Collaboration Partners:

- NSUF plus INL, ORNL, PNNL, Purdue University, Westinghouse
- NNUF plus UK NNL, Univ. of Manchester, Univ of Oxford, Univ. of Sheffield, UKAEA

NIFT-E

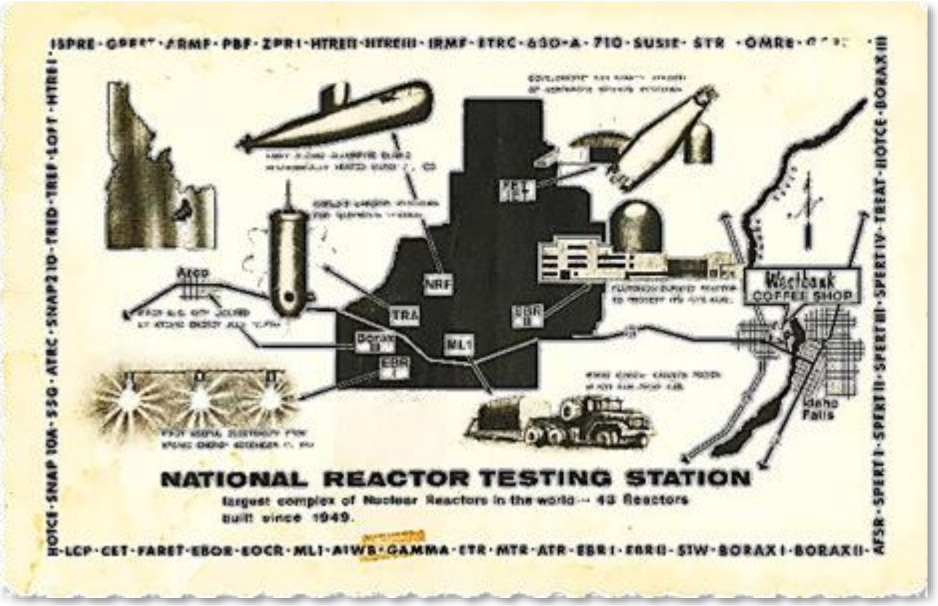
Neutron Irradiation as a Function of Temperature - Experiment

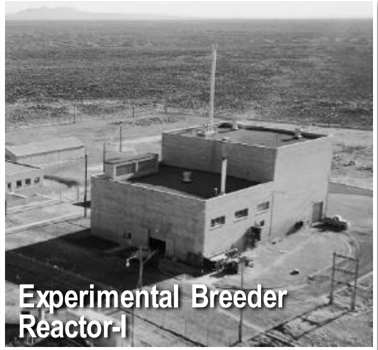
- Simon M. Pimblott, M.A., D.Phil., F.R.S.C.
- Chief Scientist
- Nuclear Science and Technology
- Simon.Pimblott@INL.Gov

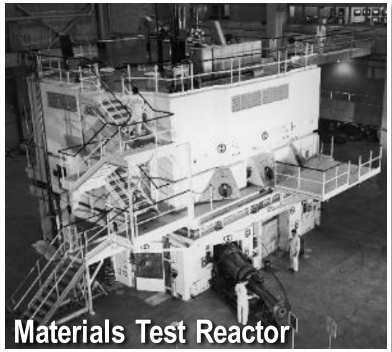
Idaho National Laboratory

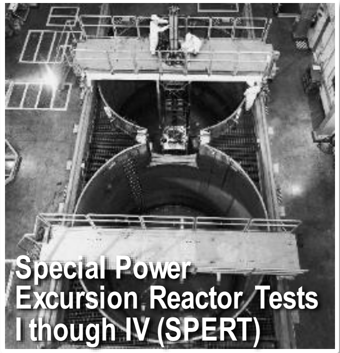
INL’s origin: The National Reactor Testing Station provided capabilities that drove nuclear innovation in the U.S. and around the world

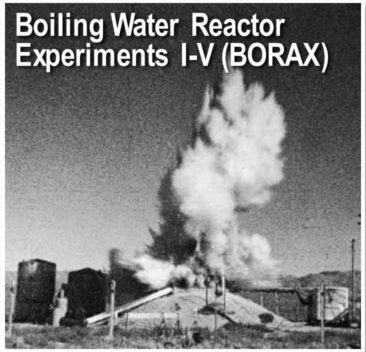
- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested
- First mobile nuclear power plant for the Army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors

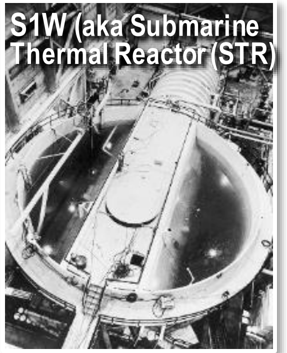


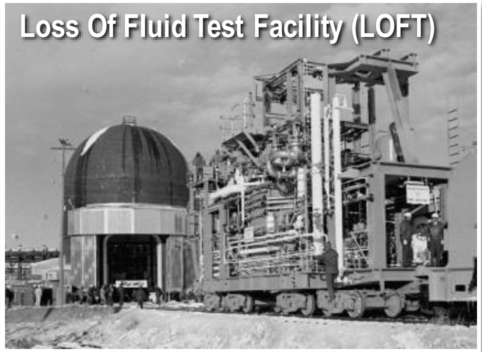




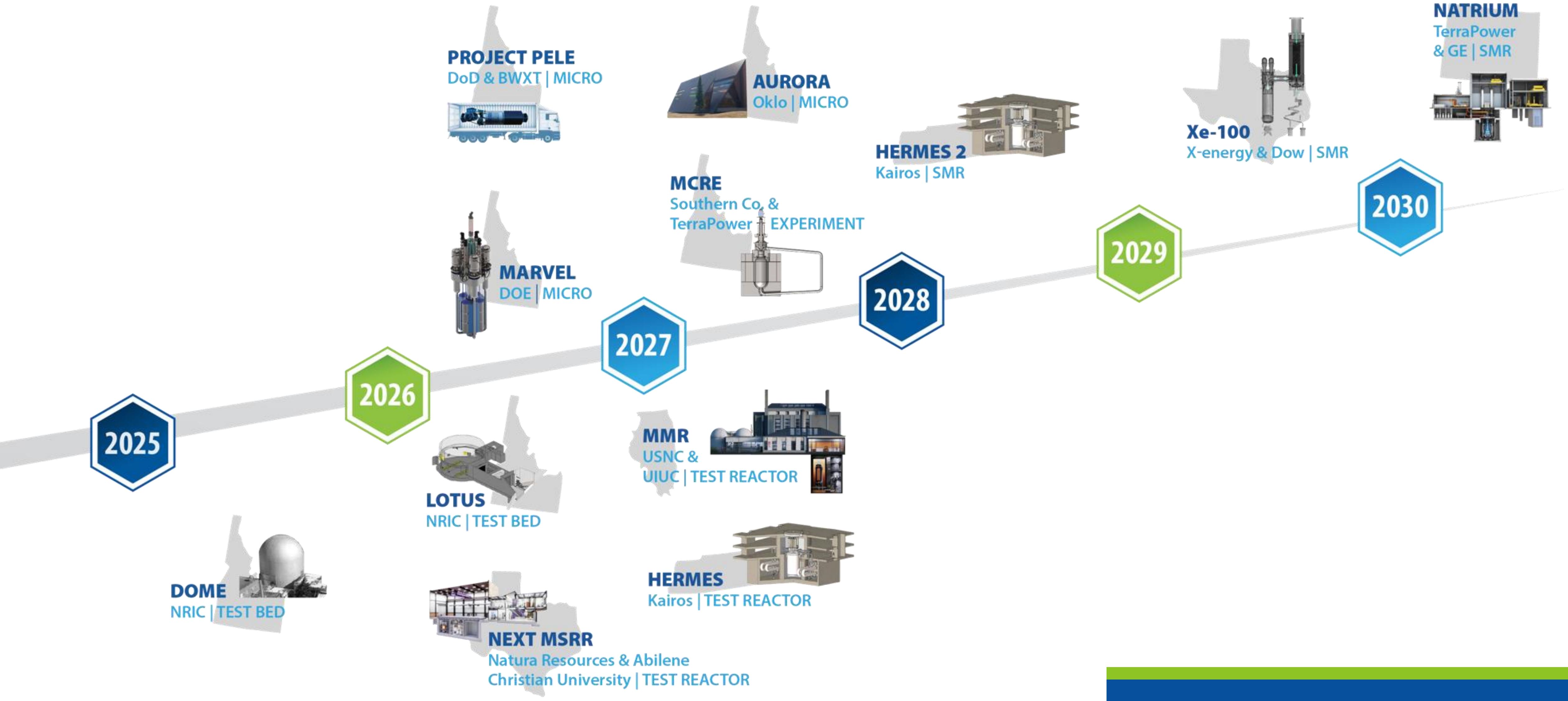








Accelerating advanced reactor demonstration & deployment



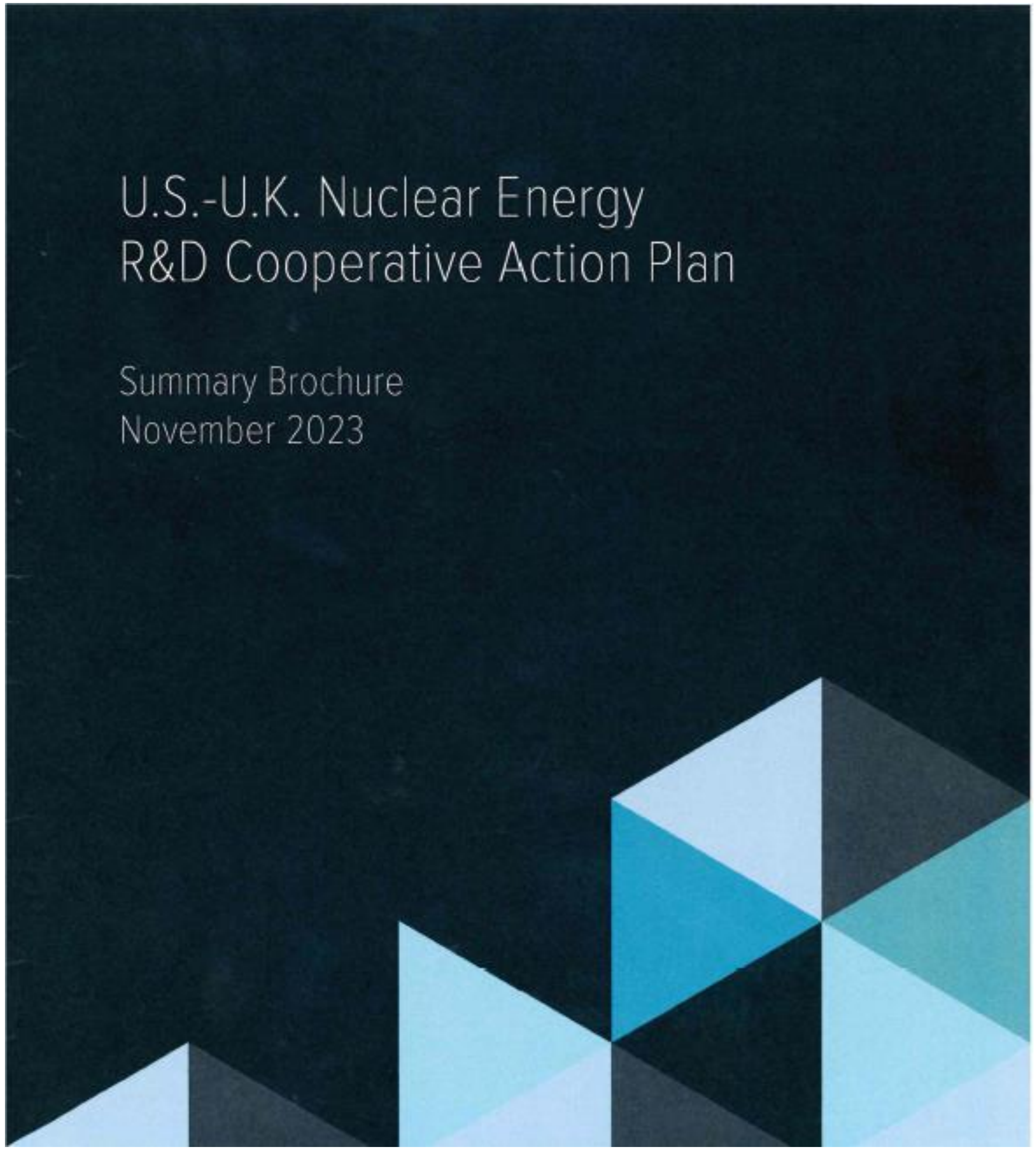
NIFT-E Objectives

Strategic

- Explore sharing of nuclear facilities between US and UK
- Further nuclear energy research collaboration between US and UK

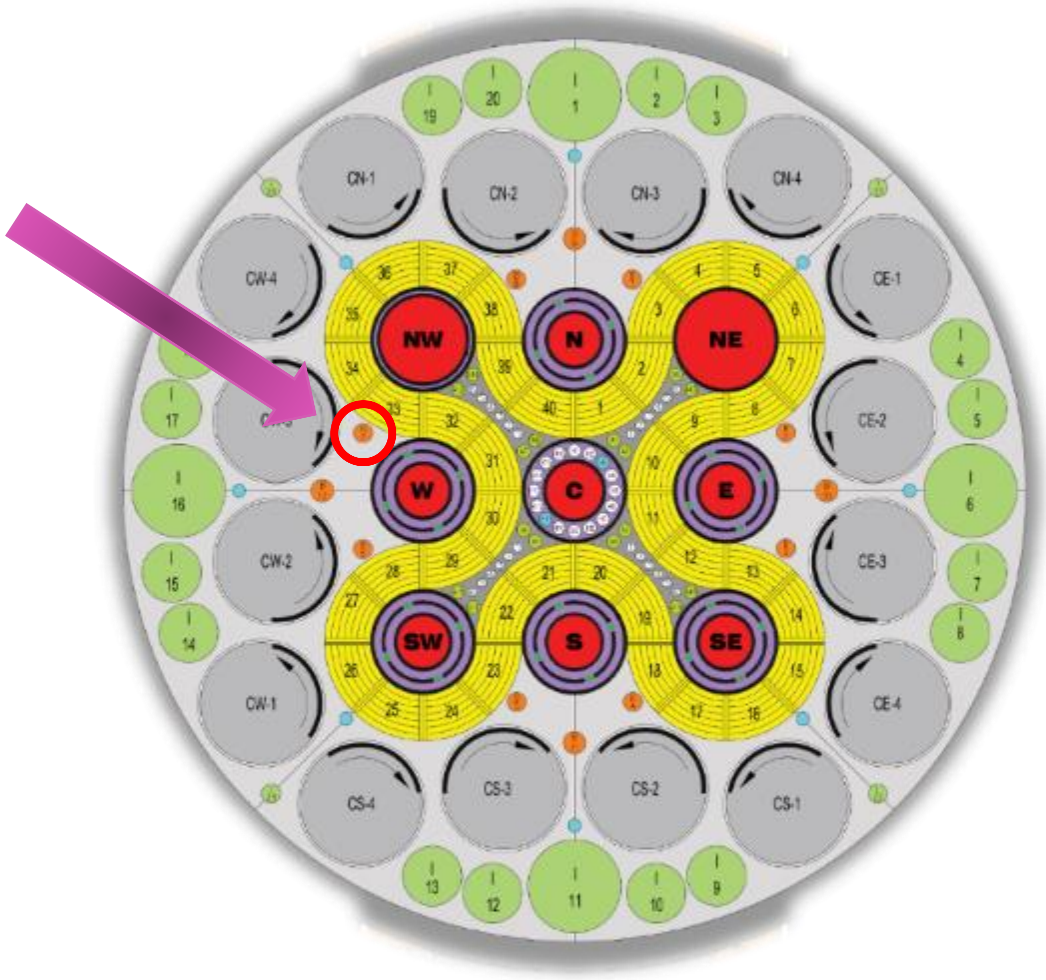
Technical

- Perform joint irradiation and post-irradiation examination campaign to
  - Capture effects of neutron irradiation as a function of temperature and dose on nuclear graphite and on alumina-forming austenitic (AFA) steels
  - Targets
    - Microstructure and mechanical property plus corrosion behavior
- Builds on previous and ongoing testing campaigns performed in US and UK



Experiment Overview

- Drop In Materials Experiment
  - 8 capsules
    - 3 Graphite
    - 5 AFA/Miscellaneous alloys
- B7 position
- First Insertion Cycle: 175C



Capsule	DPA Target	Temperature
C1	2.0 ± 0.5 dpa	750 ± 50°C
C2	4.0 ± 0.5 dpa	750 ± 50°C
C3	6.0 ± 0.5 dpa	750 ± 50°C
AFA1	1.0 ± 0.3 dpa	400 ± 50°C
AFA2	1.0 ± 0.3 dpa	650 ± 50°C
AFA3	8.0 dpa nominal	400 ± 50°C
AFA4	4.0 dpa nominal	400 ± 50°C
AFA5	4.0 dpa nominal	650 ± 50°C

Mechanical Design

- Two Designs utilizing a Zr4 Outer Capsule similar to SAM-2
  - AFA Capsule
  - Graphite Capsule
- NIFT-E Stackable Outer Capsule

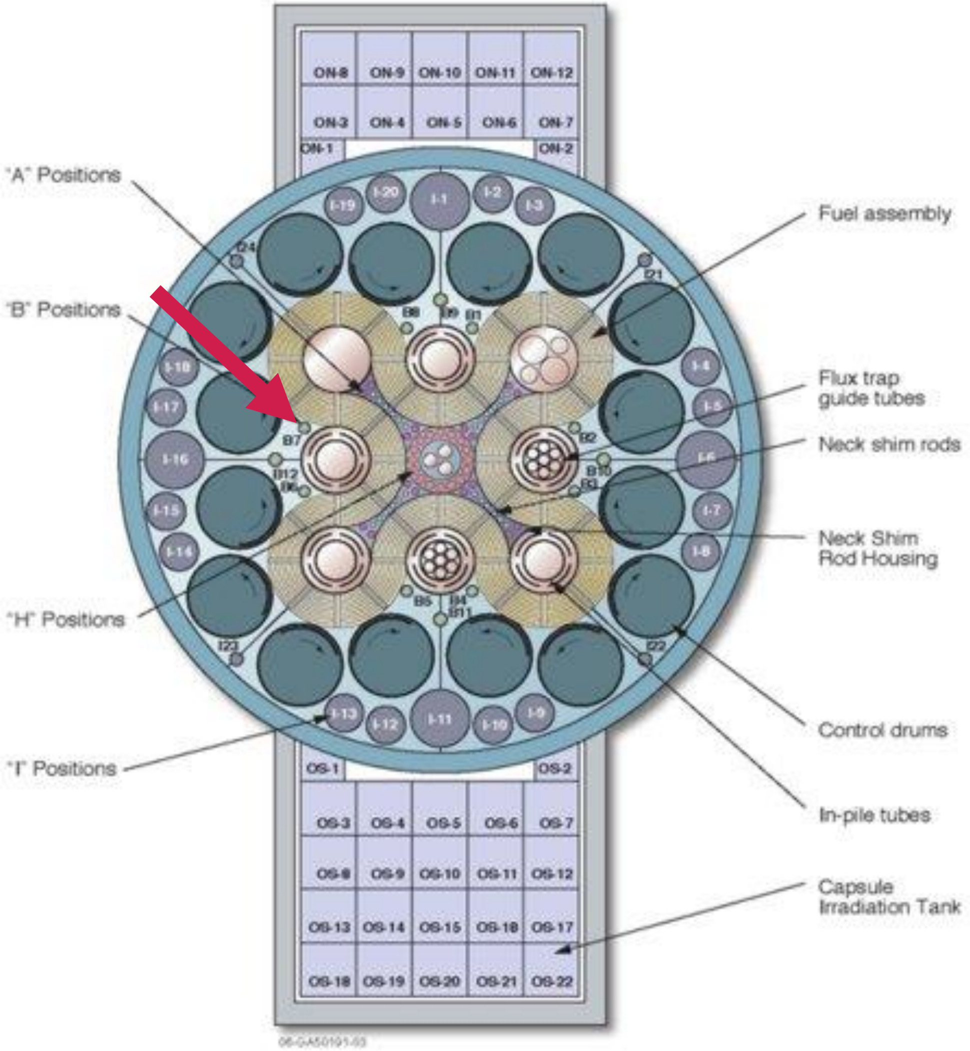
- AFA Capsule
  - Zr4 Fixture Body
  - Specimen and Passive Instrumentation

- Graphite Capsule
  - Merson 2114 Nuclear Grade Fixture Body
  - NIFT-E Can and Tungsten Heaters
  - Specimen and Passive Instrumentation

Neutronics Analysis

- Monte Carlo N-Particle transport code, MCNP, used to model and evaluate the NIFT-E experiment.
- Standard MCNP cross-section data libraries employed to calculate the neutron flux, dpa, heating rates and reactivity worth.
- The SCALE modules, COUPLE and ORIGEN, were used to calculate the activity and decay heat.
- Total core power scaled to the NW lobe.

Lobe	60-day Cycles [MW]	40-day Cycles [MW]
NW	**24**	**24**
NE	18	18
C	21.1	24.4
SW	23	32
SE	23	23



Thermal Analysis

- Two new 3D heat transfer models created in ANSYS 2022R2 for parametric studies and FDR temperatures
- Heating rates use a lobe power of 24.0 MW in the northwest lobe for the B7 position during cycle 175C and 179A
- Convective heat transfer on the capsules outer diameter assumes a 6 capsule test train
- Radiation modeled between fixture OD and capsule ID

Safety

Hale, C., "*Enveloping Thermal Hydraulic Analysis for the NSUF Standardized Capsule Design in an ATR Small B Position*", ECAR-4911, 11/20/2019.
Hale, C., "SAM-2 Thermal Analysis", ECAR-5112, 11/20/2019.

Thermal Analysis—Gap Design

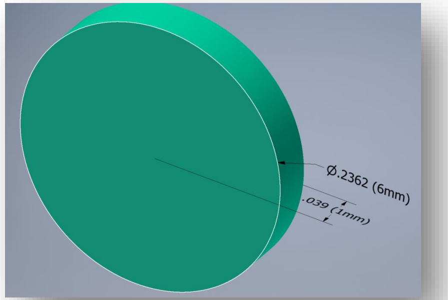
- Experiment designed for specimens to achieve the following temperature targets:
  - Capsule C1: 750 ± 50°C
  - Capsule C2: 750 ± 50°C
  - Capsule C3: 750 ± 50°C
  - Capsule AFA1: 400 ± 50°C
  - Capsule AFA2: 650 ± 50°C
  - Capsule AFA3: 400 ± 50°C
  - Capsule AFA4: 400 ± 50°C
  - Capsule AFA5: 650 ± 50°C

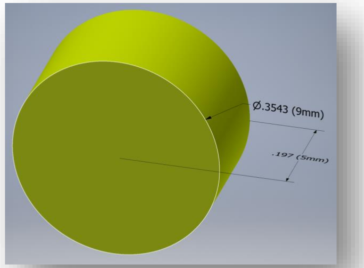
Identity			Gap Design	
Capsule	**Cycle**	**Position**	**Gap [in]**	**Gas**
C1	175C	E	0.030	100% Ar
C2	179A	E	0.030	100% Ar
C3	179A	F	0.030	100% Ar
AFA1	175C	D	0.030	100% He
AFA2	175C	G	0.032	75%He, 25%Ar
AFA3	179A	G	0.028	100% He
AFA4	179A	D	0.030	100% He
AFA5	175C	F	0.028	75%He, 25%Ar

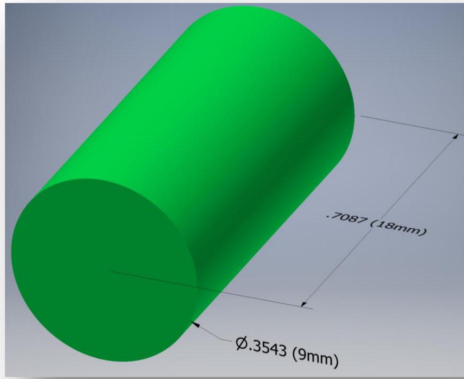
Specimen Irradiation Matrix

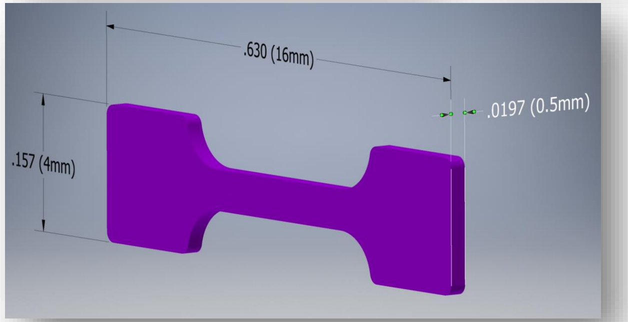
AFA/Miscellaneous Capsules			
Material	Tensile	6mm X 1mm Corrosion Discs	3 X .5mm TEM Discs
GA05 SA	12	6	-
GA05 HT	12	-	-
GA05 20Ni SA	12	-	-
GA05 20Ni HT	12	-	-
AISI Type 304L SS 3 µm Al2O3 coated	-	7	-
AISI Type 304L SS 1.5 µm FeCrAl 1.5 µm Al2O3 coated	-	7	-
Oxide-Coated F/M Steels 3µm Al2O3 coated (misc)	-	-	4
Oxide-Coated F/M Steels 1.5 µm FeCrAl 1.5 µm Al2O3 coated (misc)	-	-	4
Adv Mfg Grade 91 (misc)	-	-	8
HEAs (misc)	-	-	8
Hetero Nano-composites (misc)	-	-	8
TOTAL	**48**	**20**	**32**

Graphite Capsules				
Material	9x5 mm discs	9x18 mm cylinder specimens	3x1 mm disc specimens	6x1.5 mm disc specimens
IG110	4	2	-	-
HOPG	-	-	2	-
IPyC	-	-	-	5
NBG18	4	1	-	-
TOTAL	**8**	**3**	**2**	**5**



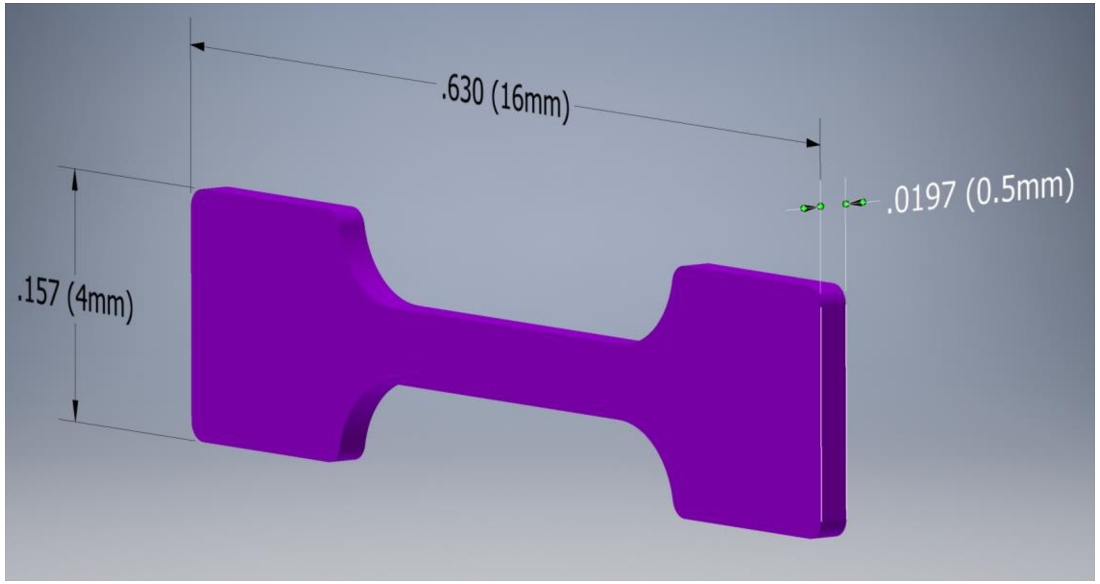


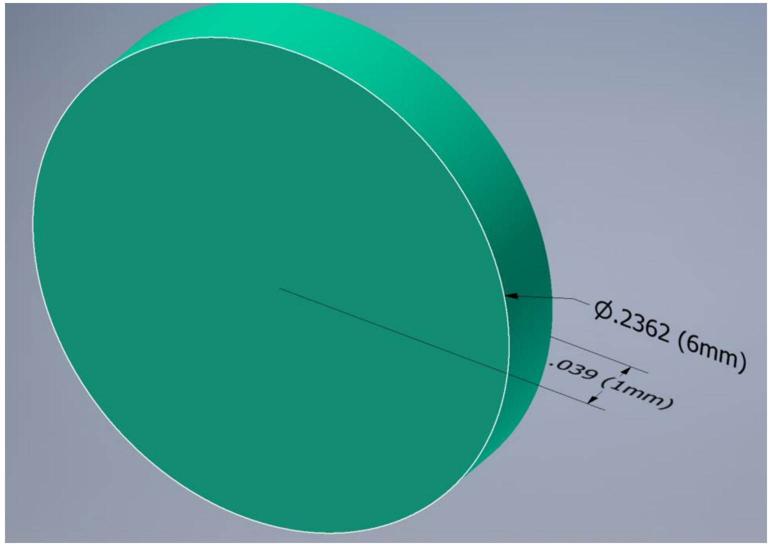


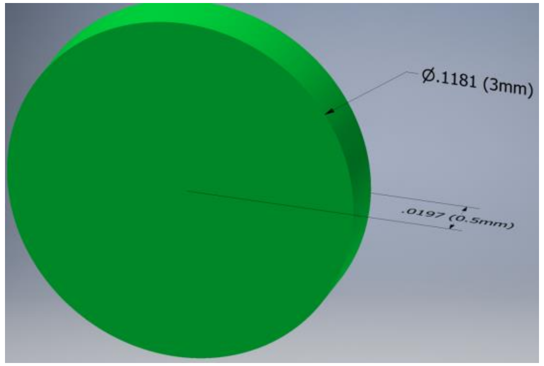


AFA SS Specimen

- Quantity and Sizes
  - (20) Ø6x1mm
  - (32) Ø3x0.5mm
  - (48) SSJ3s – 16x4x0.5mm

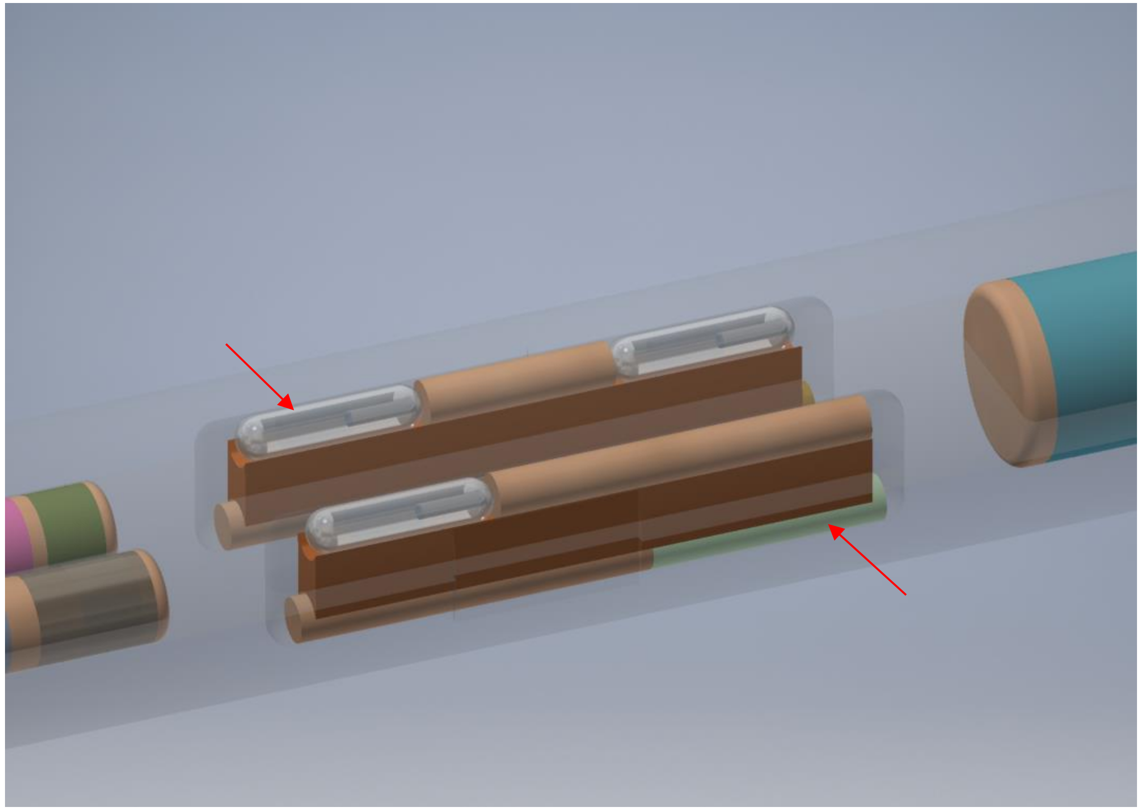


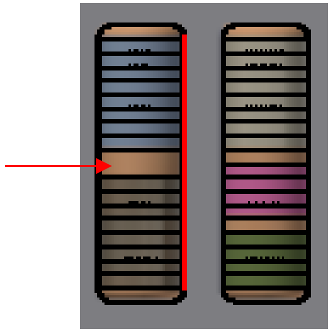




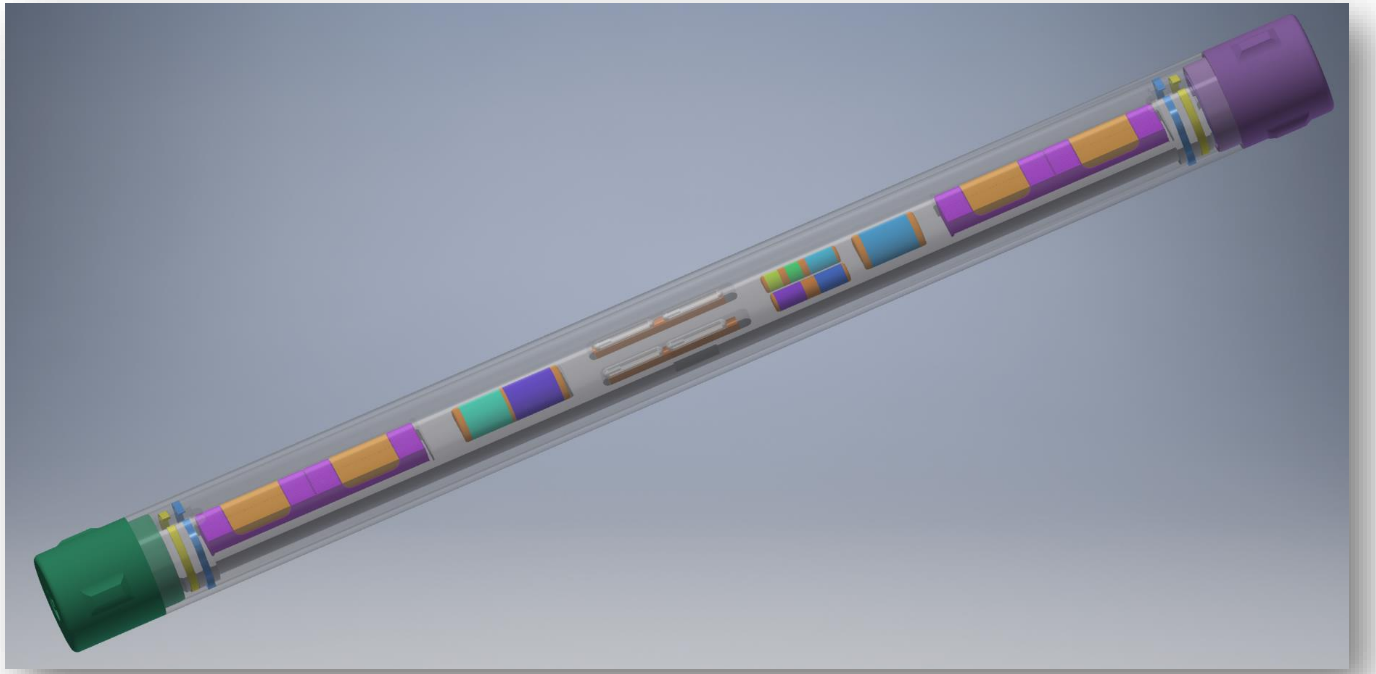
Passive Instrumentation

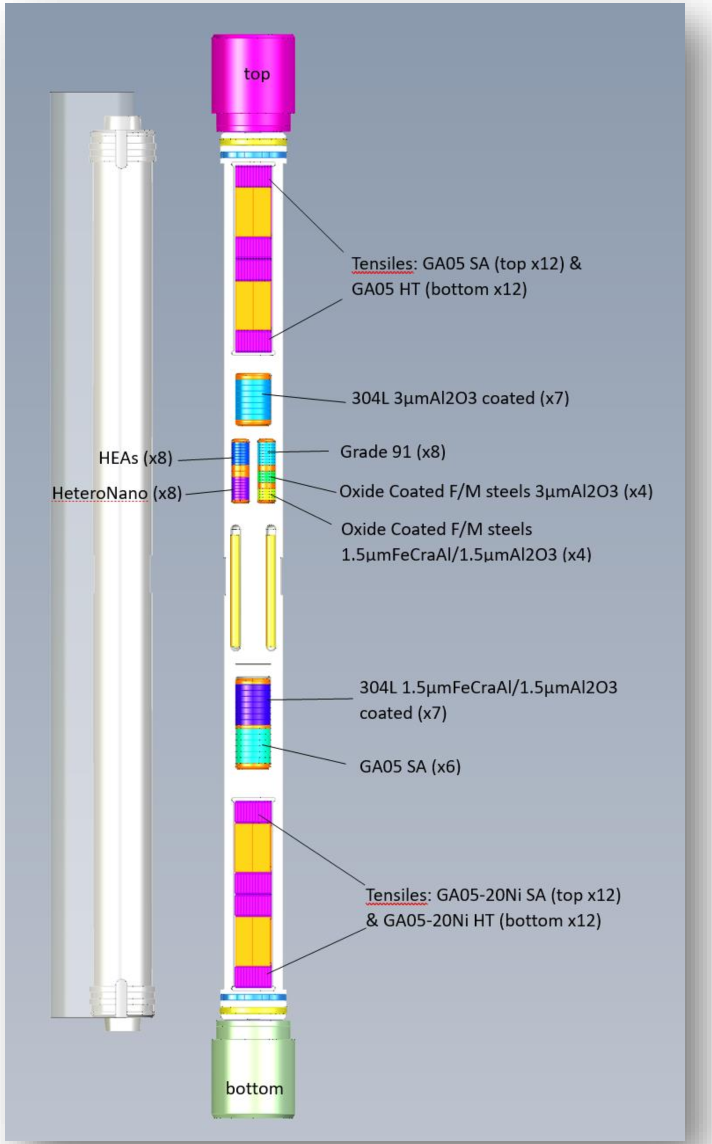
- 2 Fluence Wires (PNNL)
  - Ø.047-.054 x .315” Max
  - (1x) Al-Co
  - (1x) Fe, Ti, Nb
- 3 Melt wires (4 shown)
  - 822782-1 Assy
  - Ø.060 x .250”
  - 1 above Target Temp
  - 1 close to Target Temp
  - 1 below Target Temp
- 1 SiC monitor (Ø3x1mm)





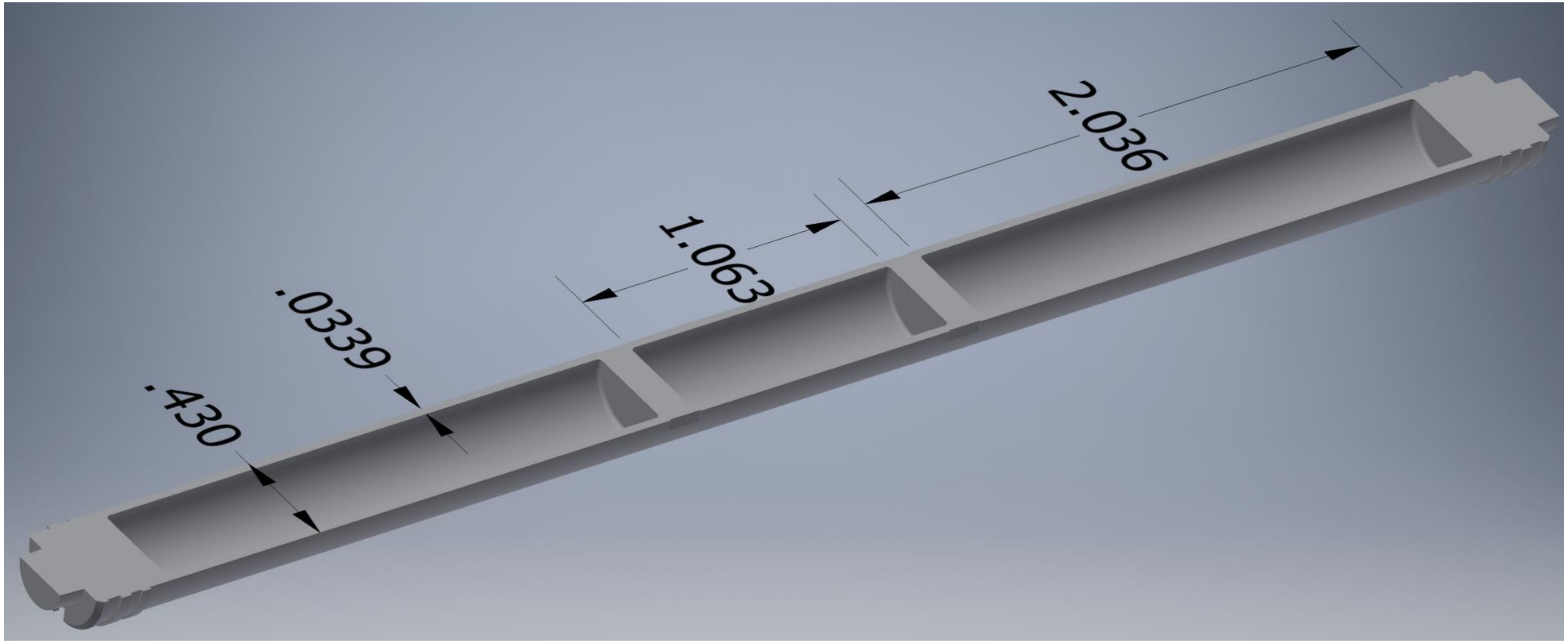
AFA/Miscellaneous Capsule



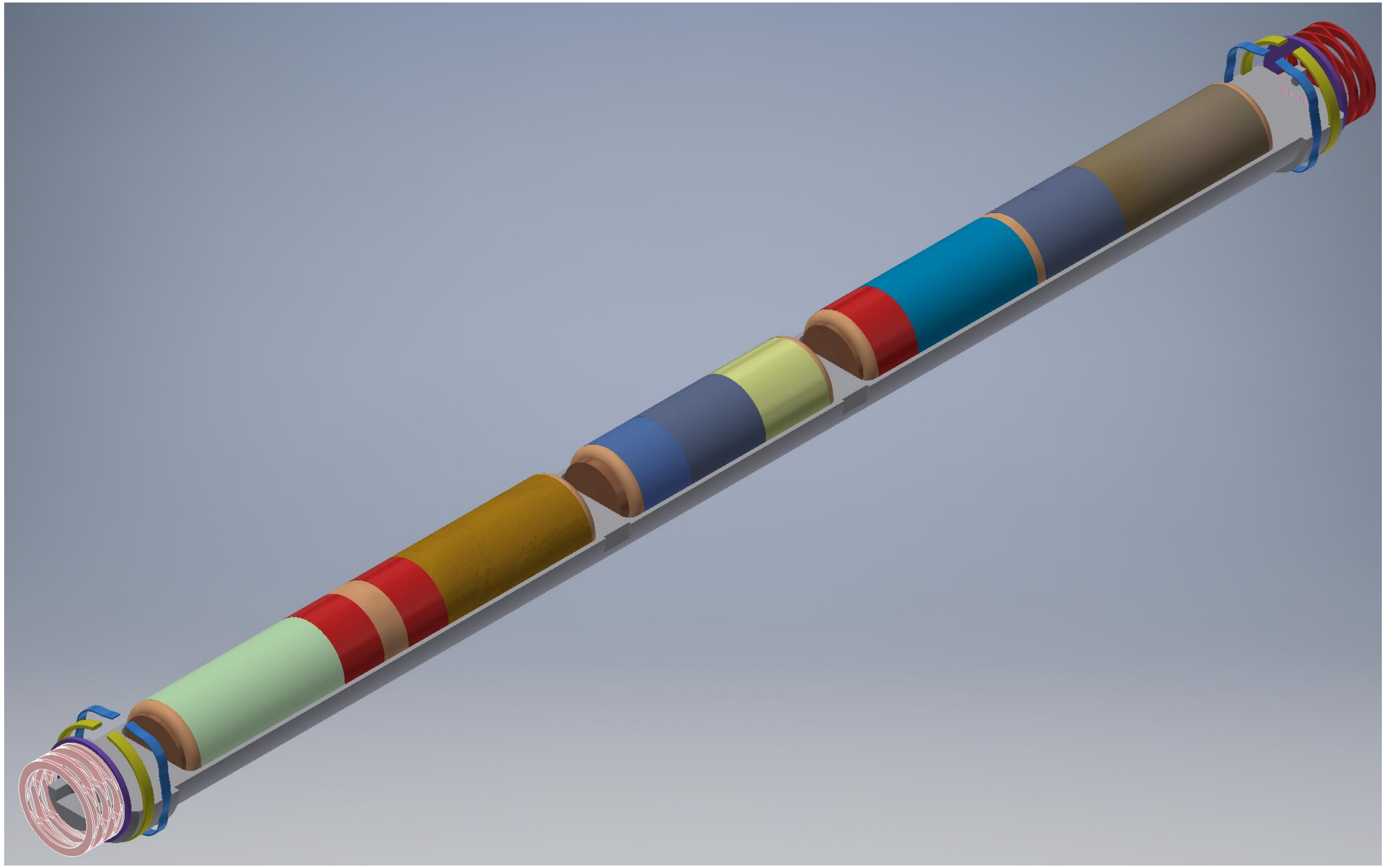


Graphite Fixture (Empty)

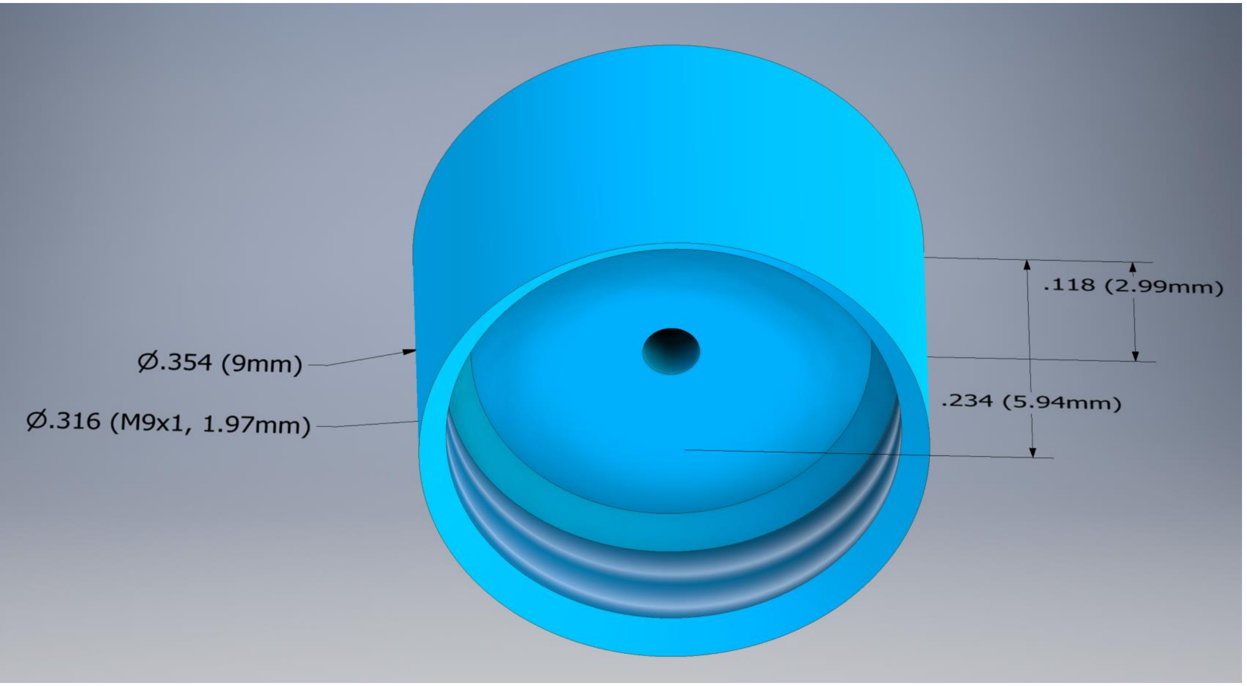
- Mersen Grade 2114 Nuclear Grade Graphite



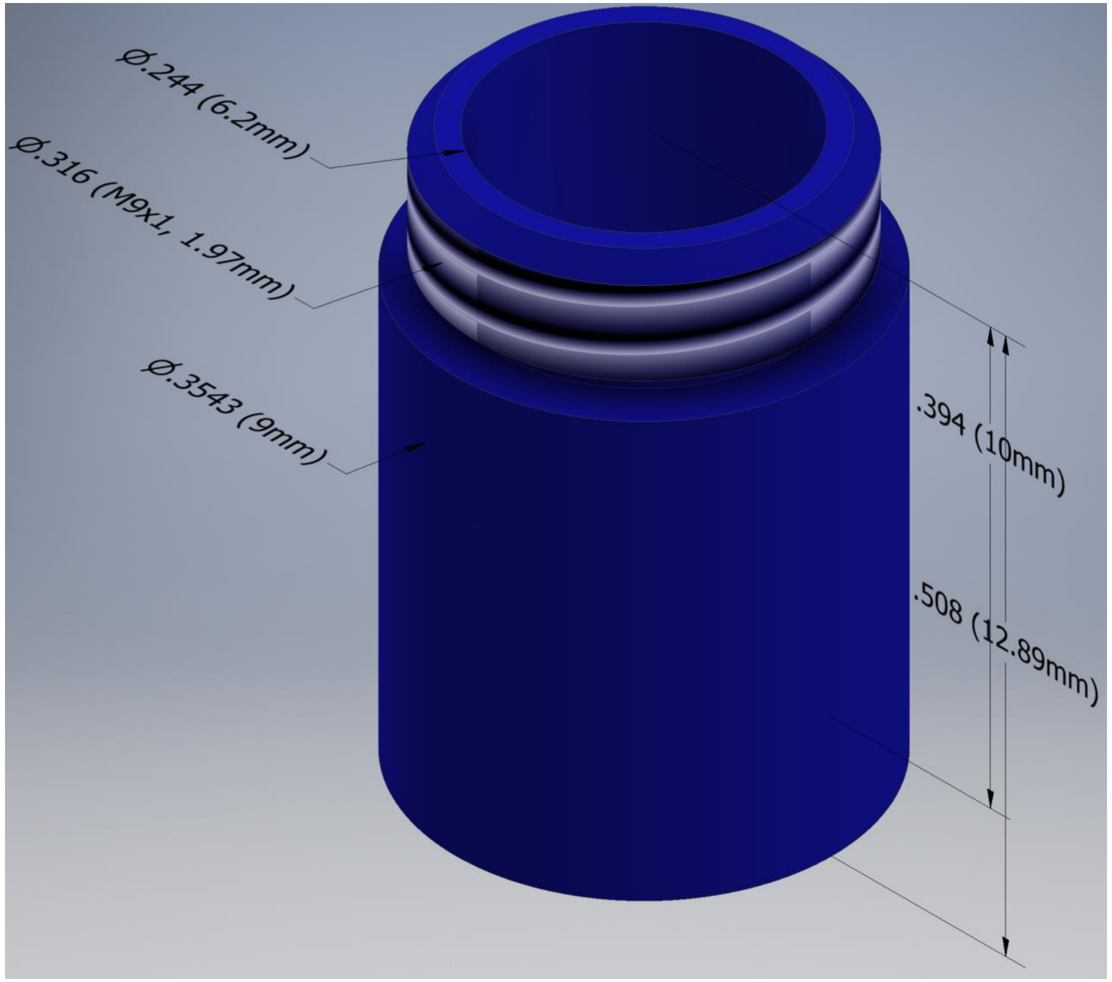
Graphite Fixture (Filled)



NIFT-E CAN



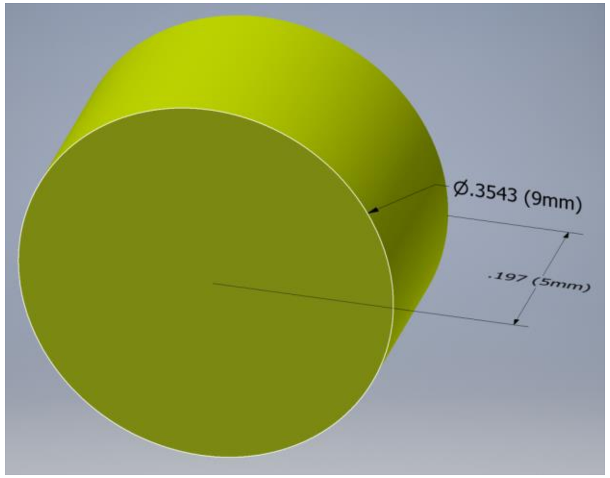
.118 (2.99mm)
Ø.354 (9mm)
Ø.316 (M9x1, 1.97mm)
.234 (5.94mm)

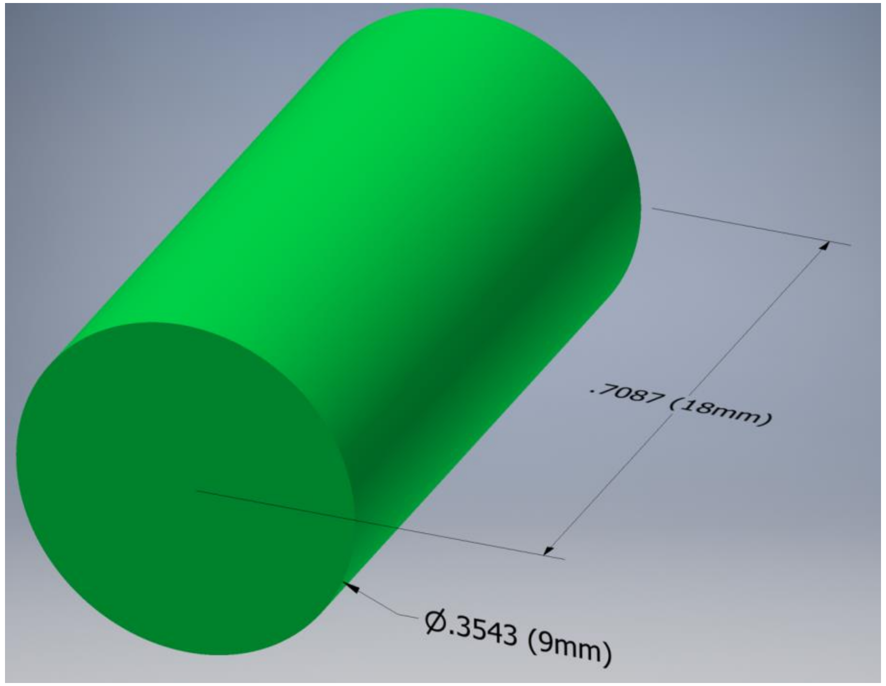


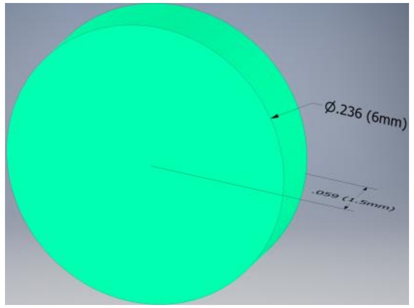
Ø.244 (6.2mm)
Ø.316 (M9x1, 1.97mm)
Ø.3543 (9mm)
.394 (10mm)
.508 (12.89mm)

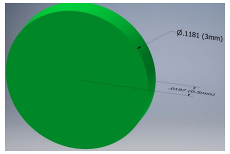
Graphite Specimen

- Quantities and Sizes (min.)
  - (8) Ø9x5mm
  - (3) Ø9x18mm
  - (2) Ø3mm disc
  - (6) Ø6mm disc



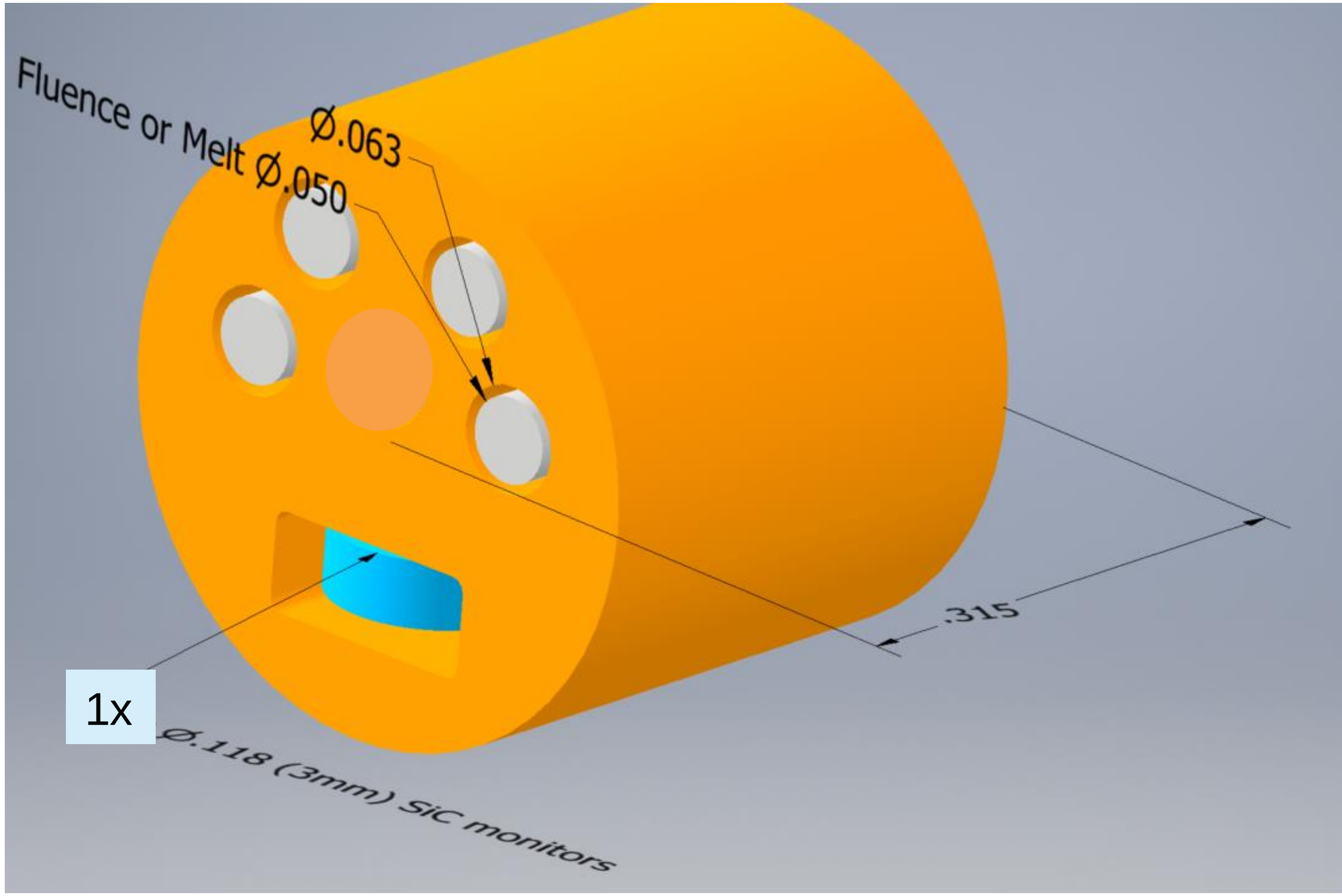




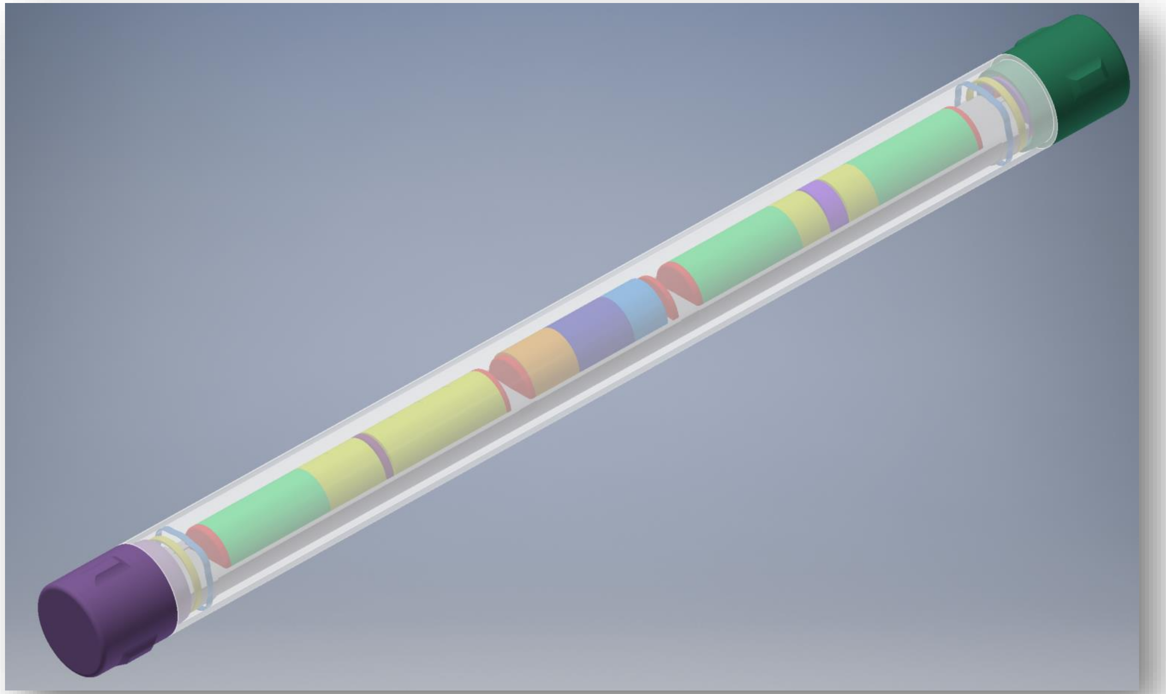


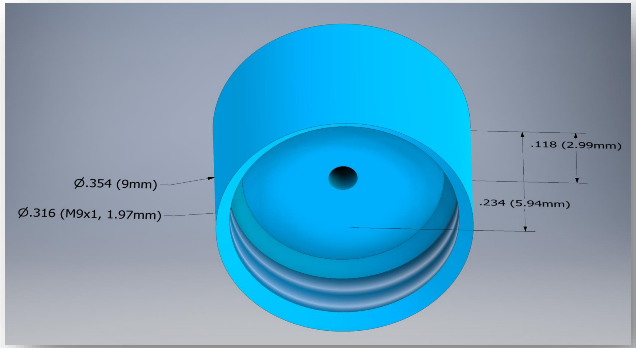
Passive Instrumentation Holder

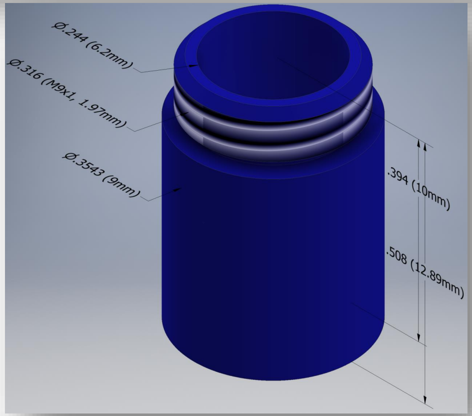
- 2 Fluence Monitors (PNNL)
  - Ø.047-Ø.054” x .314” Max
  - (1x) Al-Co
  - (1x) Fe, Ti, Nb
- 2 Melt Wires (INL)
  - Ø.060 x .314” Max
  - 681C
  - 850C
- 1 Ø3x1mm SiC monitor
- FOR Req. 2.2, 2.3

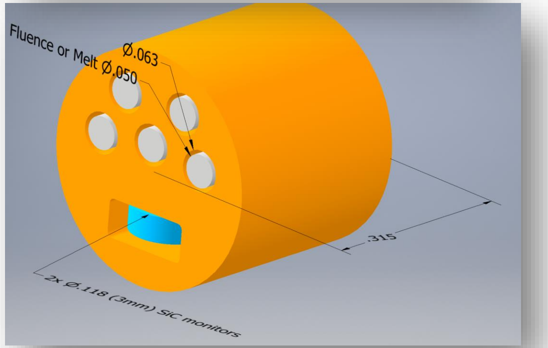


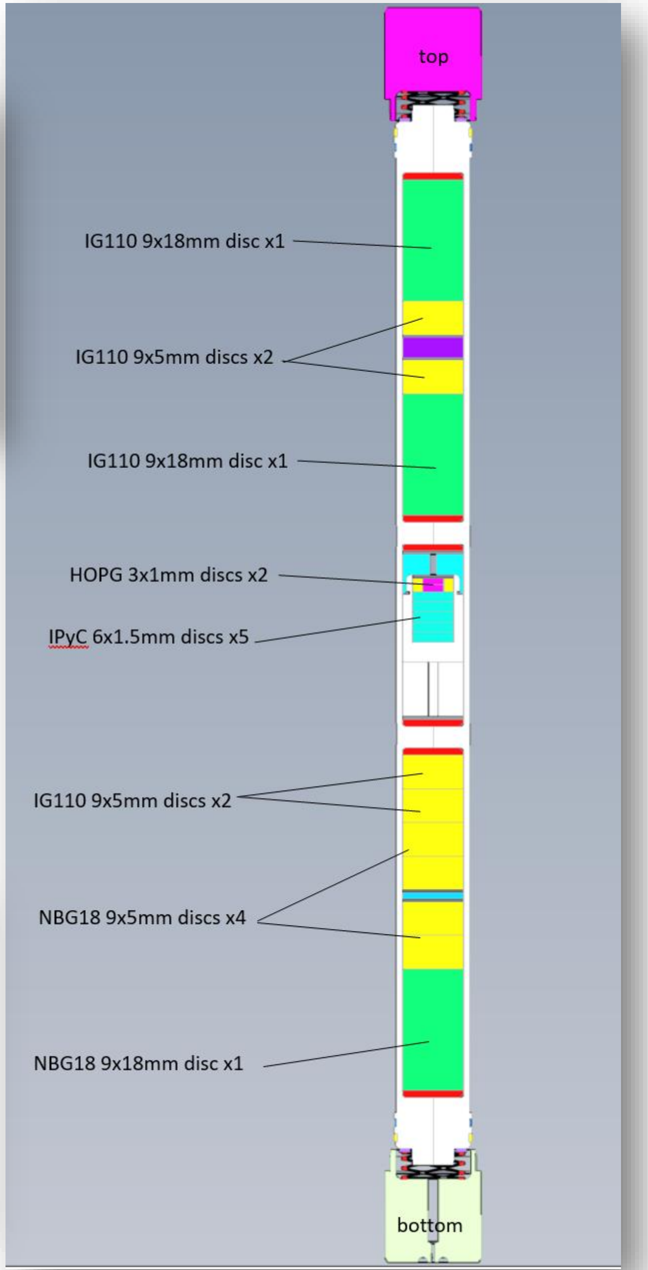
Graphite Capsule





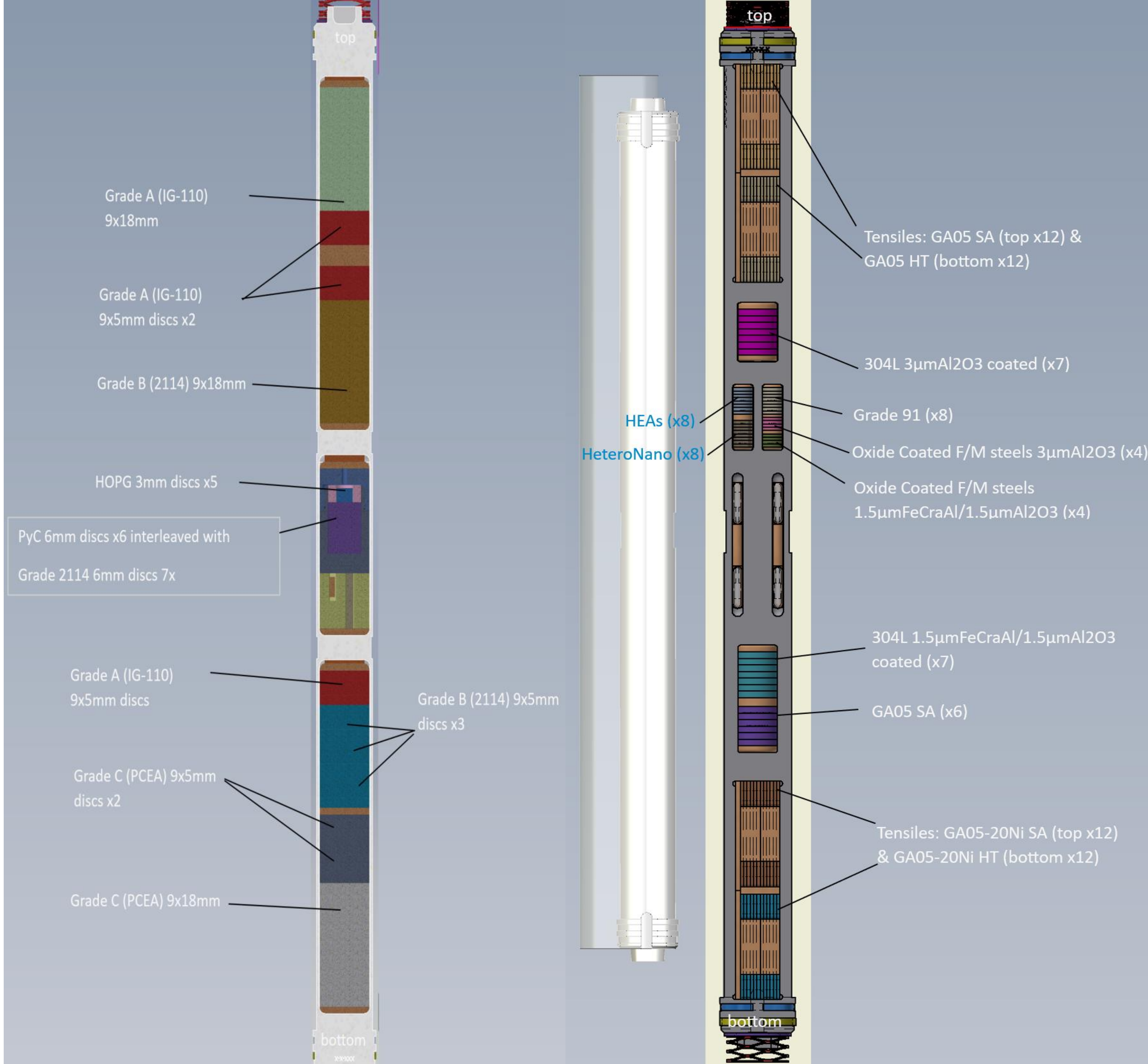






Assembly

- UKAEA Fabrication



WE ARE ATR

Project Timeline & Strategy

Activity	Finish Date
Final Design Complete	September 2023
Assembly Complete	June-July 2024
Commence Irradiation	September 2025

ATR Position B-7		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle 10	Cycle 11	Cycle 12	Cycle 13
CAPSULE POSITION	A	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE
	B	AFA1	AFA4	AFA4	AFA4	AFA4	AFA4	AFA4	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE
	C	C1	C1	C1	C2	C2	C2	C2	C2	C2	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE
	D	AFA5	AFA5	AFA5	AFA5	C3	C3	C3	C3	C3	C3	C3	C3	C3
	E	AFA2	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AFA3	AVAILABLE
	F	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE	AVAILABLE

NIFT-E Experiment Design Team

TEAM MEMBER	ROLE
Matthew Arrowood	Experiment Manager
Simon Pimblott	Program Technical Lead
Michael Fanning	Design Engineer
Angelica Mata Cruz	Neutronics Analyst
Matthew Mihelish	Thermal Analyst
Ryan Sandbek	Structural Analyst
Bryon Mowlds	Quality Engineer
Delaney Stine/Mark Hill	ATR Experiment Engineer
Ryan Marlow	ATR ESA Author
Chris Grovenor	NNUF Principal Investigator (P.I.)

NSUF

Nuclear Science User Facilities

INL

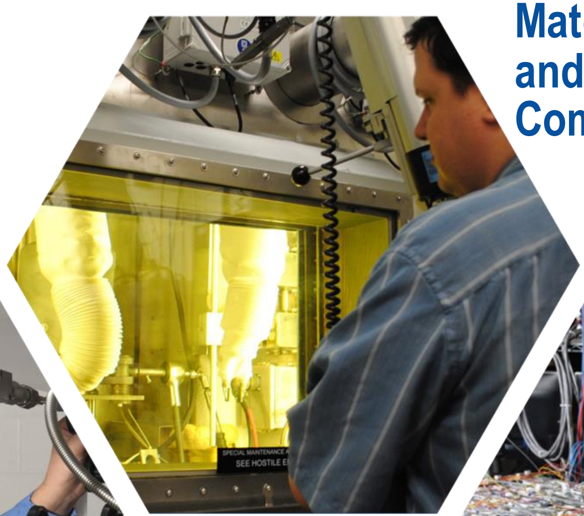
Addressing the world's most challenging problems

Advanced Test Reactor Complex

- Steady-state neutron irradiation of materials and fuels
  - Naval Nuclear Propulsion Program
  - Industry
  - National laboratories and universities

Nuclear Science & Technology

- Nuclear fuels and materials
- Reactor systems design and analysis
- Fuel cycle science and technology
- Nuclear safety and regulatory research
- Advanced Scientific Computing



Materials and Fuels Complex

- Transient testing
- Analytical laboratories
- Post-irradiation examination
- Advanced characterization
- Fuel fabrication
- Space nuclear power and isotope technologies

Energy and Environment Science & Technology

- Advanced transportation
- Environmental sustainability
- Clean energy
- Advanced manufacturing
- Biomass

National & Homeland Security Science & Technology

- Critical infrastructure protection and resiliency
- Nuclear nonproliferation
- Physical defense systems

INL

Idaho National Laboratory