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Vendor Irradiation Capsule A quick summary and update

July 2023

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Changing the World's Energy Future

Idaho National Laboratory

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Vendor Irradiation Capsule

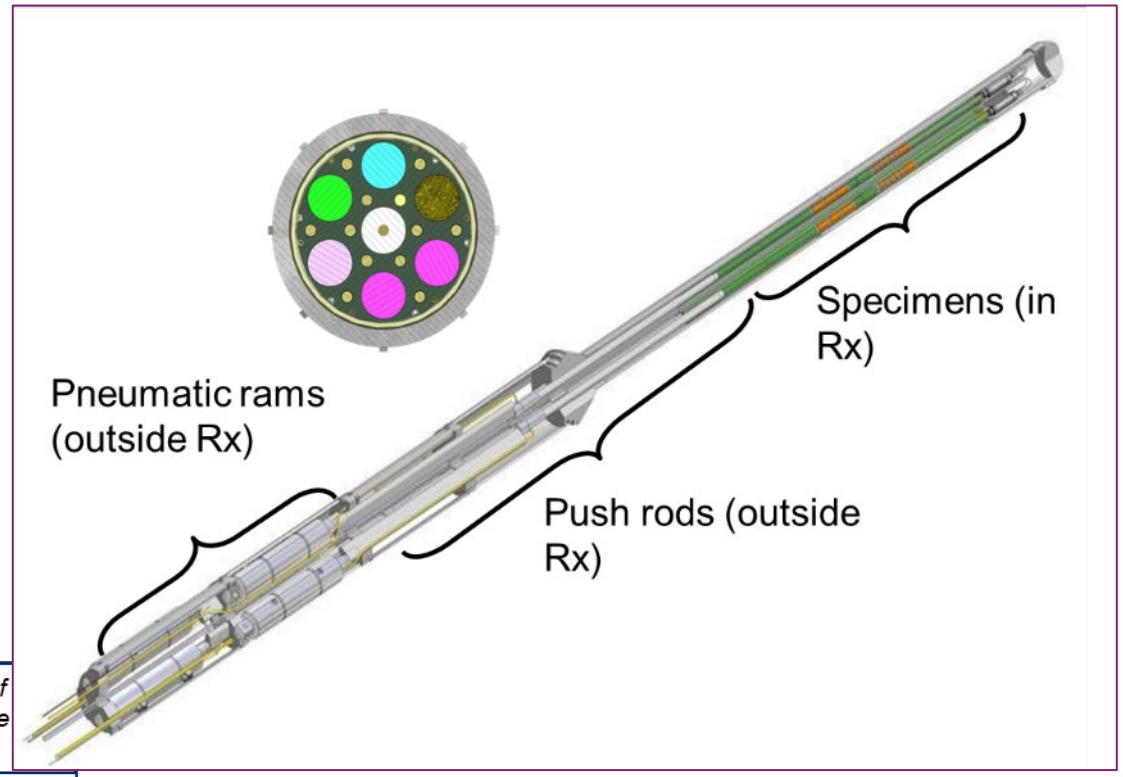
A quick summary and update

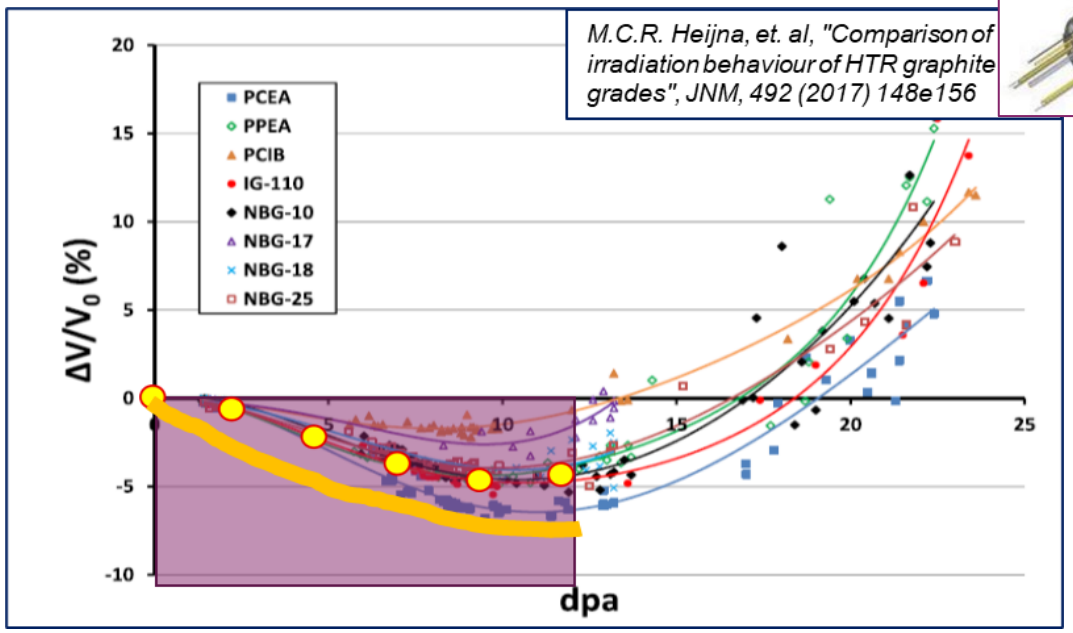
DOE ART Gas-Cooled Reactor (GCR) Review Meeting
Virtual Meeting
July 25 – 27, 2023

ART
Advanced Reactor Technologies

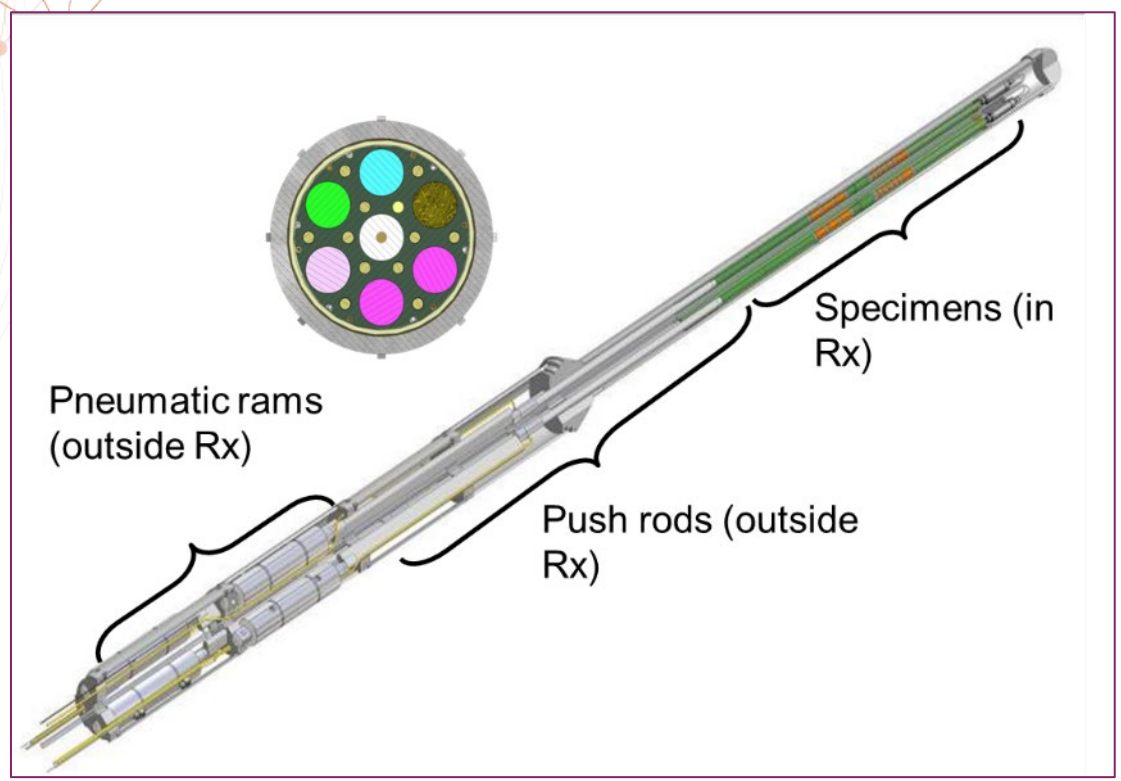
What are we talking about?

- What is the Vendor Irradiation Capsule (VIC)?
- Why is it needed?
- What are the options?
- How will data be used?
- What have we concluded?





What is the Vendor Irradiation Capsule (VIC) ?



- VIC – Vender Irradiation Capsule
  - **Graphite** irradiation capsule specific for commercial vendor irradiations
- Beyond the AGC irradiations
  - Higher or lower irradiation temperatures
  - Higher or lower irradiation dose levels
  - Different grades
    - ***Molten salt grades***
    - ***Other grades as desired***
- Funded and controlled by commercial vendors
  - DOE irradiation experts to assist
    - ***Initial design by DOE***
  - Final design by Vendors
  - Irradiation & PIE cost by Vendors
- Vendor collaboration is a must
  - Sharing cost and volume within capsule will save time, and therefore costs

Not another AGC Irradiation Experiment

Formal description of DOE activity

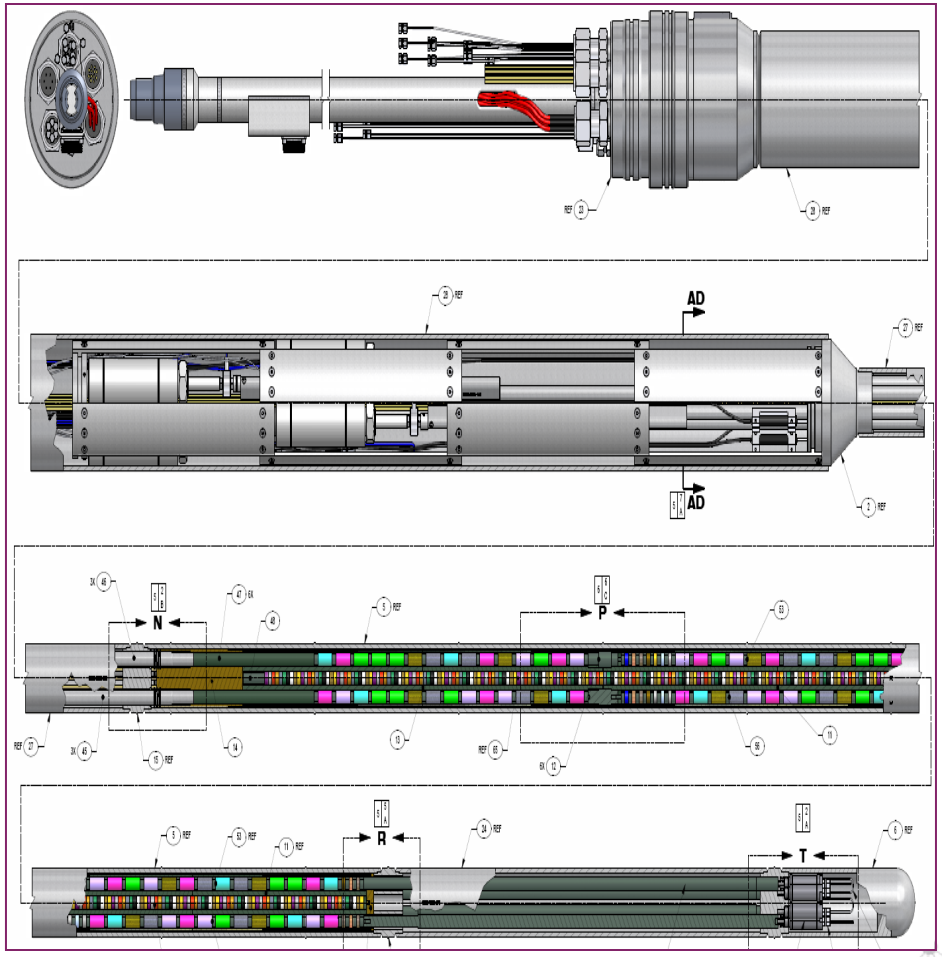
Commercial vendor specific irradiated capsule

Multiple commercial HTR vendors and nuclear graphite suppliers would benefit by ***collaborating together*** on a new irradiation capsule(s) that would include new graphite grades not included within the past AGC Experiment. This new irradiation capsule(s) would be used to answer their specific graphite licensing issues. Rather than spending money (and most especially) time in designing separate irradiation capsules for each designer ***the capsule(s) would be useful to multiple graphite and composite*** designs to maximize efficiency and promote multiple HTR designs. However, the ***primary motivation*** for assisting vendors with this new irradiation capsule(s) is ***lack of space with the existing MTRs***. Cost reduction is not the main issue; space within all available MTRs is. A common, collaborative, capsule design can be achieved for graphite and composites due to similarity of different grades. Irradiation, disassembly, shipping and PIE costs would be cost-shared by all users. Due to the similar requirements for all graphite grades it is anticipated that interest would extend across all DOE campaigns (micro-Rx, SMR, GCR, MSR, etc.). This initial DOE investment will cover at least 2 workshops and a memorandum summarizing the scope, graphite grades, irradiation temperature & dose, capsule design, and ***level of interest*** for all HTR graphite users based on their HTR design requirements.

Why we feel this VIC is needed

- Very limited space in Material Test Reactors
  - Realistically, only 3 MTRs in world capable
  - INL's **ATR** and ORNL's **HFIR** are two of them
- But commercial HTR industry needs irradiation data
  - As many HTR designs as possible
    - *Not just 1 or 2 lucky designs that get irr. data now*
  - As soon as possible
    - *Space within ATR, HFIR, and HFR is limited*
    - *Graphite specimens are necessarily large volume*
  - As efficiently as possible
    - *Use DOE experience to assist in design*
    - *Designers share capsule & irradiation costs*
    - *Multiple grades made available*
- Leverage AGC data to qualify other grades
  - ASME code rule changes based upon AGC data
  - Then AGC data can be leveraged to assist the sparse commercial irradiation data

AGC Capsule



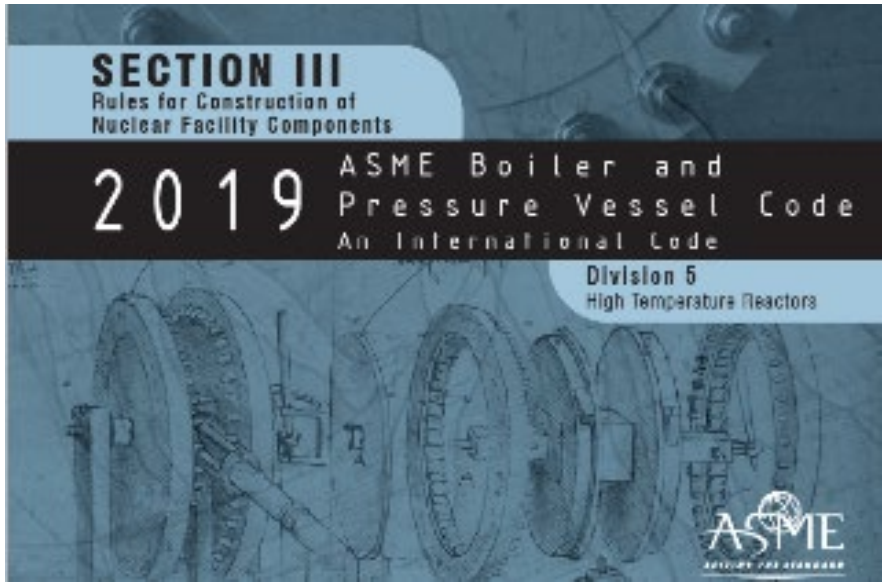
$125M - $150M for AGC Experiment

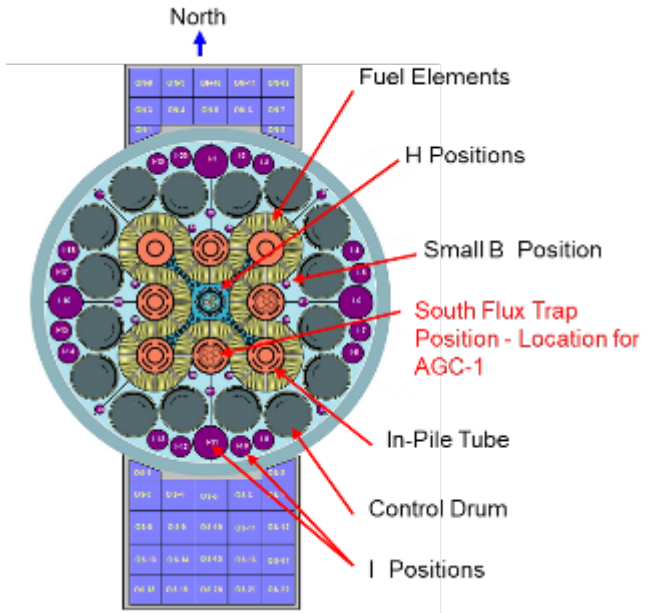
What are the options?

- What MTR's are available?
  - **Realistic** vs. theoretical irradiation possibilities
- What will DOE provide
  - It's not going to be another AGC experiment
  - Then what role does DOE play?
- Irradiated sample handling and PIE
  - How do they get the data?
  - Who gets to see it?
- How can we use the data?
  - Only limited number of samples
  - How can a handful of data points help?

Strategy for using this capsule(s)

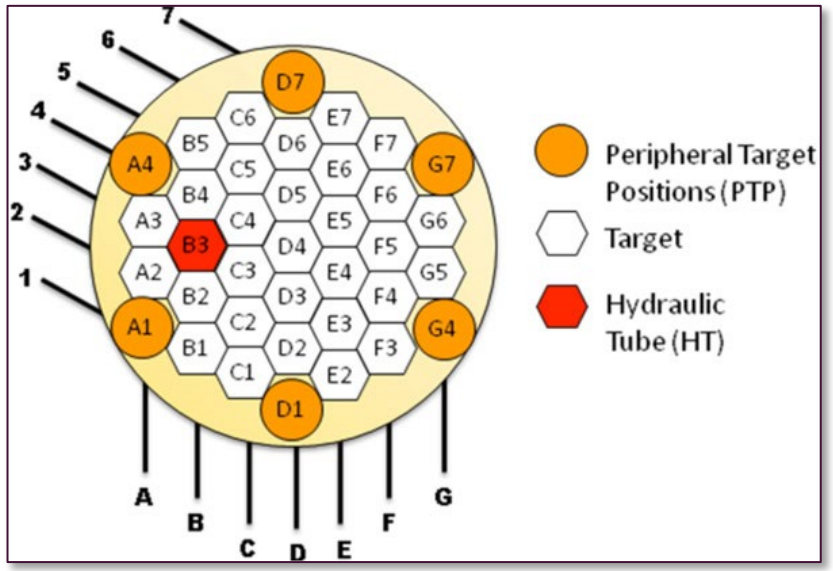
- **Use in combination with new ASME Code rules**
  - This new capsule is designed to leverage the new ASME code rules
  - ***Steve Johns (INL) and Wilna Geringer (ORNL) activity***
- **Use DOE experience**
  - DOE will provide initial capsule design for use by as many commercial vendors as possible
    - *Designers pay for completion of capsule design, assembly, disassembly, and specimen PIE*
  - DOE will assist in determining MTR availability and irradiation positions (ATR and HFIR)
    - *If USA Rx not available then we'll approach HFR (Petten)*
  - Vendors should use DOE material irradiation experience
  - ***INL – ATR and ORNL – HFIR are available***
- **DOE to assist in material testing and PIE**
  - Assist vendor in material property testing (Irr and unirr)
    - *Either at national lab or not*
  - ***INL – Carbon Lab and ORNL – LAMDA are available***





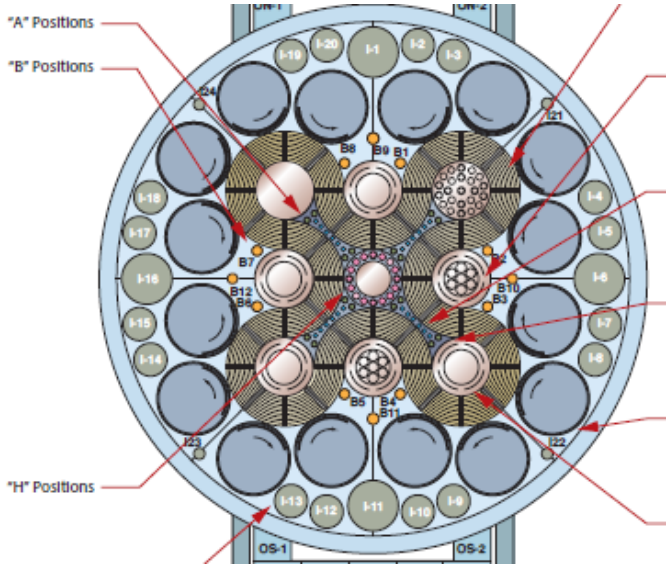
Available MTRs and realistic irradiation positions

HFIR



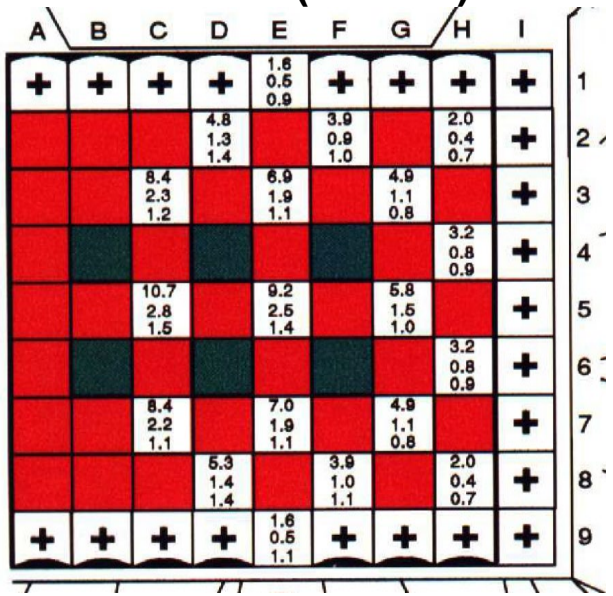
- *1-2 target positions = 1.8cm (5/8")*
  - *Instrumented?*
  - *Likely Passive*
- *Flux ~ 2 x 10^{15} n/cm^2· s*
  - ***~ 1.2 – 2 dpa per cycle***
- *Total yearly irradiation:*
  - *~ 24 day cycle*
  - *~ 5-6 Cycles per year*
  - *~ 120 – 144 EFPD*

ATR



- *"A" positions = 0.5" & 0.625"*
- *Small "B" positions = 0.875" (**Instrumented**)*
- *Flux ranges:*
  - *Small "A" ~ 2.3x10^{14} n/cm^2· s*
  - *Large "A" ~ 1.7x10^{14} n/cm^2· s*
  - *Small "B" ~ 8.1x10^{13} n/cm^2· s*
  - ***AGC (EFT) ~ 1x10^{14} n/cm^2· s (about 1 dpa / cycle)***
- *Total yearly irradiation:*
  - *~ 60 day cycles*
  - *~ 4-5 cycles per year*
  - *~ 240 – 300 EFPD*

HFR (Petten)



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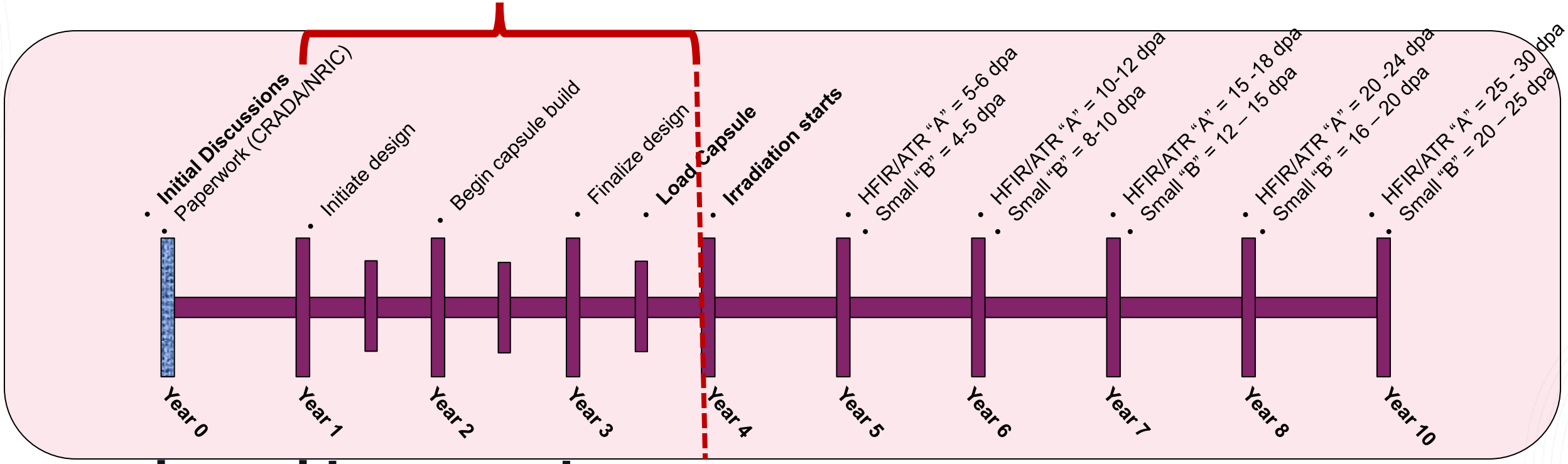
Realistic Irradiation Timelines

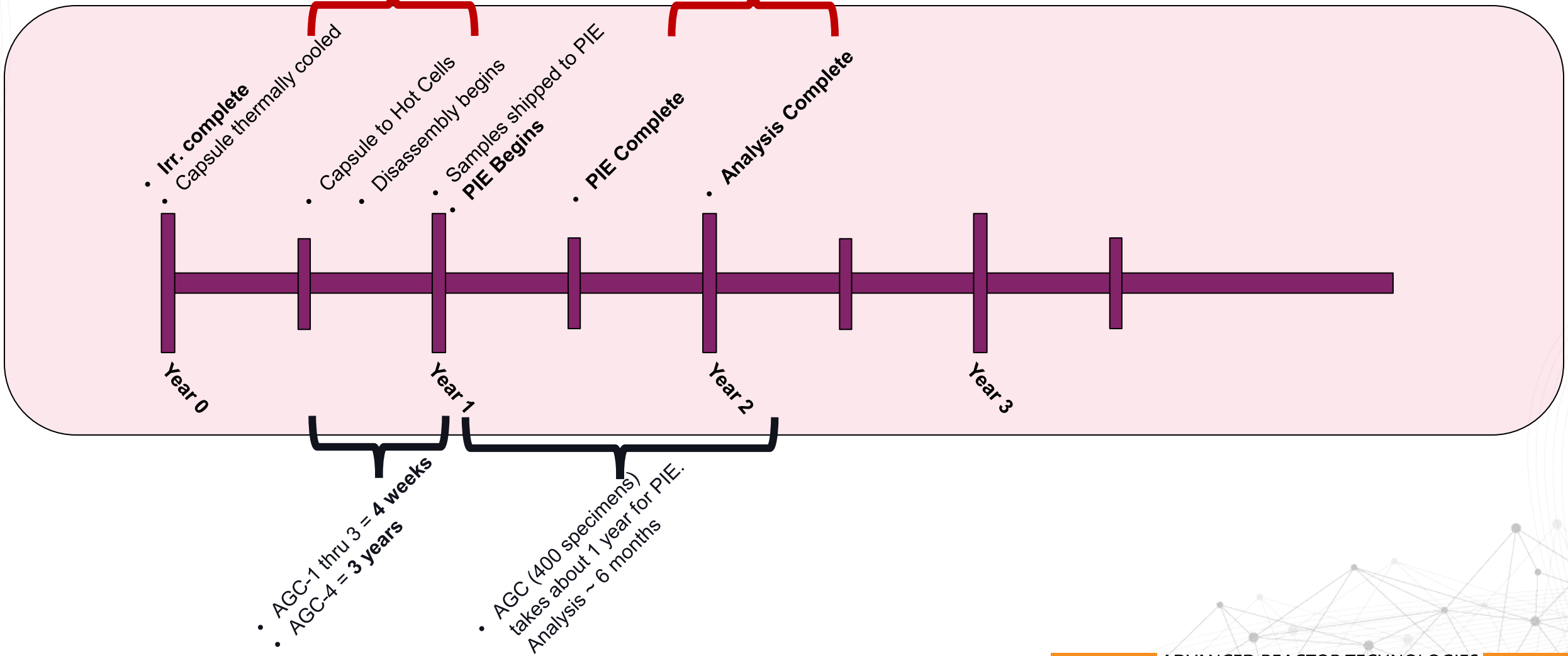
- **Installation of instrumented umbilical will take at least 3 years – parallel to capsule design**



- Paperwork can be reduced by a few months
- Development time reduced depending upon capsule design

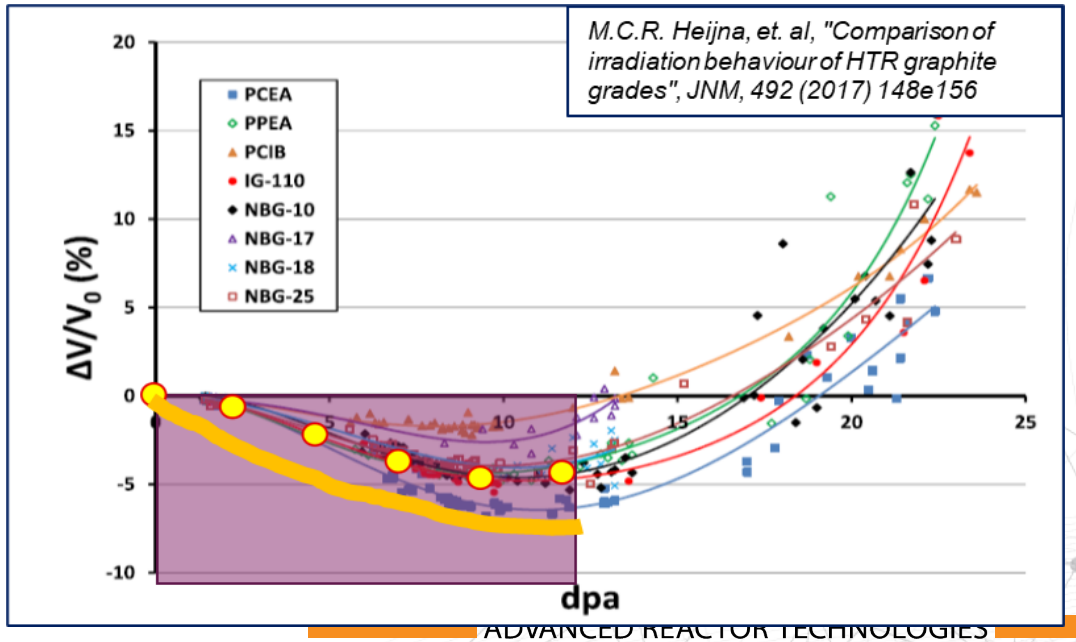
Realistic Disassembly and PIE Timelines

- **Capsule transport and disassembly usually impacted by other experiments – hot cells schedules vary by lab.**
- **PIE and analysis depends upon number of samples and tests**



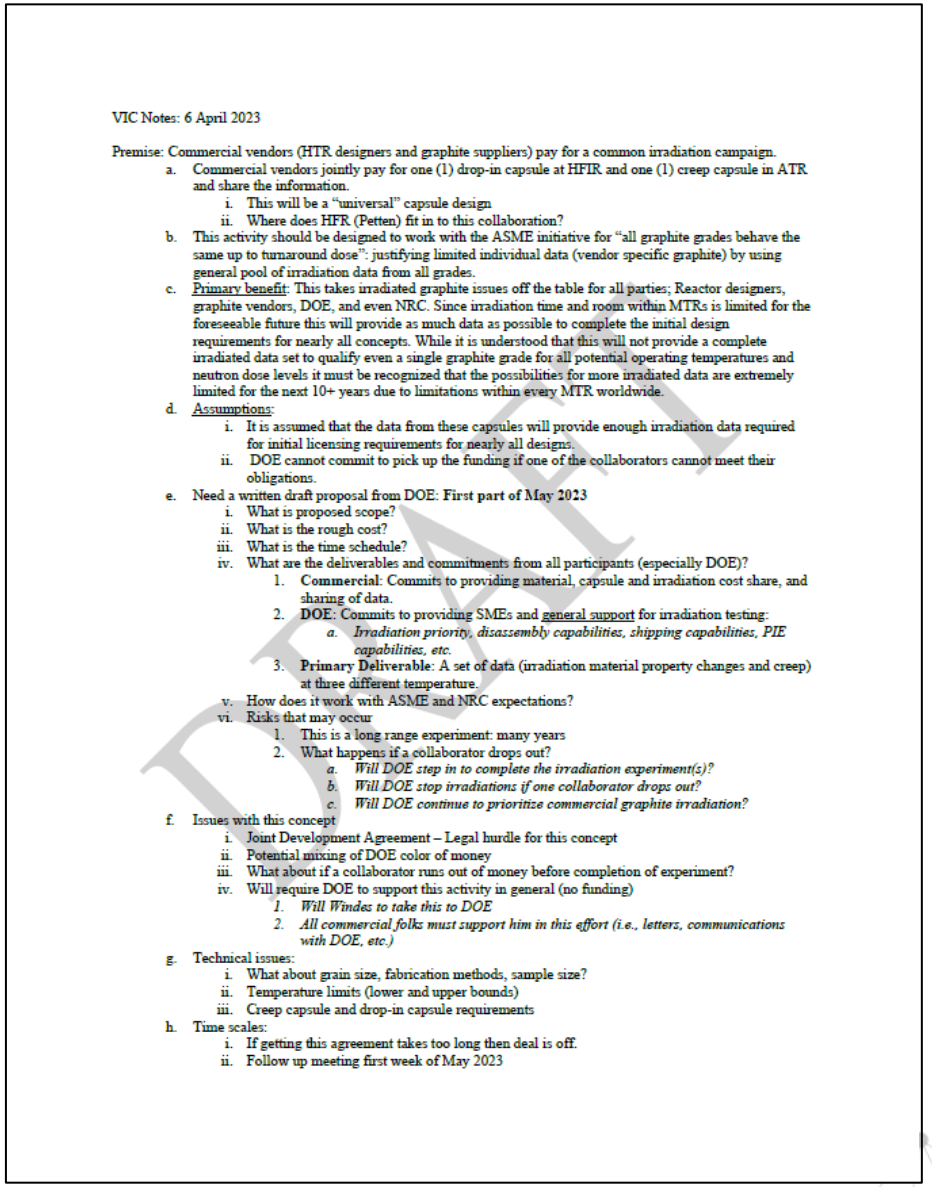
We have a few data points. Now what?

- We will use the new ASME Code rules being developed
  - As discussed in the ASME section
  - All graphite behaves similarly
- This is a viable option so long as the NRC agrees with this methodology
  - Can we get the science and data necessary to make this conclusion?
    - ***Can we do it in time?***
  - Can we draft up ASME code rules that can take advantage of this concept
  - What happens if NRC doesn't agree to this assumption?
    - ***Will NRC endorse this data and conclusions***



Where are we in the process?

- General agreement to pursuing a VIC
  - Both reactor vendors and graphite suppliers think this is a valid activity
  - Engineers are willing to agree to collaborate
- Vendor Concerns:
  - Will DOE commit to these irradiations in MTRs?
  - What happens if a collaborator drops out?
    - ***Collaborators will have to cover for them***
    - ***Told DOE is not going to step in and "save them"***
  - Will NRC endorse this data?
- DOE/Laboratory concerns:
  - Will competitors agree to collaborate?
  - Will collaborators agree to finish the experiment if partners drop out?
  - How much are collaborators willing to spend?
- Draft letter to DOE to clearly outline the objectives
  - DOE commitment vs. collaborators funding



VIC Notes: 6 April 2023

Premise: Commercial vendors (HTR designers and graphite suppliers) pay for a common irradiation campaign.

a. Commercial vendors jointly pay for one (1) drop-in capsule at HFIR and one (1) creep capsule in ATR and share the information.
   i. This will be a "universal" capsule design
   ii. Where does HFR (Petten) fit in to this collaboration?
b. This activity should be designed to work with the ASME initiative for "all graphite grades behave the same up to turnaround dose": justifying limited individual data (vendor specific graphite) by using general pool of irradiation data from all grades.
c. Primary benefit: This takes irradiated graphite issues off the table for all parties; Reactor designers, graphite vendors, DOE, and even NRC. Since irradiation time and room within MTRs is limited for the foreseeable future this will provide as much data as possible to complete the initial design requirements for nearly all concepts. While it is understood that this will not provide a complete irradiated data set to qualify even a single graphite grade for all potential operating temperatures and neutron dose levels it must be recognized that the possibilities for more irradiated data are extremely limited for the next 10+ years due to limitations within every MTR worldwide.
d. Assumptions:
   i. It is assumed that the data from these capsules will provide enough irradiation data required for initial licensing requirements for nearly all designs.
   ii. DOE cannot commit to pick up the funding if one of the collaborators cannot meet their obligations.
e. Need a written draft proposal from DOE: **First part of May 2023**
   i. What is proposed scope?
   ii. What is the rough cost?
   iii. What is the time schedule?
   iv. What are the deliverables and commitments from all participants (especially DOE)?
      1. **Commercial**: Commits to providing material, capsule and irradiation cost share, and sharing of data.
      2. **DOE**: Commits to providing SMEs and general support for irradiation testing:
         a. *Irradiation priority, disassembly capabilities, shipping capabilities, PIE capabilities, etc.*
      3. **Primary Deliverable**: A set of data (irradiation material property changes and creep) at three different temperature.
   v. How does it work with ASME and NRC expectations?
   vi. Risks that may occur
      1. This is a long range experiment: many years
      2. What happens if a collaborator drops out?
         a. *Will DOE step in to complete the irradiation experiment(s)?*
         b. *Will DOE stop irradiations if one collaborator drops out?*
         c. *Will DOE continue to prioritize commercial graphite irradiation?*
f. Issues with this concept
   i. Joint Development Agreement – Legal hurdle for this concept
   ii. Potential mixing of DOE color of money
   iii. What about if a collaborator runs out of money before completion of experiment?
   iv. Will require DOE to support this activity in general (no funding)
      1. *Will Windes to take this to DOE*
      2. *All commercial folks must support him in this effort (i.e., letters, communications with DOE, etc.)*
g. Technical issues:
   i. What about grain size, fabrication methods, sample size?
   ii. Temperature limits (lower and upper bounds)
   iii. Creep capsule and drop-in capsule requirements
h. Time scales:
   i. If getting this agreement takes too long then deal is off.
   ii. Follow up meeting first week of May 2023

DRAFT

Conclusions

- There is not enough irradiation behavior data for complete graphite license applications
  - Micro-Rx may be an exception
- There is limited room in MTRs world-wide
  - Graphite is not the only material and certainly not the priority material
- Realistic irradiation schedules:
  - 2-3 years design
  - 2-10 years irradiation (depending upon dose needed)
  - Creep experiments are expensive and difficult
- Will the NRC accept this limited data?
  - Will they endorse the “all graphite behaves the same” premise?
- Will the vendors play nice together?