

Summary of the Working Group on AI for Nuclear Fusion

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Technical Meeting on Artificial Intelligence for Nuclear Technology and Applications

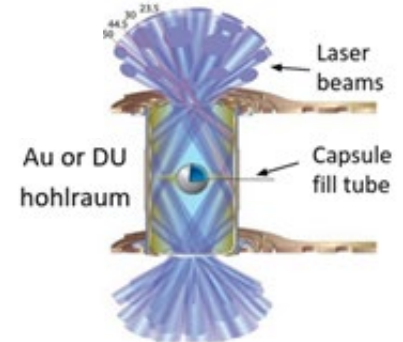
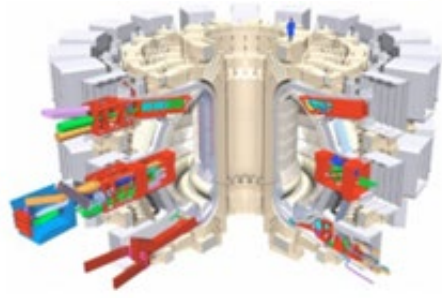
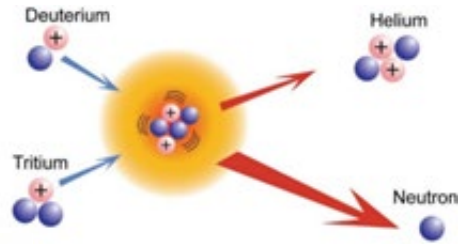
#AI4Atoms Virtual Event

25–29 October 2021

State of the Art

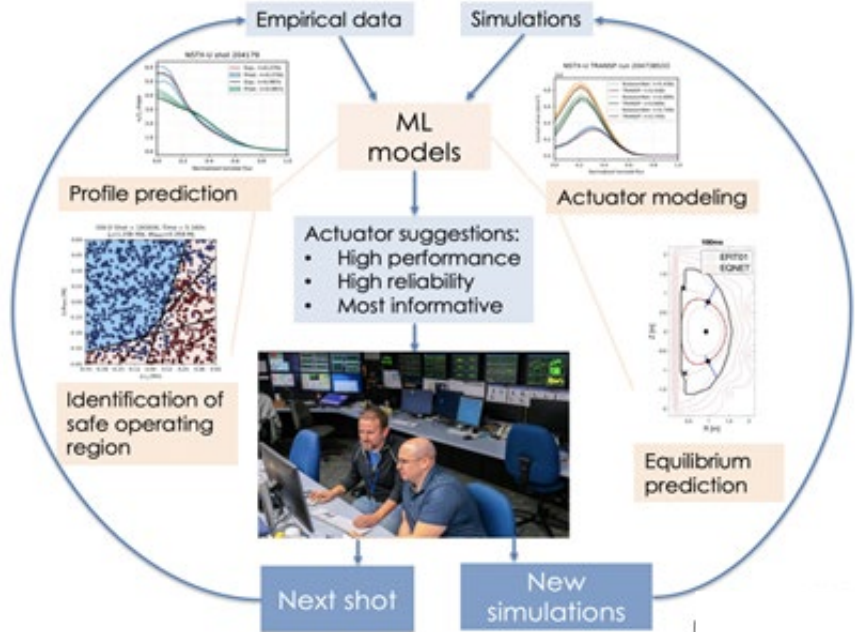
Two fusion communities brought together in the Working Group: Magnetic Fusion Energy (MFE) and Inertial Fusion Energy (IFE)

Fusion as a long term
clean energy option



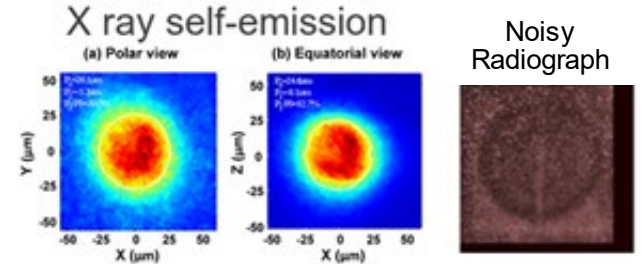
Data drives fusion experiments, from design to analysis and optimization

ML models used for performance optimization of MFE experimental operations

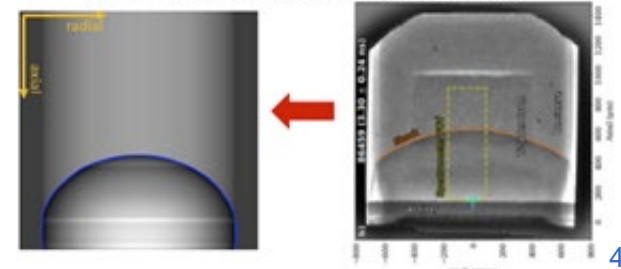


Adapted from David Smith, IAEA WG-A4NF, 10/26/2021
Courtesy of M.D. Boyer, PPPL

ML/AI tools used to improve quantitative data extraction in IFE



Trained networks to extract quantities based on simulations/ model



Adapted from John Kline, IAEA WG-A4NF, 10/26/2021

ML/AI applied fusion research highlights existing bottlenecks:

Data accessibility

Big databases needed for ML/AI model training/validation



Hybrid curricula needed to fully leverage ML/AI tools

Community integration

Common frameworks needed to create ONE community of practice focused on AI/ML for fusion (of all flavors)



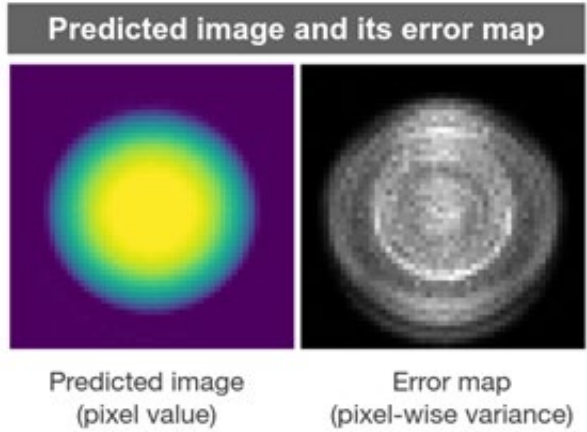
Next Steps

More computing power allows for AI/ML to advance capabilities in IFE/MFE - need to explore extrapolation to unseen domains

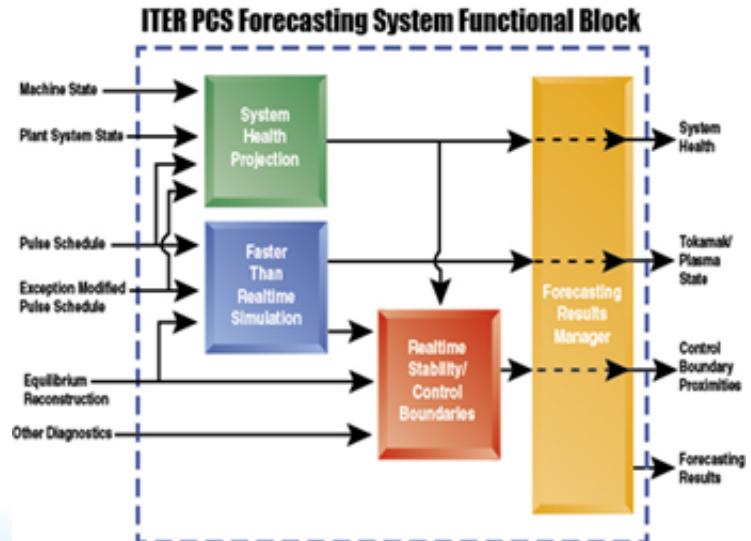


AI can enhance analysis of instrumentation (especially imaging) and potentially extract inferred quantities using models or surrogates

AI predictive modeling can be used for plasma performance optimization, event and anomaly detection and plant operations



Adapted from John Kline, IAEA WG-A4NF, 10/26/2021



Adapted from D. Humphreys, "Advancing Fusion Research with Artificial Intelligence", The Future of Atoms – Artificial Intelligence for Nuclear Applications, Sept 2020

Common bottlenecks preventing AI from accelerating IFE and MFE find analogies in other TM working groups themes/challenges

Hesitancy to share data

Ownership

Security

Intellectual property

Poor communication

Stovepiped communities

Fear of being scooped

Gatekeeping by community members

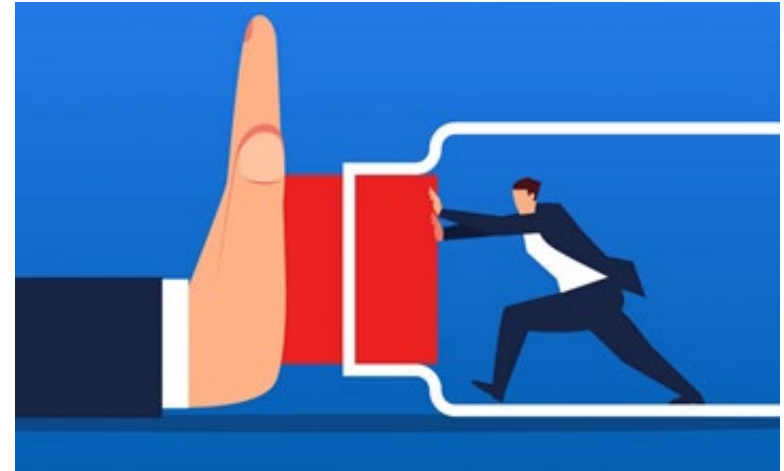
Low understanding of new methods

Reluctance to change from familiar methods

Lack of large scale coordinated effort

Low numbers of trained personnel

Fusion subject matter experts need re-skilling for AI/ML



Accelerating Progress - IAEA's Role

We identified a multitude of enabling activities for IAEA to accelerate progress in MFE and IFE



host data

workshops: basics of ML, advanced ML (multimodal), huge datasets, fusion data for fusion researchers, ...

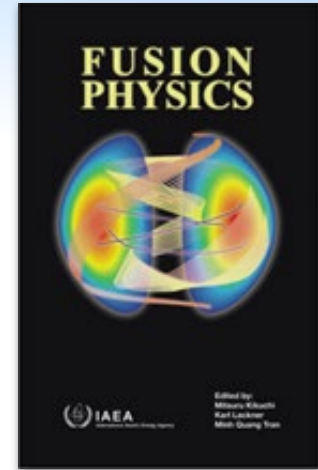


be a data steward: manage data embargos, establish common formats



act as a broker/ambassador between the data and user community

educate and engage workforce



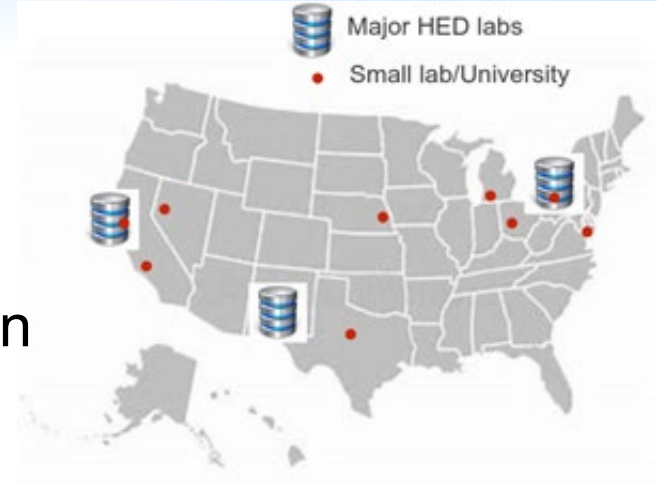
create new ways to engage the community (Kaggle-like competitions, hack-a-thons)

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IAEA's role: host data beyond national barriers



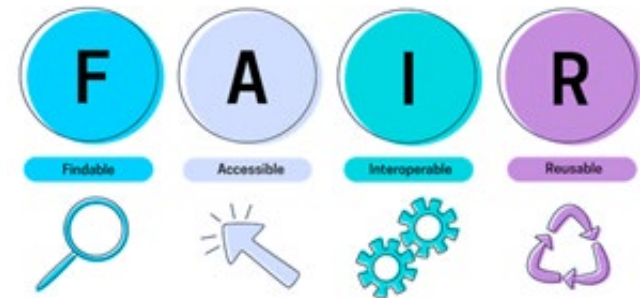
- ❖ Fusion databases hosted at different facilities in different formats, behind firewalls and not connected (worldwide)
- ❖ Need dedicated resources for db curation and management
 - **IAEA internships, fellowships, consultancy opportunities could be leveraged**



IAEA's role: host data beyond national barriers - open data access

IAEA can help build open MFE/IFE databases by:

- surveying existing efforts in fusion communities and move past their shortcomings
- developing a centralized repository of experimental/simulation/plant operation data;
- coordinating efforts to expedite willingness to share from agencies/facilities through official call for data;
- building AI/ML projects that can consume the data;
- opening participation to fusion communities worldwide;
- offering committee/staff to adhere to **OPEN/FAIR** principles.



IAEA's role: leverage open access to engage broader interest in AI for Fusion

IAEA can act as a broker/ambassador between the data and user community.

Open data access crucial for attracting talents by engaging AI/ML community and expand Fusion workforce. Open databases used for:

- outreach activities, workshops/schools, ...
- Kaggle-like competitions, hack-a-thons, ...

thus finding creative ways to engage, energize, and integrate many communities, e.g., ML experts, students, science researchers, other relevant cross-field researchers, private entities, ...



IAEA's role: educate a diverse workforce in Fusion



IAEA can establish a network to bring AI/ML/Fusion scientists together and help educate a diverse workforce.

- Added value: bringing small AI activities scattered across many institutions together, and thereby gaining critical mass, avoiding duplication, and exploiting synergies

Thanks to IAEA supporting role, the Fusion workforce will see:

- increasing participation,
- diversification to AI/ML curricula
 - potential reference academic curricula definition
 - increasing outreach to non-physics communities.



Expected Outcomes

IAEA networks and Coordinated Research Activities will accelerate progress in AI for Fusion



IAEA will have a transformative role enabling key Fusion research opportunities

A roadmap for AI deployment in Fusion

Machine Learning for
Real-time MFE System
Behavior Prediction,
Identification &
Optimization

Improve IFE Physics
Understanding through
Simulation, Theory and
Experiment Using ML/AI
Methods

- **Data stewardship**
 - Democratization of resources, data standards, ...
- **Community integration**
 - Partnering with industries, common frameworks, licensing qualification ...
- **Workforce development**
 - Outreach, education, training, ...



Thanks to all the Nuclear Fusion Working Group members for their incredible effort!



M. de Baar (DIFFER, Netherlands), D. Ferreira (U. Lisbon, Portugal), J. Kline (LANL, USA), S. Mordijck (W&M, USA), M. Murillo (MSU, USA), D. Smith (U. Wisc., USA)

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Thank you!

