U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Science User Facilities (NSUF)

Nuclear Fuels and Materials Library Update

NSUF Nuclear Science User Facilities

J. Rory Kennedy
Director, NSUF
Idaho National Laboratory

5th Nuclear Academics Discussion Meeting
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NSUF General

NSUF Nuclear Science User Facilities

- The research performed to support nuclear energy development requires specialized and increasingly rare capabilities
  - Test and research reactors
  - Hot cells
  - Ion beams
  - Support infrastructure (shipping casks, test fabrication, etc.)
  - State-of-the-Art instrumentation & Expertise
- But also intellectual capital
  - Universities
  - Nuclear Industry
  - Innovative Small Businesses
  - National Laboratories

- The NSUF aims to merge the national nuclear research infrastructure with intellectual capital to pair the best ideas with needed capability
- Focus area of NSUF is irradiation effects in nuclear fuels and materials. Expanded scope is intended.
- The NSUF offers access to capabilities and expertise at no cost to the user. The NSUF can fund experiment design, fabrication, transport, irradiation, and post irradiation examination (PIE) activities.
- The NSUF core purpose is to provide an avenue for innovative ideas that address NE mission needs to be realized.

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NSUF General

NSUF Nuclear Science User Facilities

- **Established 2007 as DOE Office of Nuclear Energy first and only user facility**
  - **Idaho National Laboratory is lead institution**
- **Generally select projects through open competitive proposal processes**
  - **Consolidated Innovative Nuclear Research (CINR FOA, 1 call/year)**
    - **Irradiation + PIE ($1.0M - $4.0M, up to 7 years)**
    - **PIE only (~$500K, up to 3 years)**
    - **Irradiation only ($500K - $3.5M)**
    - **Beamlines at other user facilities**

  - **Rapid Turnaround Experiments (RTE, 3 calls/year, limited $$, executed within 9 months)**
  - **Proposals welcome from University, National Laboratory, Industry, Int'l researchers**
- **Partner Facilities established starting in 2008 (self selection)**
  - **8 Universities + 3 universities in CAES (3 expressed interest)**
  - **4 National Laboratories (3 expressed interest)**
  - **1 Industrial**

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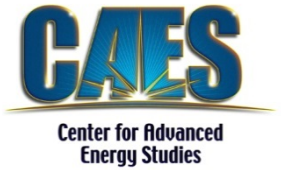
NSUF – A consortium

A group formed to undertake an enterprise beyond the resources of any one member

NSUF Nuclear Science User Facilities



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NSUF General Capabilities

NSUF Nuclear Science User Facilities

- Neutron Irradiations
  - ATR (loop, rabbit), ATRC, HFIR (rabbit), MITR (loop), PULSTAR, NRAD (Future: BR2 – SCK-CEN Belgium), Halden – Norway ?)
- Ion Irradiations
  - Tandem Accelerator Ion Beam (U. Wisc), Michigan Ion Beam Lab (U. Mich), IVEM (ANL) (Future: TAMU, SNL, LANL)
- Hot Cells
  - INL(HFEF, FCF, AL, IASCC), ORNL (IFEL, IMET, REDC), PNNL (RPL), U. Mich (IMC), Westinghouse (MCOE)
- High radiation level measurements/instrumentation
  - Neutron radiography, elemental & isotopic analyses, gas sampling and analyses, profilometry, gamma scanning, mechanical testing, electron and optical microscopy, thermal analyses, eddy current, IASCC, EPMA, AES, XPS, SIMS, focused ion beam (FIB)
- Low radiation level measurements/instrumentation
  - SEM, TEM, APT, FIB, hardness, micro- & nano-indentation, tensile, thermal analyses, XRD, XPS, AES, SIMS, NMR, PAS
- Beamlines
  - X-ray (ANL APS: MRCAT, IIT; BNL NSLS-II: XPD, NST Dept)
  - Neutron, positron (PULSTAR, NCSU)
- Visit nsuf.inl.gov under Research Capabilities tab for details at individual facilities

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NSUF Projects

NSUF Nuclear Science User Facilities

- Total of 28 awarded CINR type projects executed
- Total of 21 awarded projects currently ongoing (excluding RTEs)
- Total of 97 RTEs executed
- Total of 30 RTEs ongoing
- 176 total projects awarded
  - 122 projects to 33 US universities
  - 49 projects to 5 national laboratories
  - 4 projects to 3 international (Oxford U., Manchester U., ANSTO)
  - 1 project to industry (GE-Hitachi)
- 172 total projects across 22 states
- Interest and support levels
  - FY 2014 – $400K, 8 full proposals, 3 awards
  - FY 2015 – $4.1M, 41 LOIs, 31 pre-proposals, 17 full proposals, 5 awards (1 R&D coupled, 4 NSUF only)
  - FY 2016 – $9.7M, 80 LOIs, 67 pre-proposals, 32 full proposals, 12 awards (8 R&D coupled, 4 NSUF only)
  - FY 2017 – 124 LOIs, 109 pre-proposals

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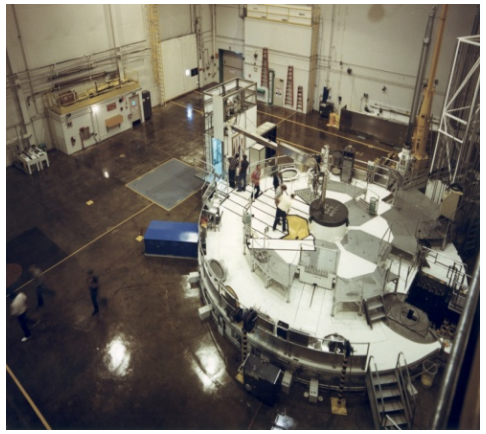
High Impact Nuclear R&D

NSUF Nuclear Science User Facilities

Project portfolio spans a variety of research objectives that are ultimately focused on both near and long-term technology development goals



- **Understanding atomic level phenomena in fuels that affect thermal transport, elemental migration/diffusion, interface interaction, etc. as complex microstructures develop under irradiation**
  - **ceramic, metallic, TRISO, ATF**
- **Understanding fundamental defect evolution in irradiated structural materials across multiple length scales as they affect mechanical properties.**
  - **RPV, austenitic, F/M, Zr alloys, ATF**
- **Development of innovative radiation resistant materials for advanced reactor systems**
- **Development of radiation resistant sensors for collecting high fidelity on-line irradiation test data**
- **Providing fundamental actinide nuclear data that can help inform advanced reactor and fuel cycle modeling and simulation campaign.**

J. Cole contributed to content of slide

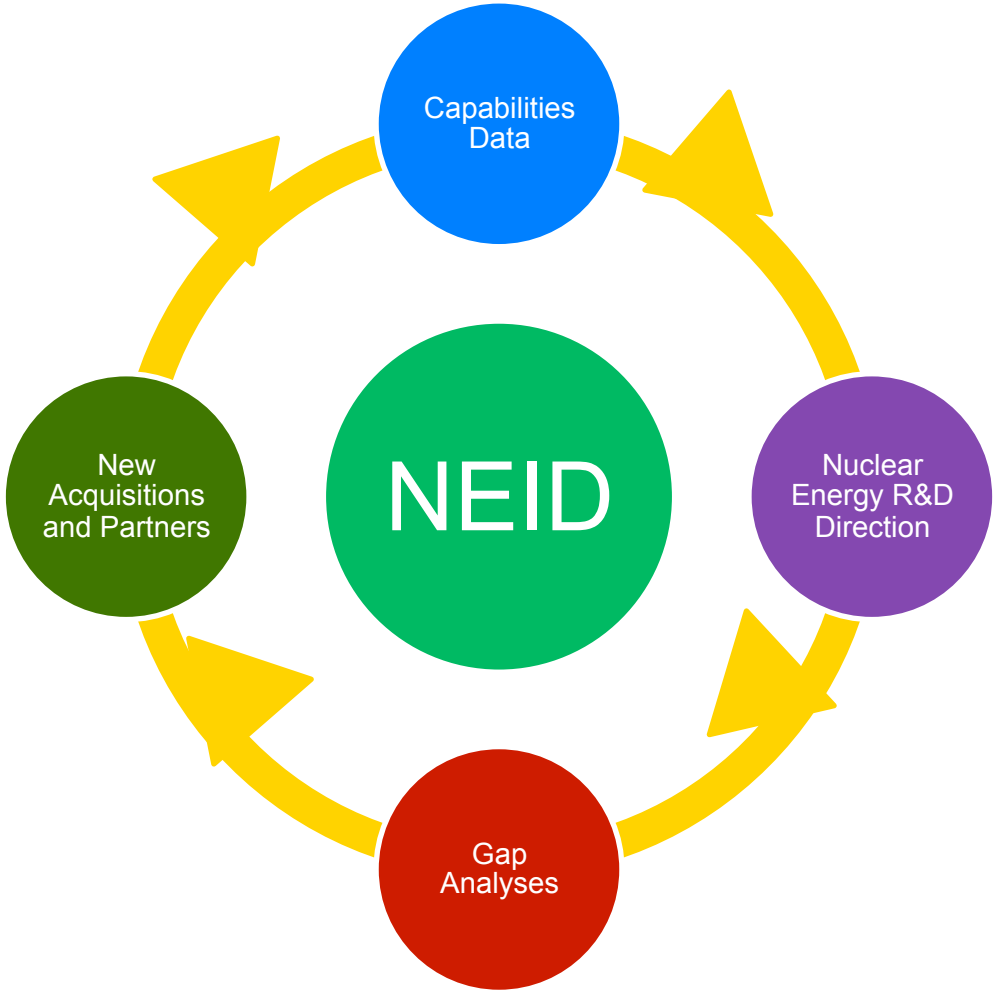
Nuclear Energy Infrastructure Database (NEID)

1. Gather Data on Nuclear Energy R&D Capabilities

2. Estimate Near, Mid and Long-term R&D Directions

3. Use these to perform gap analyses for Nuclear Energy R&D.

4. Assist funding decisions and incorporate the results into the NEID.

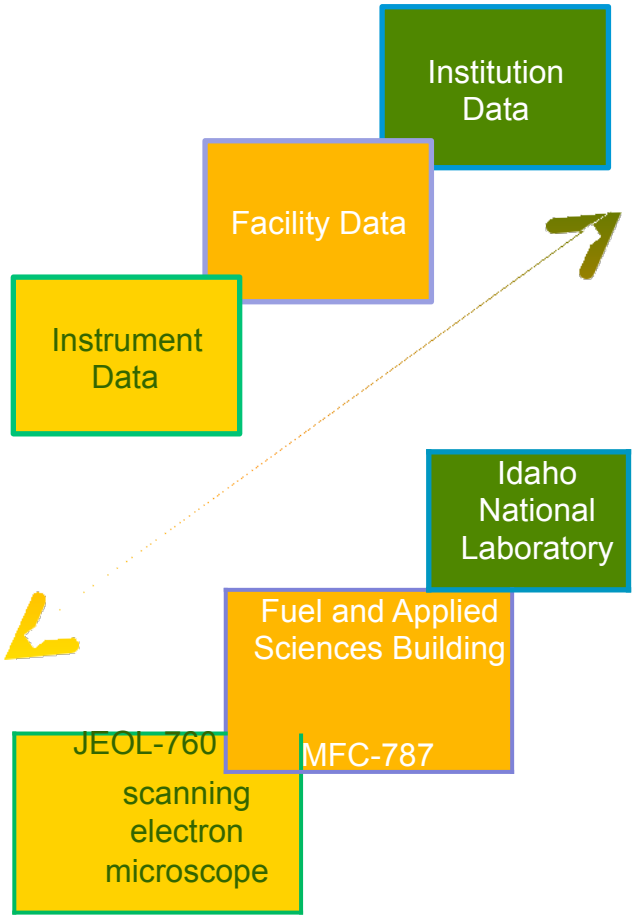


Infrastructure Management Program

B. Heidrich

Infrastructure / Capabilities

- Nuclear Energy Infrastructure Database (NEID) public web-based searchable tool launched in November 2015 (nsuf-infrastructure.inl.gov)
- Over 125 institutions operating over 450 facilities housing almost 900 instruments
- Current NEID users include researchers from 75 Federal Government and National Laboratories, 38 Universities and NGOs, and 25 Industry organizations.
- Used to complete initial infrastructure gap analysis



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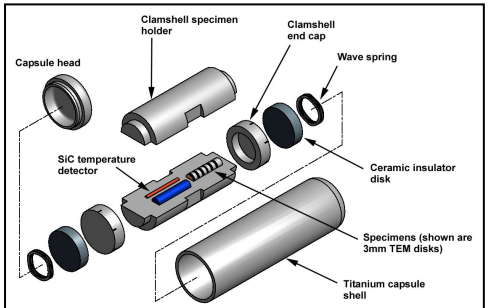
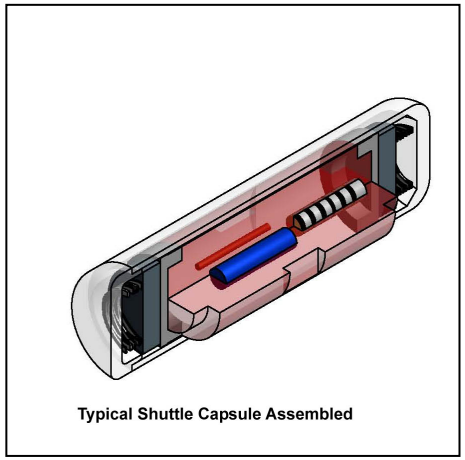
NSUF Nuclear Fuels and Materials Library (NFML)

NSUF Nuclear Science User Facilities

- Critical to reducing costs and taking advantage of new ideas and future analysis techniques and equipment.
- A detailed inventory of samples currently in the library has been completed in the form of excel spreadsheets available on website (nsuf.inl.gov) that will be used as initial population of a web-based searchable database for users to locate samples of interest (public launch Sept 14, 2016).
- Working to increase inventory of samples and establish provenance of materials throughout DOE complex for potential incorporation in NFML.
- Effort to consolidate materials into easily accessible locations to reduce costs of retrieval.
- Interest in collaboration on international efforts.



Typical Shuttle Capsule - Exploded View


Typical Shuttle Capsule Assembled

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Nuclear Fuels and Materials Library

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NSUF Nuclear Science User Facilities

- Provides irradiated samples for users to access and conduct research through a competitively reviewed proposal process.
- "Librarian" hired
- The library includes over 3500 specimens as part of the NSUF awarded research.
- 6K – 7K additional specimens by year end.
- Most materials in NFML neutron irradiated with small number ion irradiated.
- SAM irradiation series to stock library moving forward
- <u>Materials Include:</u>
  - Steels
  - Other alloys
  - Ceramics
  - Pure materials
  - Actinides
  - Fission products

INL Legacy materials

Volunteered materials from outside the INL

Supporting documentation related to samples

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Nuclear Fuels and Materials Library

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NSUF Nuclear Science User Facilities

Steels	
17-4 PH SS	Fe-Cr Alloys
304 SS	HCM12-A
304 SS welds	HT-9
Super 304H	MA-956
316 SS	MA-957
347 SS	MAR-2008
416 SS	Mo-ODS
420 SS	nCr-YWT
9Cr ODS	NF616
Borated Steel	NF709
Carbon Steel	PM2000
Cast ASS	T-91
D9 ASS	Tool Steel T-1
Eurofer 97	XM-19
F82H-IEA	various model alloys

Other Alloys	Ceramics	Pure Materials
Al_3Hf	Al_2O_3	Copper
Al1100	MgO	Iron
Al6061	$MgO\text{-}ZrO_2$	Ni/Cu/Nb (DC)
Aluminum Bronze	$Mg_2\text{-}SnO_4$	Nickel
Berylco #25	$Mg0_{1.5}Al_2O_3$	Niobium
C276 Hasteloy	$MgTiO_3$	Silver
Incoloy 800H	$Nd_2Zr_2O_7$	Tantalum
Inconel X/X-750	SiC	Tungsten
Stellite	Ti_2AlC	Zirconium
	Ti_3AlC_2	
	Ti_2AlN	
	TiO_2	
	Ti_3SiC_2	

Materials from NSUF projects, EBR-II, ATR, FFTF, HFIR, José Cabrera Nuclear Power Station, Zion 1 & 2 NPS (in negotiation).

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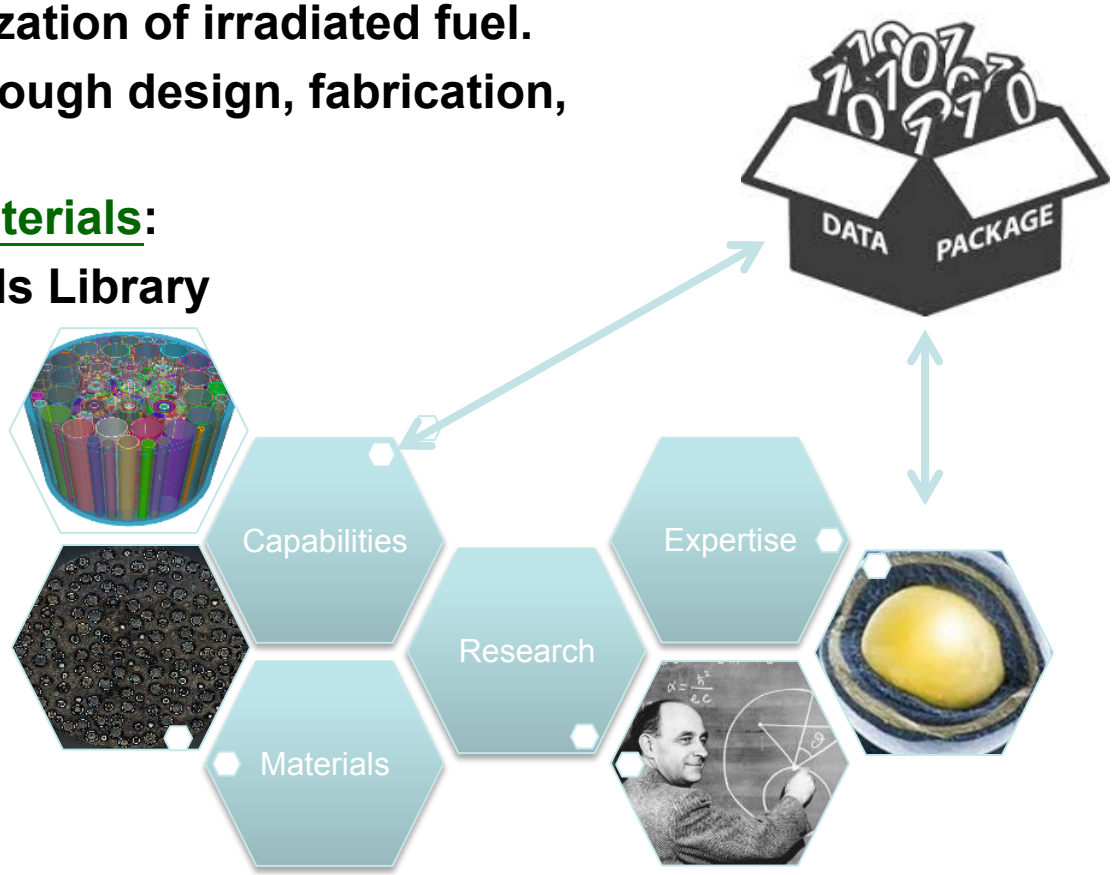
Future Initiatives: Integrating Databases

NSUF Nuclear Science User Facilities

1. We can connect facilities and instruments as parts of a process to accomplish a research method or process, such as:
   - Microstructural characterization of irradiated fuel.
   - Irradiation experiment (through design, fabrication, irradiation, etc.)
2. We can include fuels and materials:
   - Nuclear Fuels and Materials Library
   - Link to facilities utilized
   - Link to researchers
3. We can connect research:
   - Subject matter
   - Facilities utilized
   - PIs & collaborators
4. We can include expertise:



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NSUF Nuclear Science User Facilities

SME DATABASE

PI/SME Name

Research Area/Subject Matter

INSTITUTION

PROJECT DATABASE

PROJECT NAME

Project ID	Start Date	Project Type
Proposal	End Date	Material Type
CINR #	PI Name	Research Area
RTE #	Tech Lead	**INSTITUTION**
NSUF Call	Facility Tech Lead	**FACILITY**
Award Date	Collaborators	Related Documentation

NEID

INSTITUTION

FACILITY

REACTOR

REACTOR POSITION

PROJECT NAME

REACTOR

REACTOR POSITION

Sample ID Code	# of Samples
Capsule	Samples Remaining
Packet	Specimen Availability
Material Code	Availability Date
Material Name	Certification
Material Description	Certification Code
KGT #	Storage **FACILITY**
Specimen Type	Notes
Dimensions	

FUELS & MATERIALS LIBRARY

PLANNED	AS RUN DATA
Temperature	Temperature
Dose (DPA)	Actual Dose (DPA)
Fluence [$x10^{20}$]	Fluence [$x10^{20}$]
Flux [$x10^{14}$]	Flux [$x10^{14}$]
Environment	Environment

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Expanded NSUF Vision

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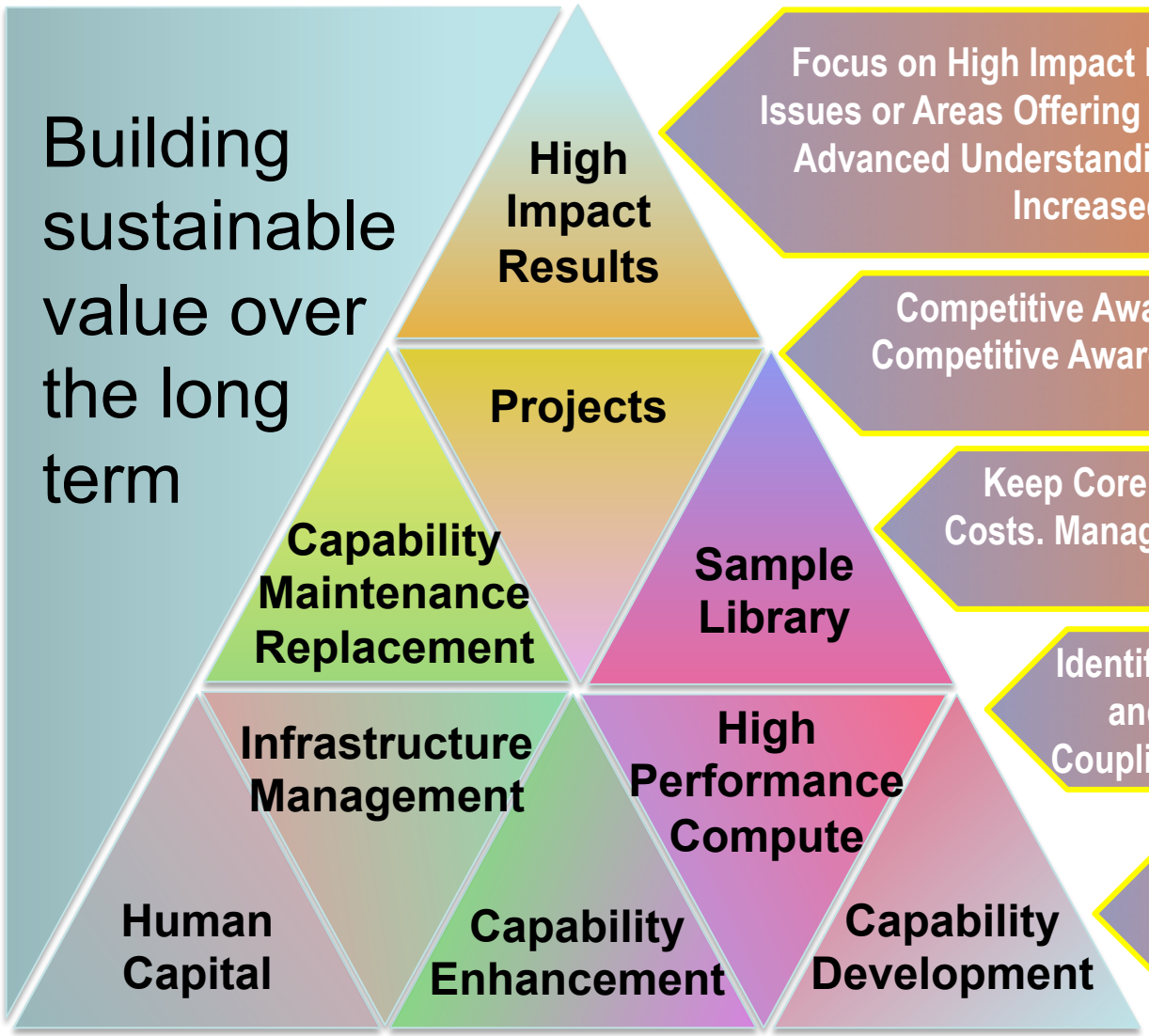

Focus on High Impact Results Addressing Most Pressing Issues or Areas Offering Greatest Potential for Advancement. Advanced Understanding of Most Important Phenomena. Increased Public Awareness.

Competitive Awards (Focused CINR Scopes). Non-Competitive Awards (NE Programs, CRADA). Forward Funded.

Keep Core Infrastructure Functional. Reduced Costs. Management of High Value Materials. Aid in Disposition Decisions

Identifying and Analyzing Capability Status and Needs. Validation & Verification. Coupling Experiment to Computation. M&S.

Cutting Edge, State of the Art Instrumentation. Internationally Recognized Expertise. Other User Facility Leveraging


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