September 16, 2022

Joy Rempe
Chairman
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission

SUBJECT: Comments in Advance of ACRS Meetings on Fusion

Dr. Rempe,

Helion Energy, Inc. ("Helion") recognizes and appreciates the dedicated work undertaken by the Advisory Committee on Reactor Safeguards ("ACRS") to advise the U.S. Nuclear Regulatory Commission ("NRC") on important matters of public health and safety.

We understand that the ACRS is holding meetings in September and October on the regulation of commercial fusion energy devices. We offer the below limited comments in advance of these meetings to aid the ACRS's evaluation. These comments (I) further describe of the diversity of the commercial fusion energy industry; and (II) summarize certain previously submitted analyses by Helion on fusion's safety case, including as compared to particle accelerators and other industrial uses of radioactive materials. They are intended to build on and align with the NRC staff's analysis of commercial fusion in its draft white paper "Licensing and Regulating Fusion Energy Systems."[1]

We hope to serve as a resource to ACRS as it evaluates this exciting field and would be happy to support a direct briefing or answer questions as helpful.

I. The Diversity of Approaches in Commercial Fusion

A. Commercial Fusion is a Diverse Industry, Distinct from ITER-Style Approaches

There are currently over two dozen private-sector companies pursuing commercial fusion. Each is pursuing a distinct approach to fusion, with innovations that amplify fusion's already strong inherent safety case. Appendix A provides a broad outline of this diversity in the fusion community.

---

[1] White Paper - Licensing and Regulating Fusion Energy Systems (Draft, Sept. 13, 2022) ("Draft White Paper").

Importantly, these private sector approaches differ substantially from large-scale public fusion research projects such as the ITER project in Cadarache, France. Such research projects may have understandably been used in the past as archetypes for commercial fusion devices, and the ACRS appears to have looked to ITER in its 2020 analysis.[2] But the approaches being pursued by the private sector today stand in stark contrast. A look at a sample of five private fusion companies in North America that have each raised over $200M (Helion, along with Commonwealth Fusion Systems, General Fusion, TAE Technologies, and Zap Energy) immediately highlights many distinctions between these approaches and ITER.[3]

Figure 1: Example Differences in Private Sector Approaches Compared to ITER
(Sample: Five Private Fusion Companies in North America that Have Raised > $200M)

Diversity in Confinement	• Four of the five approaches do *not* use tokamaks (and the other uses a high-field, compact approach).
Diversity in Fuel	• One of the five approaches uses D-^{3}He fuel; and another p-^{11}B fuel.[4] Those approaches that use D-T fuel take advantage of newer methods to breed tritium than associated with ITER.
Low Inventories	• Tritium inventories are expected to be much lower than the kilogram quantities associated with ITER.[5]
Small Scale	• All private sector approaches are anticipated to require much smaller site footprints than ITER.[6]

ITER represents an incredibly safe approach to electricity generation that takes advantage of fusion's inherent safety benefits.[7] However, ACRS is encouraged to evaluate the *even stronger* safety cases supported by the diverse private sector approaches being pursued.

B. Helion is an Example of the Success of Diverse Approaches

Helion's *Plasma Accelerator* technology enables pulsed, non-ignition fusion and direct capture of fusion energy, resulting in small, efficient, fusion energy devices with no need for a steam cycle balance of plant. We intend to use deuterium and helium-3 fuel, which substantially reduces the

---

[2] *See* ACRS Letter to Chairman Kristine Svinicki, Re: 10 CFR Part 53 Licensing and Regulation of Advanced Nuclear Reactors, at 3 (Oct. 21, 2020).

[3] Fusion Industry Association, The Global Fusion Industry in 2022 Survey, at 6 (listing the five companies in North America with over $200M in private sector funding). In this letter, following Helion, the other companies are listed in alphabetical order. Any information provided concerning companies other than Helion is based on Helion's understanding after review of publicly available sources.

[4] D-^{3}He fusion results in much fewer, and lower-energy (2.45 MeV) incidental neutron emissions (produced via D-D side reactions) with lower activation impacts; p-^{11}B fusion offers even lower incidental neutron emissions.

[5] *See* I.R. Cristescu *et al.,* IAEA Nuclear Fusion Journal, *Tritium Inventories and Tritium Safety Design Principles for the Fuel Cycle of ITER* (June 25, 2007). One reason ITER is anticipated to have kilograms of tritium on site is because it does not intend to breed tritium in substantial quantities, and thus would need to store tritium. A commercial D-T fusion device would instead actively breed tritium during operation, which would keep overall tritium inventories lower. General Fusion has estimated that its commercial fusion power plant will have 2-4 grams of tritium in total inventory at any time, and Commonwealth Fusion Systems has estimated 50-90 grams. *See* *Updates on Plans for Fusion Demonstration Plant in the UK* (Oct. 21, 2021) (slide 27, pdf page 29); Commonwealth Fusion Systems, *Fusion Attributes in the Private Industry Context* (Mar. 30, 2021) (slide 6, pdf page 81) (ARC fusion device).

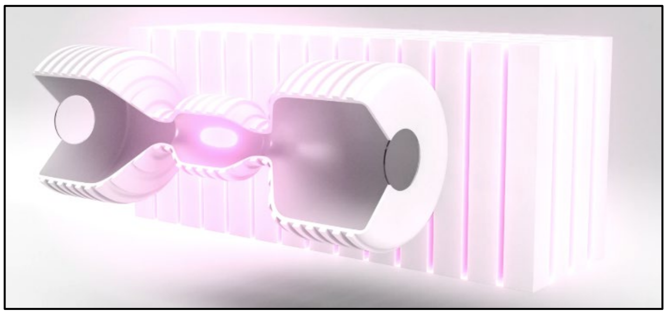
[6] For example, Helion expects that a 50 MWe Helion generator and related power electronics would be able to fit within a small set of shipping containers, and thus when deployed occupy a far smaller site footprint compared to ITER.

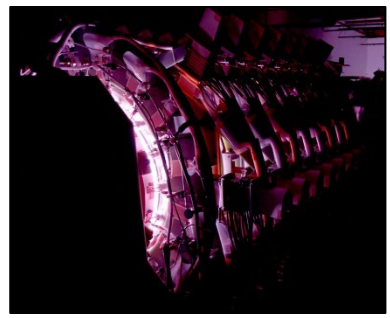
[7] Although the private sector approaches differ from ITER's, ITER is still fundamentally different from a fission reactor because it cannot sustain a chain reaction, a defining facet of fission reactors. Moreover, ITER (along with private sector designs) does not need active cooling upon shutdown. ITER Website, *Frequently Asked Questions, Could a Fukushima-type Catastrophe Occur at ITER?*

already-low radiological impacts associated with fusion. An overview of our approach is provided in our March 2022 NRC public meeting presentation,[8] and on our website.[9]

Helion has built and operated six prototypes since 2008, which have demonstrated the viability of our approach. Our most recent 6th-generation prototype, called "Trenta," was the first private-sector fusion device to reach fusion-relevant plasma temperatures of 100 million degrees (and did so on a reproducible basis as part of a 16-month, 10,000-pulse campaign).[10] Our accomplishments have been audited by a former technical leader at Sandia National Laboratories, and we have presented our results at multiple technical conferences.[11]

Figure 2: Images of Helion's Fusion Devices





(Left: An artist's conception of a commercial Helion fusion device. Right: An angled view of one of Trenta's plasma formation sections; the fuchsia color seen in this right photo comes from plasma ionization (Balmer Series spectra).)

Following Trenta's successful operating campaign, we raised $500 million in 2021, fully funding our efforts through commercialization. Our focus is now on development of our 7th-generation prototype, called "Polaris." We intend to demonstrate *net electricity* from fusion with Polaris in 2024. Thereafter, we plan to start working towards deployment of the world's first commercial fusion power plant, with a capacity of 50 MWe.

Our 6th generation prototype Trenta is licensed by the Washington Department of Health under its particle accelerator framework. Licensing for the 7th-generation Polaris device is ongoing in close cooperation with the state regulator, and we have recently obtained the x-ray/particle accelerator registration for the first phase of Polaris operations.

II. Commercial Fusion's Safety Case

Helion believes that applying an appropriate and risk-informed regulatory framework for commercial fusion can enable the timely deployment of this technology, as well as build public trust and acceptance. We applaud the NRC staff on its thorough regulatory evaluation of fusion technologies, spanning two years and multiple public meetings to solicit stakeholder input. Its

[8] Helion Energy, *Supplemental Safety Case Analysis* (Mar. 23, 2022) (slide 108).
[9] www.helionenergy.com. We also have a video available online that describes our approach in more detail.
[10] World Nuclear News, *Helion Passes 100 Million Degrees Celsius* (June 23, 2021).
[11] *See, e.g.,* D. Kirtley *et al.*, 2021 IEEE Symposium on Fusion Engineering, *Helion Presentation on Vacuum Vessel and Diverter Design and Results of 16-Month Operation of the Trenta Magneto-Inertial Fusion Prototype* (Dec. 17, 2021); D. Kirtley *et al.*, 60th Annual Meeting of the APS Division of Plasma Physics, *Overview of Staged Magnetic Compression of FRC Targets* (Nov. 5, 2018); J. Slough *et al.*, IAEA Nuclear Fusion Journal, *Creation of a High-temperature Plasma Through Merging and Compression of Supersonic Field Reversed Configuration Plasmoids* (Apr. 13, 2011). Additional papers, presentations, and patents/patent applications describing our technology are listed on our website or available upon request.

Draft White Paper reflects a thoughtful and well-reasoned first-principles analysis of fusion's safety case and regulatory options, after taking in copious information from public and private sector sources.

Following this extensive process, the NRC staff found that the risks of fusion energy "appear lower than typical utilization facilities and more similar to byproduct material facilities."[12] This is not a conclusion that fusion is zero-risk, but an acknowledgement that risk-informed regulation of commercial fusion is possible—and perhaps more appropriate—under a byproduct materials approach compared to a utilization facility approach. Helion concurs with the NRC staff's determination that "[t]he Part 30 approach provides a scalable and technology neutral basis for the licensing and oversight of the wide range of fusion energy systems currently under development."[13]

To aid the ACRS in its own review, we summarize below certain analyses previously shared with the NRC—using Helion as an example—that speak to the close alignment of fusion's safety case with particle accelerators and industrial facilities over fission reactors.

A. March 2022 Analysis – Commercial Fusion Impacts are Distinct from Fission

In March 2022, Helion presented directly on the anticipated impacts of its planned commercial 50 MWe fusion devices.[14] We shared the following findings for example:

- **No need for post-shutdown cooling (slide 116).** We estimated that the approximate device temperature increase upon shutdown would be less than 20 °C in room air conditions, and radiation from activation products would decay sufficiently to permit entry into the Plasma Accelerator main room within a few days after shutdown.

- **Minimal impacts in accident scenario (slide 119).** We estimated that even in hypothetical, extreme bounding scenarios (e.g., the whole vacuum vessel is turned into dust, freely released into the air), the estimated maximum dose to the public or workers would be just 11.3 mrem, 1/9th of the annual public dose limit.

These strong results in the case of Helion are driven in part by the lower materials inventory and neutron emissions associated with the Helion's approach. As discussed in the March presentation, Helion's device is anticipated to have only on the order of 0.015 mg of tritium within the fusion medium at any time, generated as products of each fusion pulse that are subsequently exhausted (slide 110).[15] Cleanout of the vacuum vessel through a gas puff, glow discharge, or similar mechanism can be performed between fusion pulses to keep tritium adsorption on the vessel surface limited. Furthermore, neutron output in the case of Helion's 50 MWe device is anticipated to be on the scale of 10^{18} n/s, orders of magnitude lower than what is anticipated for ITER (up to ~10^{21} n/s).[16] Neutrons emitted by the Helion device are 2.45 MeV; this energy is below the activation thresholds for many materials, resulting in a limited activation profile

[12] Draft White Paper at 7.
[13] Draft White Paper at 8.
[14] *Supra* note 8.
[15] Tritium and helium-3 are both produced as a result of D-D side reactions that occur during the D-^{3}He fusion pulse.
[16] ITER Newsline, *Counting Neutrons to Measure Fusion Power* (June 13, 2016).

compared to higher energy neutrons. The Helion approach is but one of many innovative avenues being pursued across the private sector that enhance fusion's already strong inherent safety case.

B. August 2022 Letter – Commercial Fusion Impacts Align with Particle Accelerators

In a letter submitted to the NRC staff on August 12, 2022,[17] Helion outlined the safety considerations for commercial fusion devices and how they align with various particle accelerators in both operational and accident scenarios. In particular, we discussed how the *types* of risks associated with fusion devices are essentially the same as found in particle accelerators, indicating that the regulatory approaches to address those risks can also align (see pages 6-8 of the letter for further details).

Figure 3: Commercial Fusion Device Impacts
(Aligned with General Particle Accelerator Impacts)

Operational Impacts
(1) Neutron and Photon Radiation. Both fusion devices and other particle accelerators emit neutrons and/or photons as subatomic particles move within the device and upon particle collisions. The neutron emission rate may be greater in the case of fusion, but often at lower energy levels. **(2) Radioactive Material Input/Output.** Both fusion devices and other particle accelerators can require radioactive materials as input constituents or output radioactive materials, including tritium. The accelerator community, including operators of high-energy cyclotrons for medical isotope production, has significant experience handling intentional and incidentally produced radioactive material in relatable contexts. **(3) Incidental Activated Material.** Both fusion devices and other particle accelerators can irradiate shielding or other device components, activating the materials. Although potentially emitting more neutrons, the lower-energy 2.45 MeV neutrons anticipated from Helion's fusion approach for example activate fewer materials than the higher-energy neutrons from many particle accelerators (e.g., a cyclotron emitting 30-MeV neutrons that can cause spallation, therein producing tritium in the shielding, soil, and groundwater).
Accident Impacts
(1) Release of In-Device Material & Dust. Both fusion devices and other particle accelerators can have radioactive material within the device's operating medium or on the vacuum vessel surface that can be released in some fraction in an accident scenario. In the Helion example, the activated material and tritium if released are estimated to contribute to only a small percentage of annual background dose. **(2) Release of In-Process or Stored Generated Materials.** Both fusion devices and other particle accelerators have to manage the radioactive byproducts coming off the particle accelerator, such as medical radioisotopes or tritium. In the case of Helion, tritium will be independently stored after generation.
Avoided **Impacts & Hazards**
(1) No Criticality. Neither fusion devices nor other particle accelerators can sustain a chain reaction. Both devices turn off on demand, and passively deactivate in the event of a material abnormality. **(2) Limited Inventory.** Both fusion devices and other particle accelerators have a low inventory of radioactive materials in the device at any time, whereas a fission reactor typically holds an entire uranium core (a year or more worth of fissionable material and fission products) in the reactor vessel.

[17] Helion Energy, *Classification of Fusion Devices as Particle Accelerators; and Supplementing Common Defense & Security Discussions* (Aug. 12, 2022).

C. June 2022 Analysis – Part 30 Tools Can Create a Foundation for Fusion Regulation

As stated above, Helion agrees that an appropriate and risk-informed regulatory framework for commercial fusion can enable and enhance deployment. To this end, in June 2022, Helion openly discussed example design and operational topics potentially warranting regulatory oversight—and explored how existing tools in 10 CFR Parts 30-39 could serve as a foundation to address them (see slides 16-30, pdf pages 59-73, in particular).[18] In line with Option 2 of the Draft White Paper, these tools could eventually be implemented through guidance and/or development of new, scalable regulations within the byproduct materials regulatory framework. We concur with the NRC staff that the facility approach to regulating panoramic irradiators in 10 CFR Part 36 can be explored as a model for future regulation of fusion devices.[19]

* * *

Thank you for your time in reviewing this letter. We hope that this additional information on the diverse fusion technologies being pursued and their safety case can aid the ACRS's analysis.

As the ACRS continues its review, we hope to serve as a resource to the committee. To this end, a member of the ACRS in a May 2021 meeting with the NRC staff suggested that "additional training and oral presentations of the different technologies" may prove useful.[20] Helion would be excited to support any such effort, including through a live briefing to the ACRS accompanied by a diverse set of fusion companies, or by answering additional questions by ACRS members.

Sachin Desai
General Counsel
Helion Energy, Inc.

Cc: Members, Advisory Committee on Reactor Safeguards

Scott Moore, U.S. Nuclear Regulatory Commission
Derek Widmayer, U.S. Nuclear Regulatory Commission
Andrew Proffitt, U.S. Nuclear Regulatory Commission

David Kirtley, Helion Energy, Inc.
Michael Hua, Helion Energy, Inc.
Scott Krisiloff, Helion Energy, Inc.

[18] Helion Presentation, *AEA Common Defense and Security and Application of Materials Framework Tools for Fusion* (June 7, 2022) (pdf pages 44-75).
[19] Draft White Paper at 6.
[20] Transcript of ACRS May 6, 2021 Meeting, at 77.

Appendix A – Diversity of Approaches to Commercial Fusion Energy[21]

---

[21] The Global Fusion Industry in 2022 Survey, at 7, 10.