HELION

Leveraging Particle Accelerator and Radioactive Material Safety Paradigms for Regulating Fusion Devices

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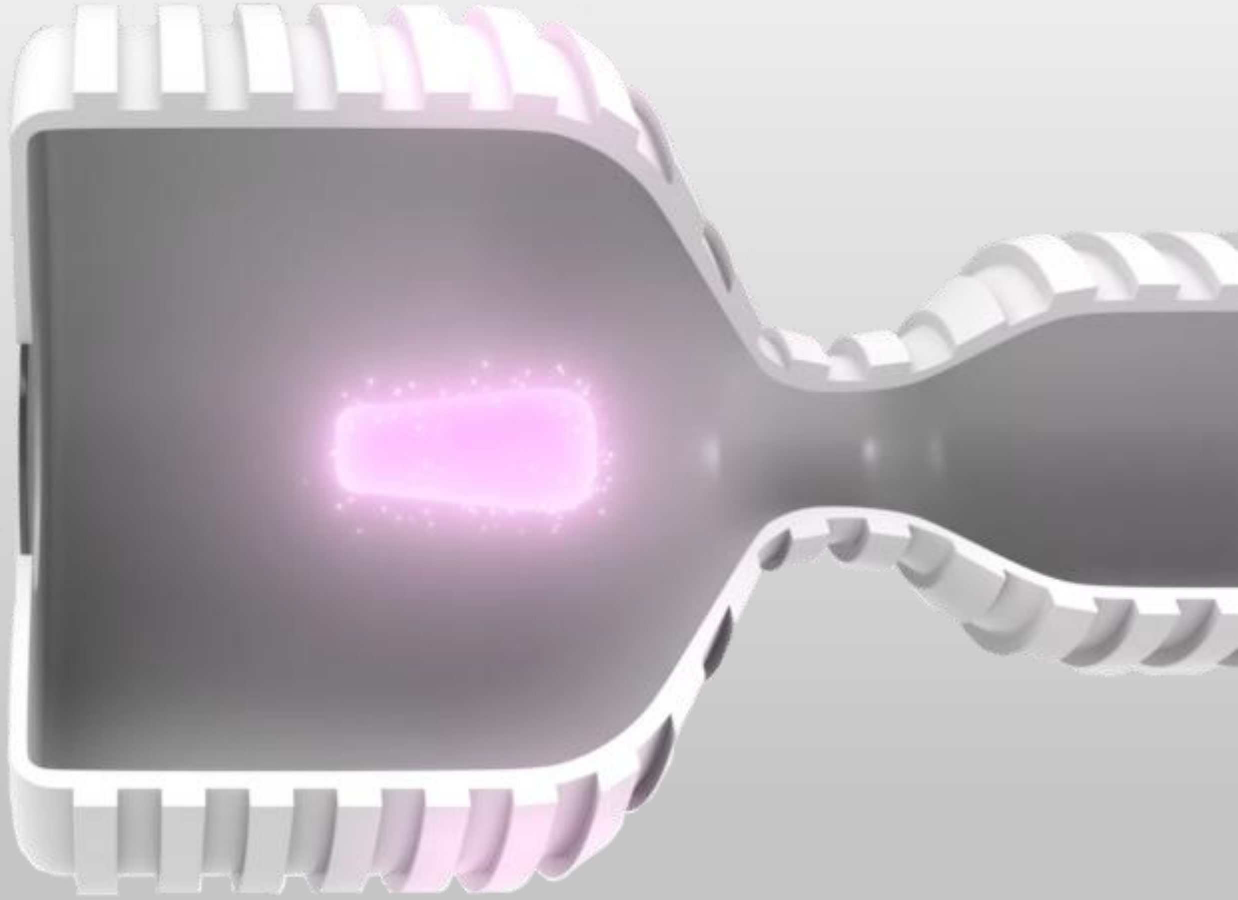
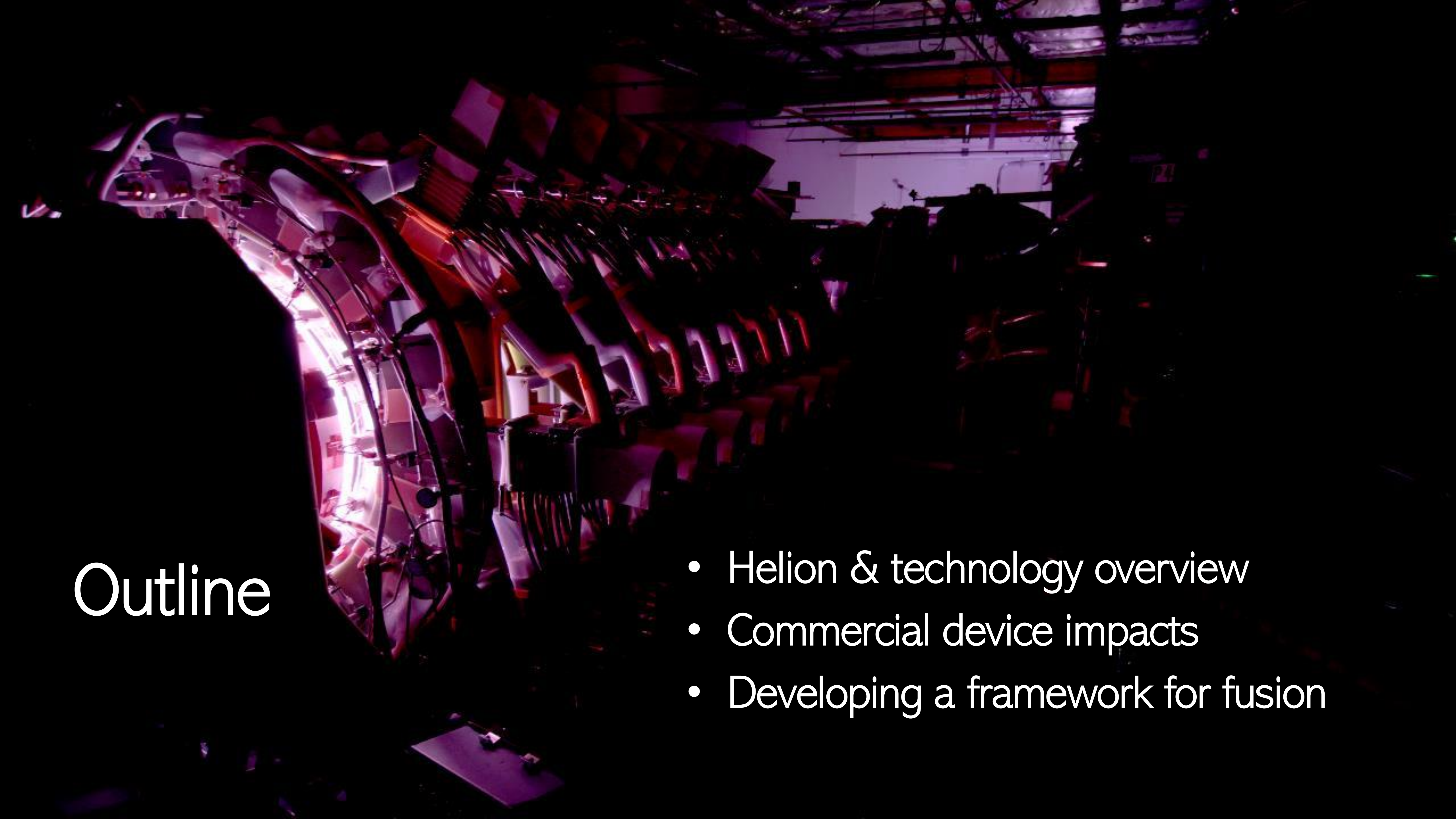
Helion Energy

Technical Meeting on Synergies in Technology Development between Nuclear Fission and Fusion for Energy Production

06 – 10 June 2022

Vienna, Austria (hybrid)





Outline

- Helion & technology overview
- Commercial device impacts
- Developing a framework for fusion

Helion & Technology Overview

Introducing Helion

- Based in Everett, Washington (founded 2013)
- 85 people | Expected to reach 150+ in 2022
- Devices licensed by the Washington DOH
- Fully funded to reach commercialization ($570M)

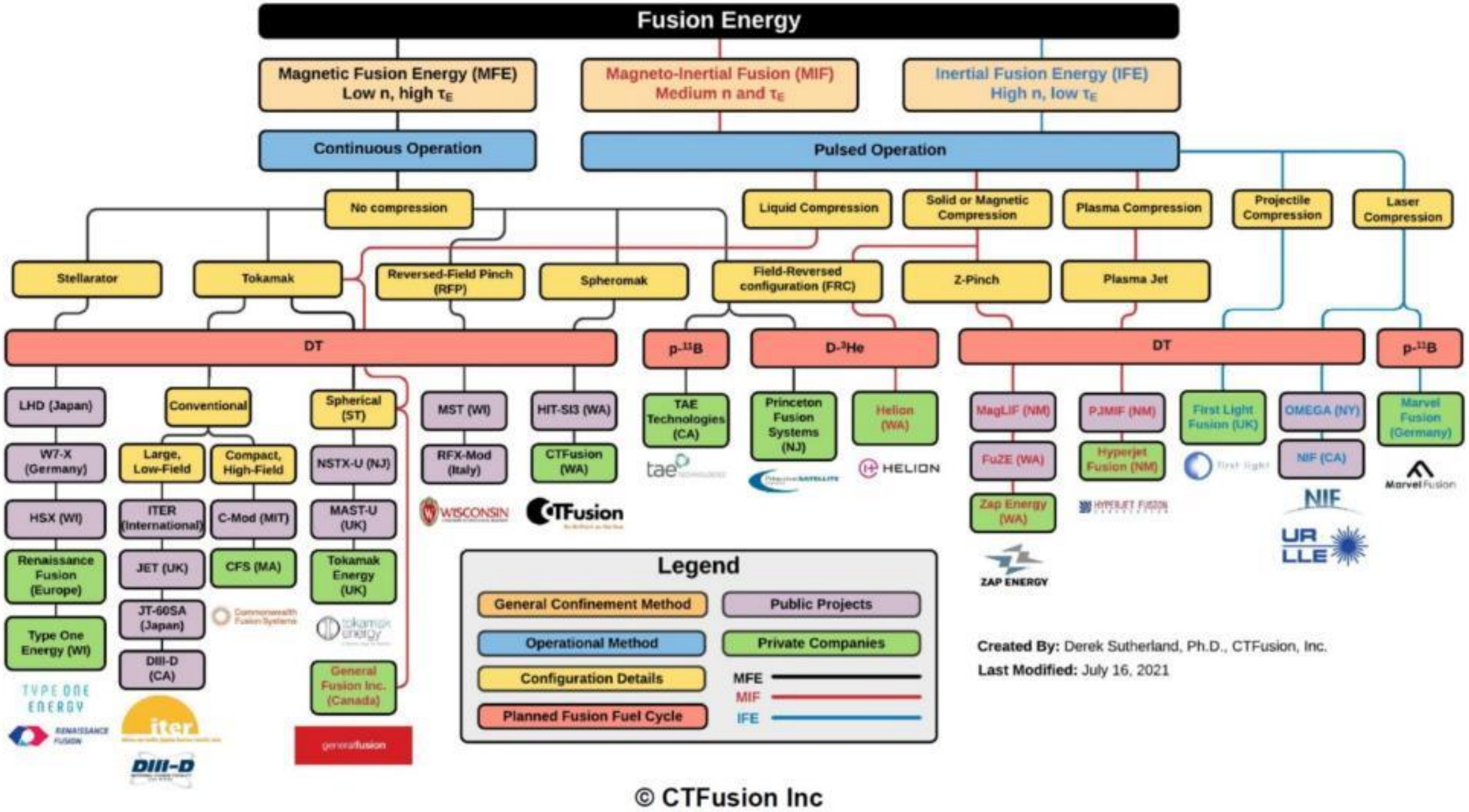
- *Doing fusion today*

Current, 6th prototype: Trenta

I have been waiting for yesterday for 52 years... They have the premier fusion device in the world.

Independent auditor Pace Van Devender
Former CTO Sandia National Laboratories

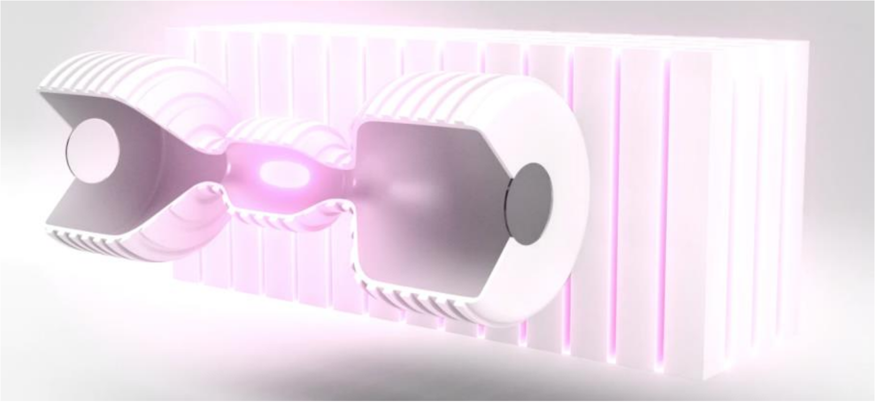
There is a diversity of fusion concepts



How Helion works

Magneto-Inertial Fusion

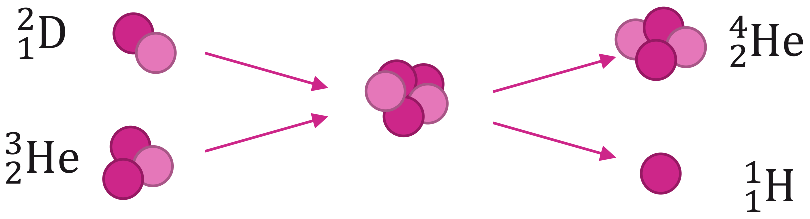
- Two toroidal plasmas (FRCs) are accelerated from opposite ends of the accelerator
- They collide supersonically and are adiabatically compressed by a magnetic field to fusion conditions
- Process is 100 microseconds, enables 1-10 Hz pulses



Non-Ignition Fusion

- Uses D-^{3}He fuel (~95% fusion energy released as charged particles, only ~5% in neutrons)
- Energy is recaptured through magnetic fields and recycled in capacitor bank—enabling deployment at Q<2

$$^{2}_{1}\mathrm{D} + ^{3}_{2}\mathrm{He} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{1}\mathrm{H} + 18.3\ \mathrm{MeV}$$



Polaris

- Helion's 7th gen facility
- Regulated by WA DOH (R&D device)
- *Net Electricity Demonstration: 2024*

Vision: Operational commercial fusion

- 50 MW
- 70 feet x 10 feet
- Entirely factory-built

Impacts of a Commercial Fusion Device

Context for impacts and regulatory discussions

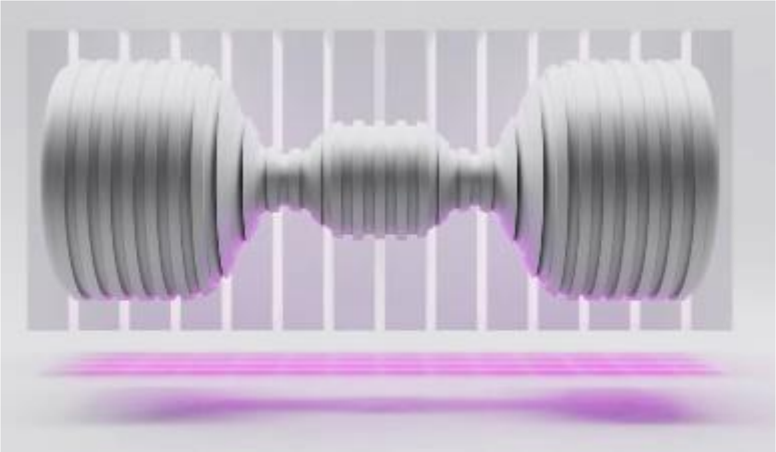
- **US focus** – Principal regulatory body is the Nuclear Regulatory Commission (NRC)
  - Part 30: radioactive materials and accelerators
  - Part 50: utilization facilities (reactors)
  - Part 70: special nuclear material (special fissionable material)

- **Helion focus** – We can only speak to our device, but analysis can be transferable

Fusion during operation

Key Concept: Fusion's operational impacts are fundamentally similar to those a of a particle accelerator

Fusion Device



- Neutron and photon radiation
- In-process fuel/accelerated particles and exhaust
- Activated shielding

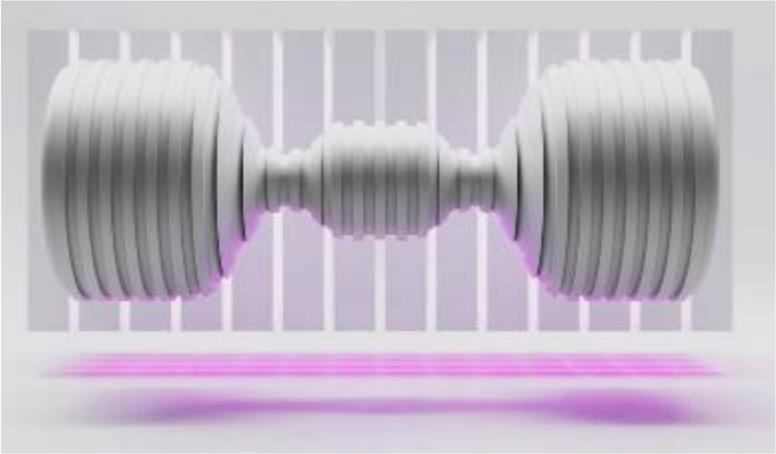
Accelerator (e.g., cyclotron)

- Neutron and photon radiation
- In-process fuel/accelerated particles and exhaust
- Activated shielding

Fusion during accidents

Key Concept: Fusion impacts are fundamentally akin to those of industrial facilities

Fusion Device

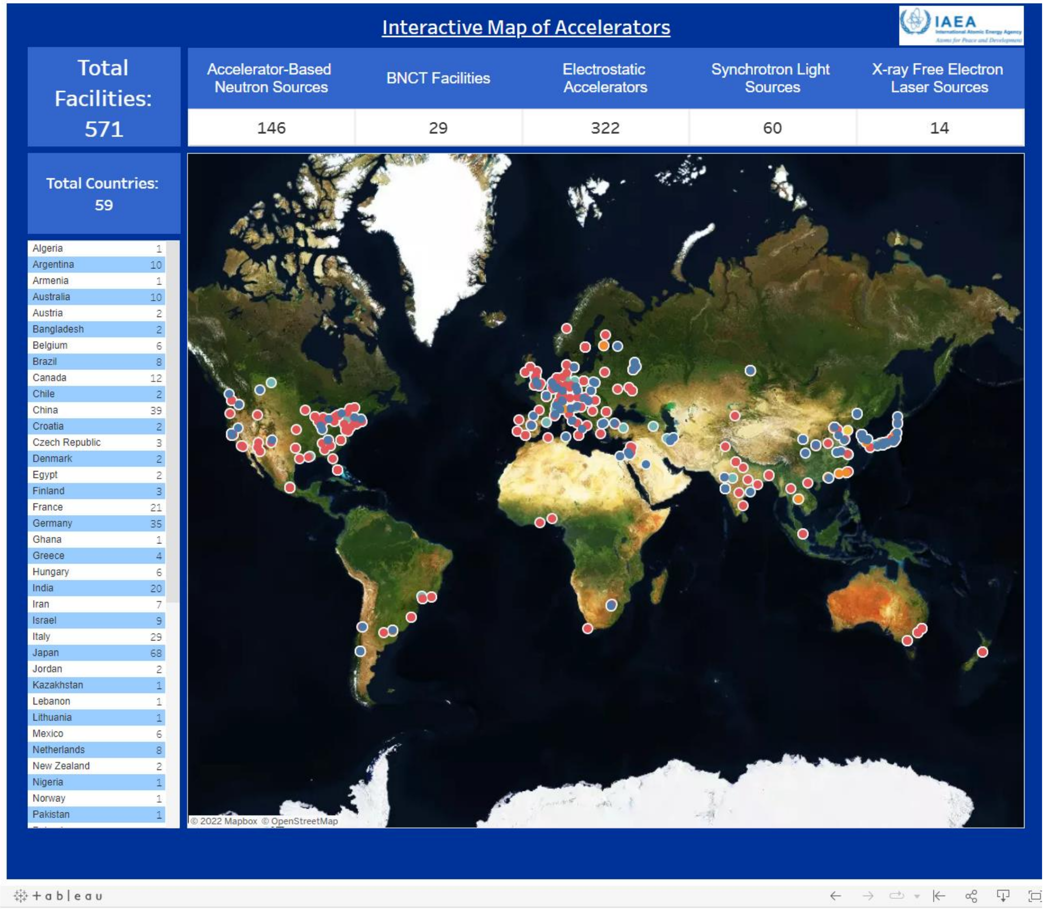


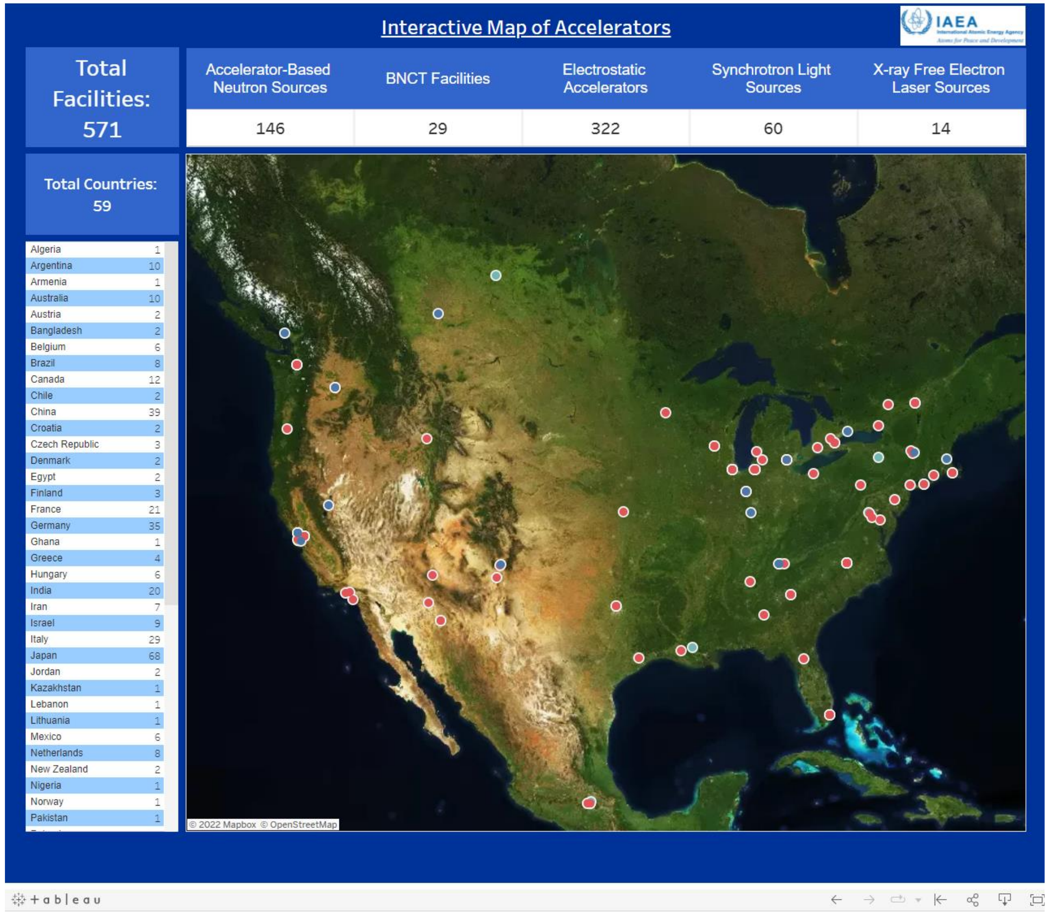
- Reactions (fusion) immediately ceases
- Device has very limited releasable inventory
- No need for active cooling (may have pools)
- Tritium handling is complex *materials* issue

Industrial Facility

- Reactions (decay) continue – may need to close shielding
- Devices have small-to-large releasable inventory
- Usually, no need for complex active cooling (pools instead)
- Diversity of issues to evaluate

There is broad experience regulating particle accelerators

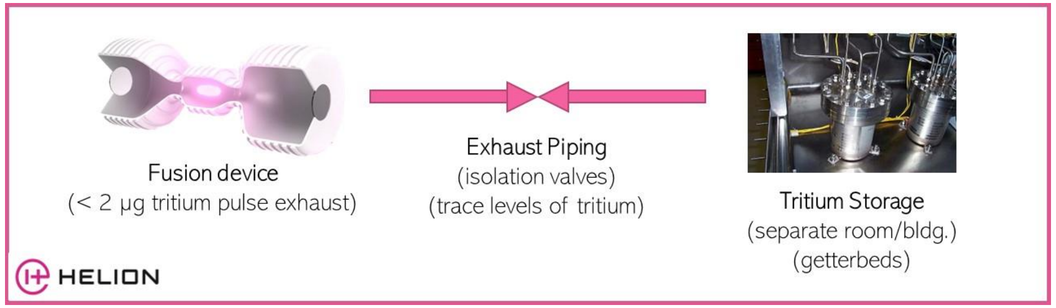




IAEA Website: https://nucleus.iaea.org/sites/accelerators/Pages/default.aspx

Inherent risk mitigating aspects of fusion

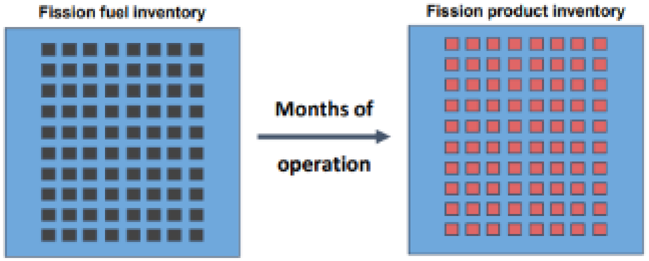
Byproduct and device are separable



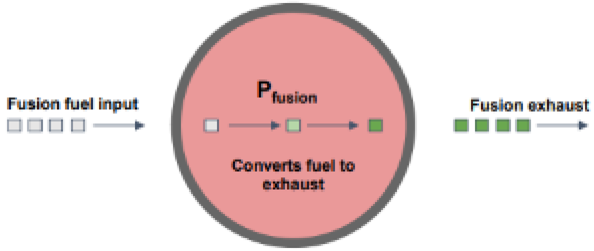
- Tritium can be separated from the Helion device and addressed as separate materials handling issue
- Fission synergy: Part 50 focuses on the device, whereas Part 70 focuses on material (e.g., spent fuel pad)

Inventory is limited and fixed

Fission
- Fuel present
- Must actively stop



Fusion
- Fuel moved in/out
- Must actively start and maintain



Images from FIA presentation at March 2022 NRC Public Meeting

Fusion's accident impacts (Helion Example)

- Simplified Analysis (extreme hypothetical):
  - All tritium gas released and converted to HTO
  - Entire vacuum vessel wall turned to dust
- Tritium Release Evaluation:
  - 2 ug → < 1 urem (max value at 470m)
  - A safety factor of 1000x for wall build-up/conservatism still results in very small dose for an accident scenario: 1 mrem
- Dust Release Evaluation:
  - Primary dust concern: ^{31}Si created w/ 2.45 MeV neutrons
  - Dust equilibrium: 190 Ci in hours
  - Vacuum chamber wall → 11.3 mrem (max value at 460m)
  - Physically realistic impacts would be much less

Analytical Tools

- **Release Mapping – HotSpot v.3.1.2**
- **Dust Activation Rate Analysis – MCNP6.2**

Note: Industry-Wide Analysis

- Fusion Industry Association (FIA) estimates maximum offsite dose consequence for all member devices in extreme hypothetical scenarios would be < 1 rem
- FIA: post-shutdown cooling not required
- Supports generic finding that fusion's accident impacts are fundamentally more limited compared to fission systems, and akin to industrial facilities

Summary

From a technical perspective, fusion device impacts are far more akin to a particle accelerator or industrial facility than a fission reactor.

Operational Impacts

- Impacts profile identical to particle accelerator
- Addressed through common shielding practices
- No need for active cooling on shutdown

Accident Impacts

- The device is the unique consideration; stored tritium is a standard radioactive materials management issue
- Tritium & dust release concerns are consistent with industrial facilities

Developing a Regulatory Framework

Tools needed to regulate fusion

Design

- *Access*
- *Shielding*
- *Fire*
- *Monitoring*
- *Device Control*
- *Vault Integrity*

Oper'nl

- *Operators*
- *Emergencies*
- *Personnel Survey*
- *Leak Detection*
- *Maintenance*
- *Entry & Exit*

Other

- *General*
- *EP*
- *Matl. Security*
- *Novel Issues*

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Part 36 (irradiators)

Part 30 (general)
Part 35 (medical)
Part 37 (security)

Other

- *General*
- *EP*
- *Matl. Security*
- *Novel Issues*

Example: § 36.25 Shielding

The following mark-ups are meant to be illustrative, not complete and comprehensive

a. The radiation dose rate in areas that are normally occupied during operation of a ~~panoramic irradiator~~ fusion device may not exceed 0.02 millisievert (2 millirems) per hour at any location 30 centimeters or more from the wall of the room when the sources are exposed. The dose rate must be averaged over an area not to exceed 100 square centimeters having no linear dimension greater than 20 cm. Areas where the radiation dose rate exceeds 0.02 millisievert (2 millirems) per hour must be locked, roped off, or posted.

b. The radiation dose at 30 centimeters over the edge of the pool of a ~~pool irradiator~~ fusion device may not exceed 0.02 millisievert (2 millirems) per hour when the ~~sources are in the fully shielded position~~ device is on.

c. The radiation dose rate at 1 meter from the shield of a ~~dry-source-storage panoramic irradiator~~ fusion device when the ~~source is shielded~~ device is off may not exceed 0.02 millisievert (2 millirems) per hour and at 5 centimeters from the shield may not exceed 0.2 millisievert (20 millirems) per hour.

Power Failures / Shutdown

Fission Reactors

- Require post-shutdown cooling
- Must actively shutdown (insert control rods)
- NUREG 0800 (guidance document):
  - Reactivity control
  - Reactor coolant makeup
  - React pressure control
  - Decay heat removal
  - Suppression Pool Cooling (BWR)
  - Electric power systems
  - Component cooling water
  - Service water
  - Instrument air systems

Fusion Devices: can just turn off (inherent)

§ 36.37 Power failures (shutdown)

a. If electrical power at a ~~panoramic irradiator~~ fusion device is lost for longer than 10 seconds, the ~~sources~~ device must automatically ~~return to the shielded position~~ shutdown.

b. The lock on the door of the radiation room of a ~~panoramic irradiator~~ fusion device may not be deactivated by a power failure.

c. During a power failure, the area of any ~~irradiator~~ fusion device where sources are located may be entered only when using an operable and calibrated radiation survey meter.

Example: § 36.41 Construction monitoring and acceptance testing

The following mark-ups are meant to be illustrative, not complete and comprehensive

a. *Shielding*. For ~~panoramic irradiators~~ fusion devices, the licensee shall monitor the construction of the shielding to verify that its construction meets design specifications and generally accepted building code requirements for reinforced concrete.

b. *Foundations*. For ~~panoramic irradiators~~ fusion devices, the licensee shall monitor the construction of the foundations to verify that their construction meets design specifications.

c. . . . .

The Part 30 framework can scale to the diversity of fusion

- Horizontal scaling can address different design themes and subsystems

- In Part 35, for example:
  - Subpart F – Manual Brachytherapy
  - Subpart G – Sealed Sources for Diagnosis
  - Subpart H – Photon Emitting Remote Afterloader Units, Teletherapy Units, and Gamma Stereotactic Radiosurgery Units
  - Subpart K – other uses (35.1000)

- Vertical scaling can address different sizes of device (pertaining to radiological impact)

- Examples:
  - Part 37 scales with onsite inventory with thresholds
  - Part 30: emergency plan required if offsite dose consequence is above 1 rem/5 rem to thyroid
  - Part 30: exempt quantities

Conclusions

- There is a diversity of fusion energy concepts ranging from private industry (small) devices to ITER
- Commercial fusion devices have similar risk profiles to accelerators and industrial facilities, not fission reactors
- A materials-based regulatory framework accommodates the risk profile of commercial fusion energy

Questions?