**Summary of NSTX-U Monday Physics Meeting (December 2, 2024) – AI-ML Brainstorming Session**

**1. AI-ML Efforts at NSTX-U: Review of Past Work**

Jack Berkery presented a review of AI-ML projects already conducted for NSTX/-U, including:

* **Profile Prediction:** ML for Te profiles (Clayton, 2013), reversed magnetic shear (Uzun-Kaymak, 2024), and density/electron pressure profiles (Boyer, 2021).
* **Database/Experimental Measurements:** AI used in studies of Alfvenic chirping (Woods, 2020), ELM patterns (Smith, 2016), and ST pedestal prediction (Parisi, in progress).
* **Transport:** ML models for electron thermal transport (Chung, in progress) and surrogate models (Leard, 2024) for multi-mode transport.
* **Code Surrogate Models/Speed-Up:** AI applied to accelerate heat flux simulations (Looby, 2020) and ICRF power absorption (Sanchez-Villar, 2024).
* **Operations/Real-Time:** ML in scenario planning (Boyer, 2020), EFIT for NSTX-U (Wai, 2022), and NUBEAM-Net (Boyer, 2019).
* **Stability/Disruptions:** AI used for modeling ideal MHD (Piccione, 2020), resistive wall modes (Piccione, 2022), and vertical stability (Tobin, 2024).

**2. Future Directions for AI-ML at NSTX-U**

The group emphasized the need to coordinate AI-ML efforts going forward, as past efforts were fragmented and often not sustained.

**Key Ideas:**

* **Curated Public Database:**
  + Proposals included creating a publicly accessible, curated database for NSTX-U, with contributions from existing datasets like Ege’s and Steve Sabbagh’s DECAF, as well as the IAEA’s "AI for Fusion" initiative.
  + **Dave Smith** suggested launching a Kaggle competition to engage external researchers and boost NSTX-U visibility.
  + Discussions included whether to create a centralized database or a generator that processes data on demand (as seen with DIII-D).
  + **Fatima Ebrahimi** and **Joe Schmidt** mentioned hybrid databases combining experimental and simulation data, while **Nate Ferraro** suggested focusing on simulations for future fusion pilot plant (FPP) devices.
* **Digital Twin Concept:**
  + There was discussion about creating a "digital twin" for NSTX-U, potentially starting with smaller, concrete aspects like CAD and real-time measurements. **Nate Ferraro** noted the potential for such an effort, and **Laura** highlighted an opportunity to define key measurement needs.
* **AI for Diagnostics and Fault Detection:**
  + **Mate Lampert** proposed using AI for diagnostic fault detection, helping identify issues early and minimizing the loss of valuable data.
  + **Dave Smith** emphasized real-time diagnostics, leveraging high-throughput engines to process data streams, which could align with the CHIPS Act and benefit from new computing technologies.
* **Alignment with NSTX-U's Five-Year Plan:**
  + **Dave Smith** suggested integrating real-time FIDA measurements and simulations with NSTX-U's plasma control system, focusing on fast ion physics and energetic particle modes.
  + **Phil Bonofiglio** and **Bill Heidbrink** discussed the importance of labeled datasets for real-time mode identification and using FIDA to measure fast ion distributions.
* **AI for Plasma Operations and Experiment Planning:**
  + Ideas included developing AI-driven systems for scheduling experiments, automatic logging, and improving user coordination for NSTX-U as a "user facility."
  + **Jason Parisi** proposed the possibility of AI eventually managing NSTX-U operations, while **Dom Power** referenced the growing field of AI in experimental design to optimize data collection.
  + **Laura** emphasized the need to document the challenges and successes of these efforts to build community trust.

**3. Resources and Next Steps:**

* **Documentation and Collaboration:** The group agreed on the importance of documenting trials, challenges, and results to foster transparency and collaboration.
* **Shared Resources:** A link to shared resources was provided to support future AI-ML work (Google Drive link).

In conclusion, the brainstorming session outlined key opportunities for AI-ML integration in NSTX-U, focusing on creating open, accessible databases, improving real-time diagnostic and operational capabilities, and aligning efforts with NSTX-U's long-term research objectives.