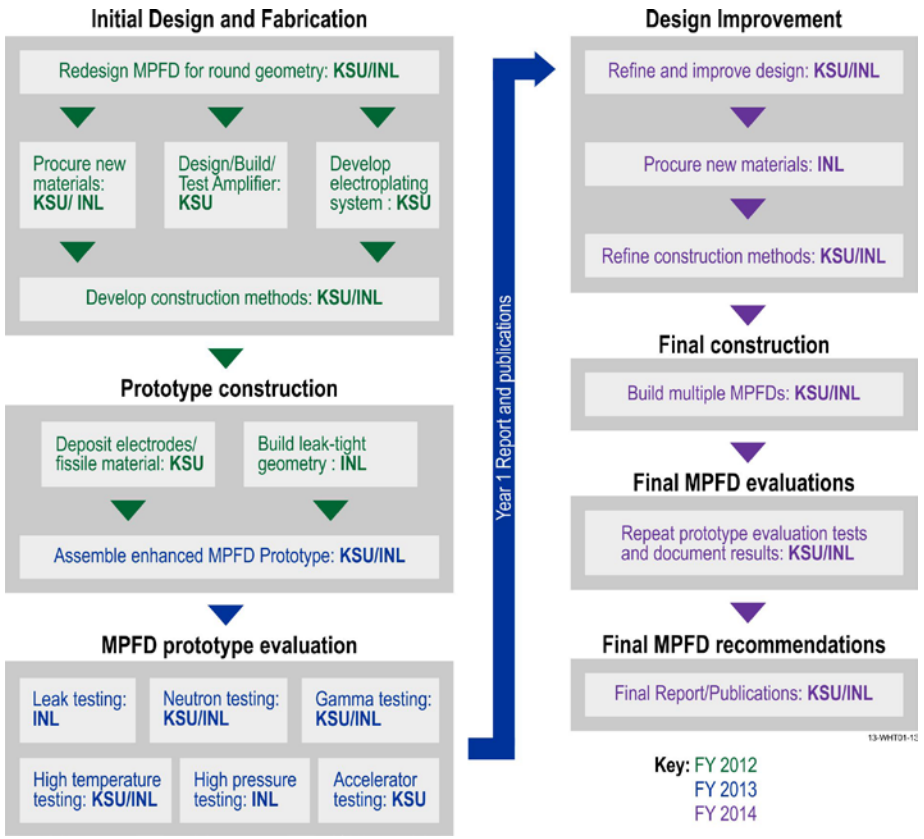
# Planned Accomplishments




## FY2013: (In Progress)

- Test prototype survivability in high temperature furnaces and high pressure/high temperature autoclave environments
- Test device response in ɣ and neutron fields
- Conference and Journal Publications
- Issue “NEET Micro-Pocket Fission Detector – FY 2013 Status Report”

## FY2014 (Planned)

- Refine prototype design (as required)
- Evaluate final prototype in various radiation fields (transient testing)
- Conference and Journal Publications
- Issue final program report

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# Crosscutting Benefits

- **Collected list of customer requirements through interactions with cognizant leads in NGNP, ARC, SMR, LWRS, FCRD, TREAT restart, and ATR NSUF programs**
  - Neutron sensitive (BOTH fast and thermal)
  - Temperature sensitive with integral high-temperature thermocouple
  - Compact size
  - Radiation resistant
  - High temperature and pressure compatibility using appropriate materials
  - High accuracy, high resolution
  - Flexibility (variable sensitivities, lifetimes and detector responses)
  - Fast response
  - Long lifetime
- **State-of-the-art sensor positions U.S. for leadership in irradiation testing**
  - Minimizes flux perturbation associated with typical real-time in-core sensors
  - Permits 3D modeling and triangulation of data for validation
  - Higher fidelity data for modeling and simulation of materials and fuels
  - Potential to increase US MTR customer base (DOE-NE, NR, industry, regulators, etc.)

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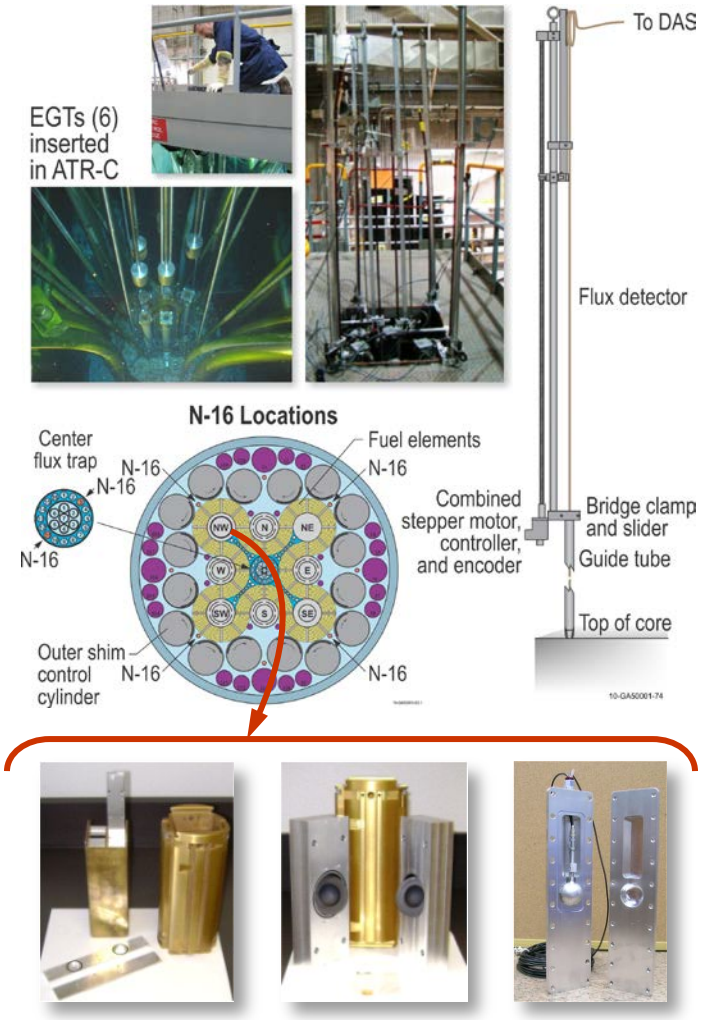
# Crosscutting Benefits (Cont.)




## FCRD

- Enables in-pile measurement of fast flux, thermal flux, and temperature in high temperature irradiation tests and in transient tests
- Multi-purpose sensors provide high accuracy data required for validating new multi-scale fuel models

## ATR NSUF

- Enables in-pile measurement of fast flux, thermal flux, and temperature in high temperature ATR NSUF irradiations
- Provides US MTR users high accuracy, high temperature flux and temperature data
- Ideally suited for cross-calibrations using specialized fixturing from previous NSUF detector calibration project

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# Crosscutting Benefits (Cont.)

## NGNP

- Enables in-pile measurement of fast flux, thermal flux, and temperature in high temperature irradiation tests and on-line monitoring of conditions in first plant
- Multi-purpose sensors provide real-time data to validate model predictions during irradiation and during reactor operation

## LWRS / Industry Programs

- Enables in-pile measurement of fast flux, thermal flux, and temperature in fuels and materials irradiation tests
- Multi-purpose sensors provide data required for demonstrating performance of accident tolerant fuels during irradiation testing during steady-state and transient conditions
- Multi-purpose sensors provide real-time data for characterizing conditions during materials irradiations.

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# Crosscutting Benefits (Cont.)

## ARC

- Enables in-pile measurement of fast flux, thermal flux, and temperature in high temperature irradiation tests
- Multi-purpose sensors provide data for validating new multi-scale models.
- Long lifetime sensor ideal for in-vessel operational measurements where vessel stays closed

## Advanced SMR

- Enables in-pile measurement of fast flux, thermal flux, and temperature in high temperature irradiation tests
- Multi-purpose sensors provide high temperature real-time data to validate fuel and material properties during irradiation
- Long lifetime sensor ideal for in-vessel operational measurements where vessel stays closed

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# Transition to Competitive Research

- **Enables sensors to meet DOE-NE and industry irradiation requirements**
  - Compact size
  - Multiple parameter measurement (e.g., temperature, fast flux, and thermal flux)
  - Radiation resistant
  - High temperature compatibility with appropriate materials
  - High accuracy
  - High resolution
  - Flexibility (variable applications, sensitivities, resolution, accuracies, etc.)
- **Anticipated hand-off to occur at end of program**
  - Demonstrate long duration irradiation performance in ATR NSUF awarded or specific DOE NE or industry program irradiation test.

# Conclusion

- **Compact, multi-purpose advanced neutron detector is essential for high temperature, high pressure, high flux irradiations identified by LWRS, NGNP, ATR NSUF, FCRD, and Industry Programs**
- **Data from fast response, accurate, miniature neutron detector will be a critical tool for validating new high-fidelity multi-scale codes under development by DOE-NE**