NEXT STEP FUSION

Next Step Fusion

Tokamak Design, Simulation, Optimization, and Control

Team

Unique, interdisciplinary team of **20+ experts** in plasma physics, tokamak simulation and control, AI/ML, and software development

- Private company established in **April 2023**
- Based in **Luxembourg**, Spain, and Portugal
- Experience with **ITER, KTM, T-10, T-15MD, DIII-D,** and **ISTTOK**
- Demonstrated **track record** in the fusion industry


DIII-D
NATIONAL FUSION FACILITY


COLUMBIA
ENGINEERING


UC San Diego


FUSION
INDUSTRY ASSOCIATION
the voice of the private fusion industry


ISTID


THE
FUSION
CLUSTER


CER
Center for Energy Research


European
Fusion Association


TUSCIA
RESEARCH
UNIVERSITY
SMALL
TOKAMAK


UNIVERSIDAD
D SEVILLA
1505


NVIDIA
Inception
Program

Overview

We offer plasma control solutions, advanced simulations, tokamak design, and AI/ML for the fusion industry

Our **projects and partnerships** are built on trust and delivering reliable results:

- PPP via barter, grants, and direct sponsorship
- Commercial one-off and subscription projects and services

High-Quality Professional Solutions

Services and Products

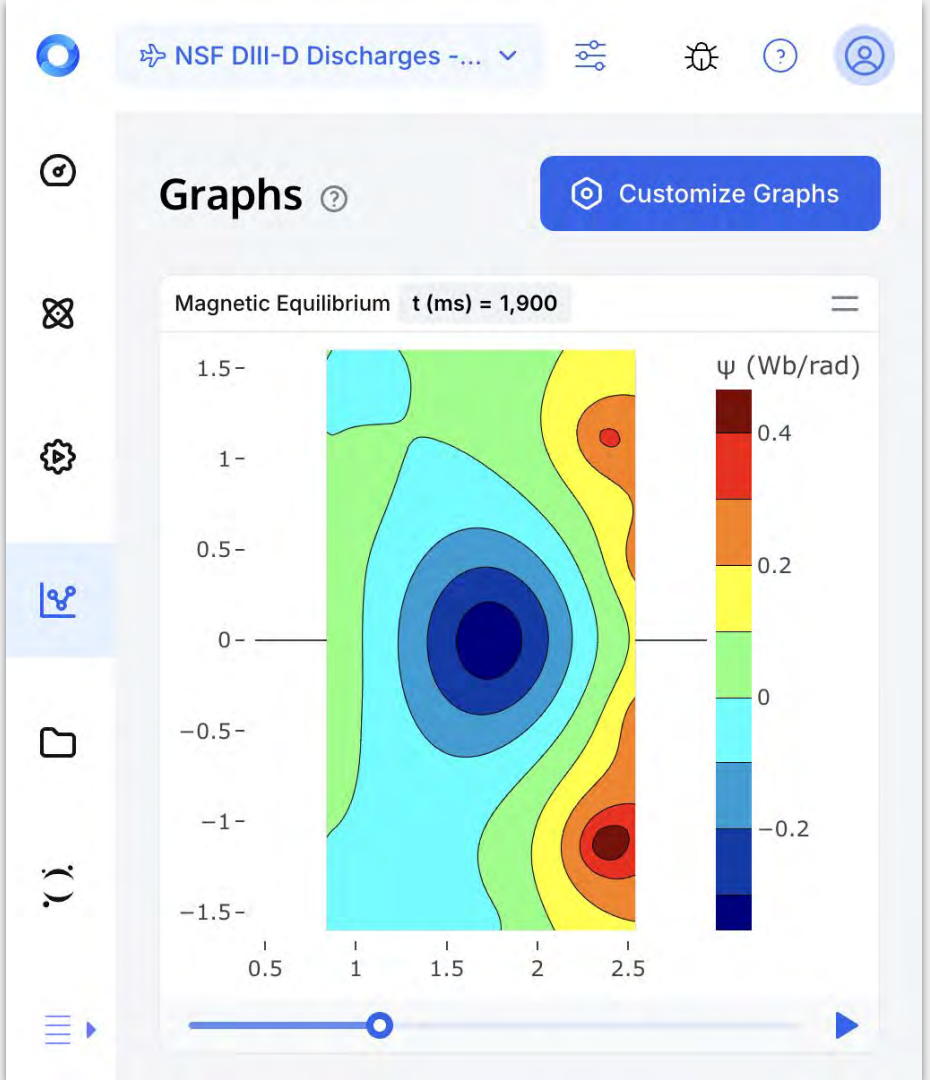
High-Quality Professional Solutions

Advanced Tokamak Simulations

Advanced Tokamak Simulations

We apply our expertise and proven tokamak simulator to offer services in:

- **Feedforward simulations** for plasma equilibrium evolution
- **Discharge scenario development** to reliably achieve specific targets
- **Plasma performance optimization** to meet specific performance goals
- **Disruption simulation and analysis**



NSFsim

- **NSFsim** is an advanced 2D Grad-Shafranov solver designed for simulating and controlling free-boundary plasma equilibrium and transport in tokamaks
- Based on the renowned DINA simulation approach and a modular architecture that has been extensively tested with numerous tokamaks
- Couples plasma evolution with external circuits, conducting structures, and magnetic diagnostics to provide accurate and reliable predictions
- Uses so-called **digital replicas**, models of tokamaks based on the geometrical and electrical characteristics of the magnetic system and passive conducting structures, including poloidal field coils, the vacuum vessel, and the limiter
- Simulates synthetic signals of magnetic diagnostics, such as magnetic probes and flux loops, by calculating the mutual magnetic fields arising from toroidal currents in the plasma, as well as active and passive elements

NSFsim Capabilities

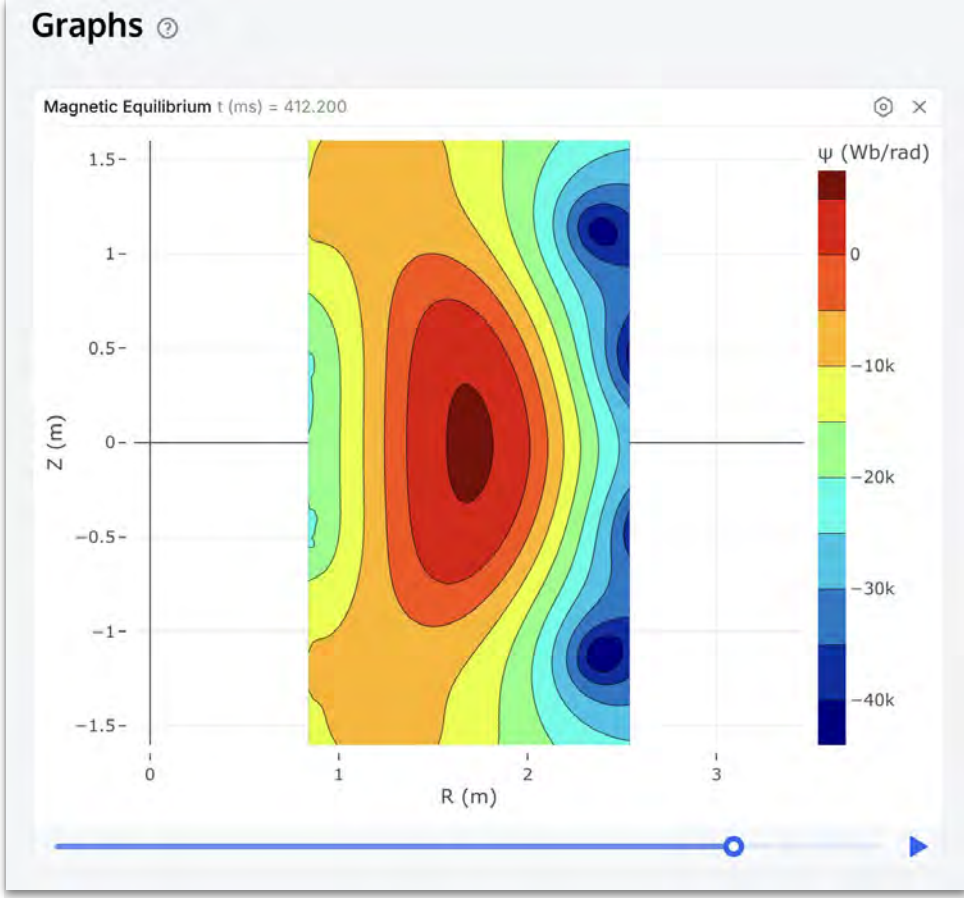
NSFsim allows us to solve the following device-specific tasks:

- Magnetic equilibrium and transport simulation, reconstruction, interpretive simulation, disruption prediction and analysis
- Relatively fast environment for training plasma control Reinforcement Learning models
- Synthetic dataset generation and validation

NSFsim

We keep improving for various cases:

- Better calculation of the transport coefficients with the help of TGLF
- Better calculation of the radio frequency heating and current drive with the help of TRAVIS and neutral beam heating codes
- Better features and performance for the Reinforcement Learning model training pipeline
- Support all existing modules within the Platform, including the digital replica builder



NSFsim Case Study

Scenario prediction for fast compression experiments of General Fusion on DIII-D

generalfusion

In this project, NSFsim and our team's expertise have been applied to simulate and demonstrate the feasibility of General Fusion's experiment on the DIII-D tokamak:

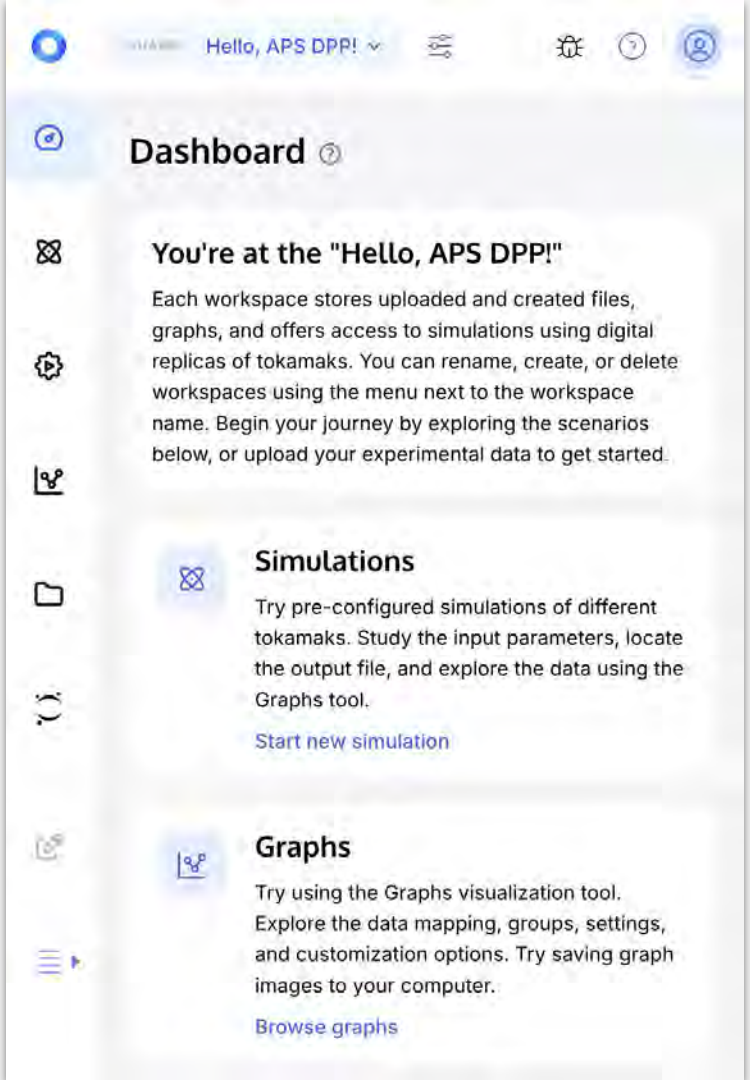
- Predicted plasma performance in a non-standard tokamak experiment using **NSFsim and the digital replica of the DIII-D tokamak**
- **Proved feasibility and helped prepare** for a long-awaited and expensive experiment
- Consulted on complex questions regarding DIII-D facility data access and analysis

High-Quality Professional Solutions

Fusion Twin Platform

Fusion Twin Platform

- **Available for free at FusionTwin.io**
- Simulations using NSFsim and digital replicas of well-known tokamaks: DIII-D, ISTTOK, SMART – with more coming soon!
- Fusion data uploading, mapping, visualization, and management
- Flexible data sharing and collaboration features
- Coming soon are discharge scenario builder, tokamak digital replica builders, and much more!



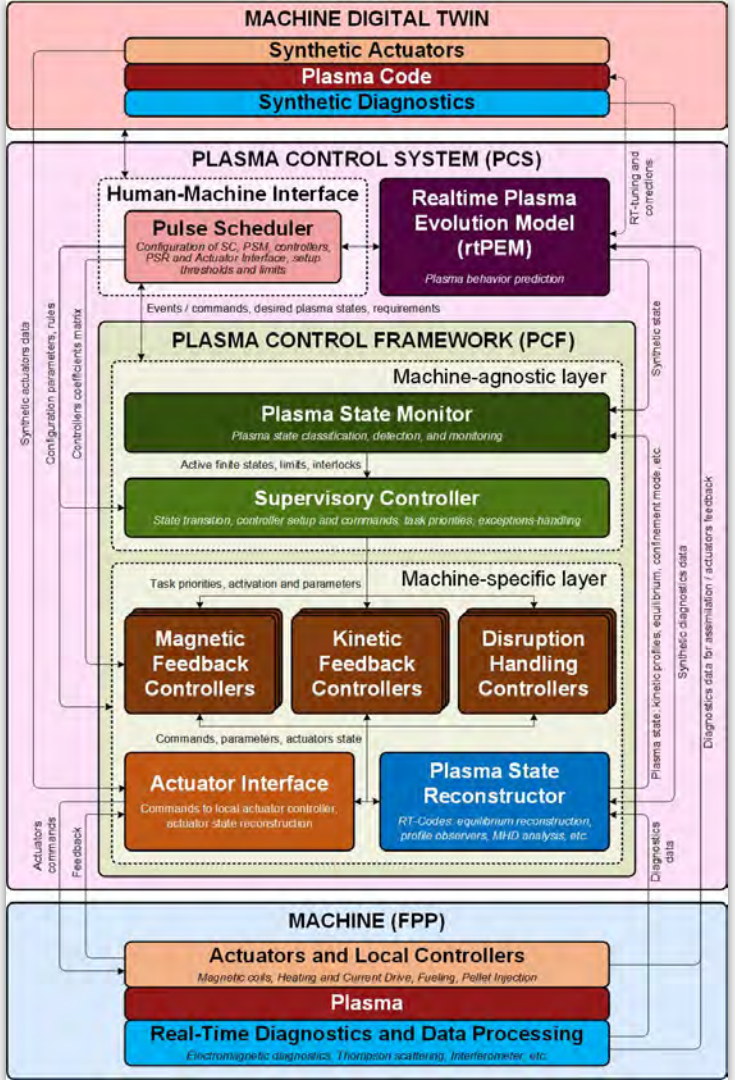
High-Quality Professional Solutions

Plasma Control Solutions

Plasma Control System

In development:

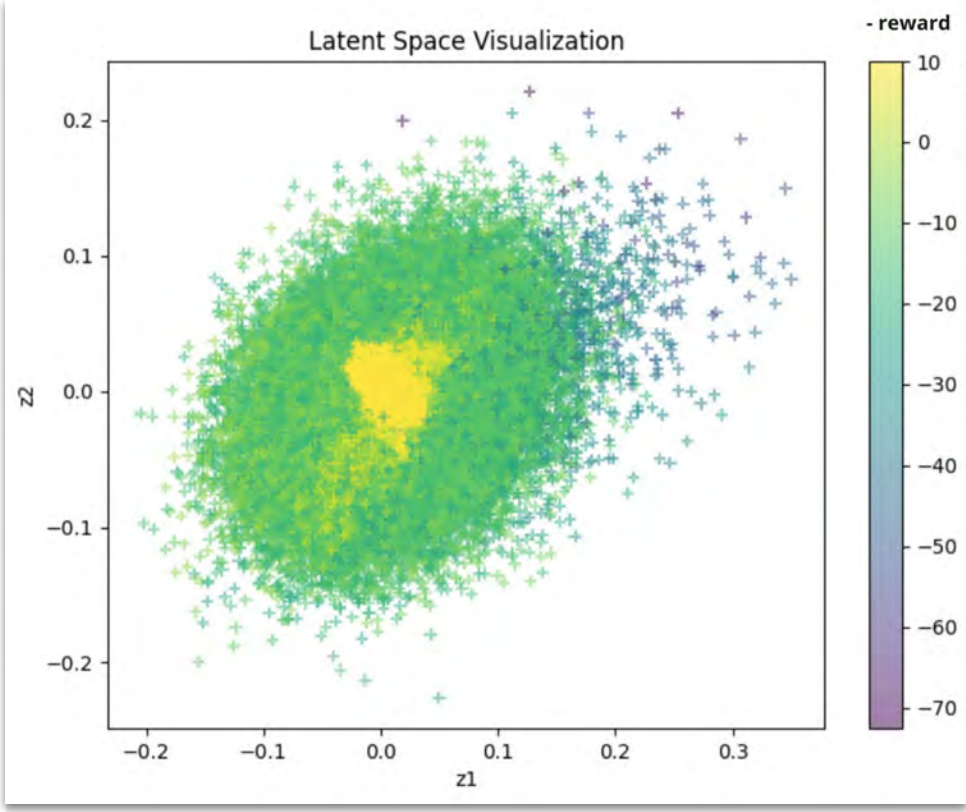
- Modern state-oriented PCS for tokamaks and stellarators
- Combines conventional and ML-based control methods to ensure reliability and efficiency
- Features a clear separation of control layers
- High-quality solution for the next generation of fusion devices and future power plants



Plasma States Explorer

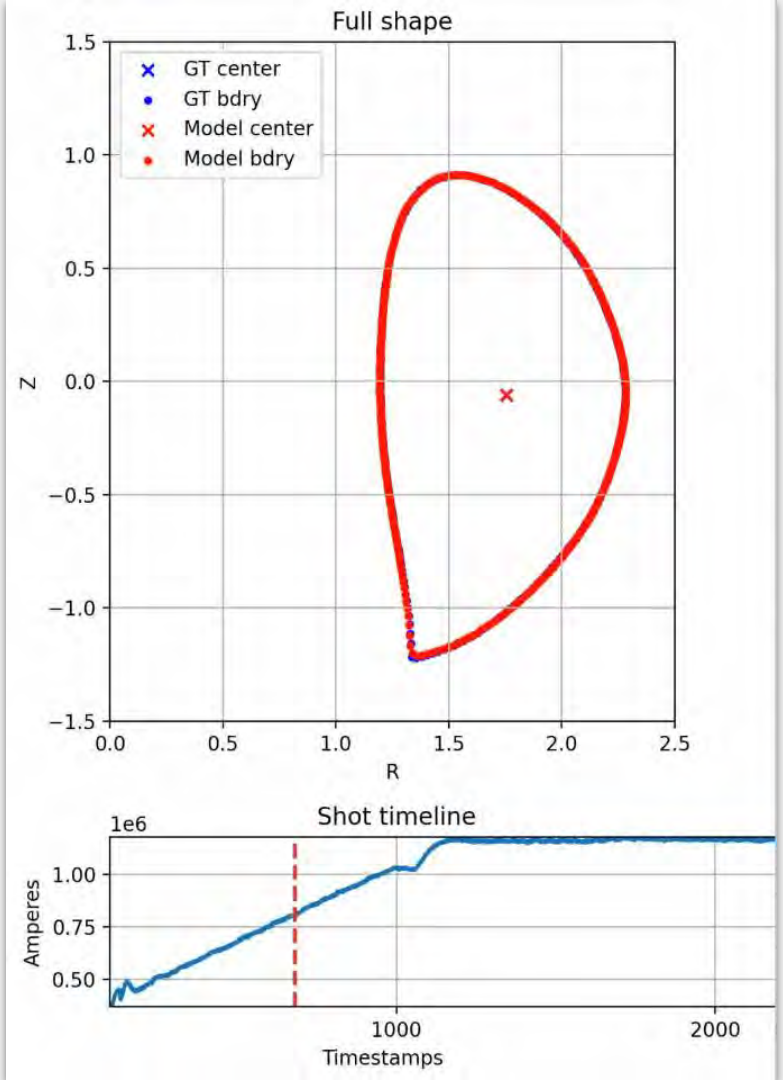
ML toolkit for efficient discovery of plasma states possible on this specific tokamak:

- States discovery and classification
- Parametrized states generation with requested characteristics
- Discharge scenario planning
- Identification of optimal operational parameters
- Automatic validation of discovered states using NSFsim



Plasma Mind

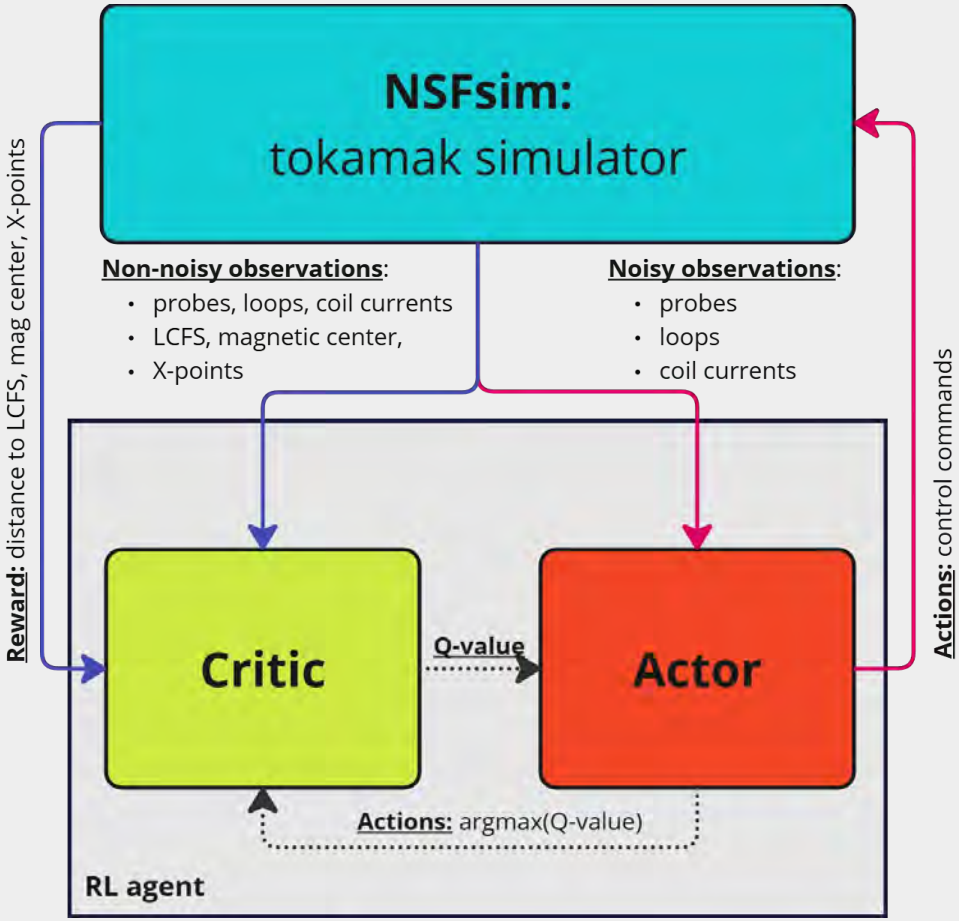
- ML toolkit for training tokamak-specific surrogate ML models
- Addresses the challenges of data-poor, weak-actuator, reactor-relevant environments
- Suitable for newly built devices with no, limited, or biased historical datasets
- Employs modern data science for reliability and robustness
- Synthetic datasets generation



Plasma RL

Reinforcement Learning toolkit, where the model learns through numerous trial-and-error iterations within an envi`ronment that combines a precise digital replica of a tokamak with our NSFsim simulator:

- Training algorithm rewards the model for achieving specific plasma parameters (e.g., shape, position, temperature, density, etc.)
- The resulting model is ultra-fast, real time or even faster, without any need for computationally expensive calculations



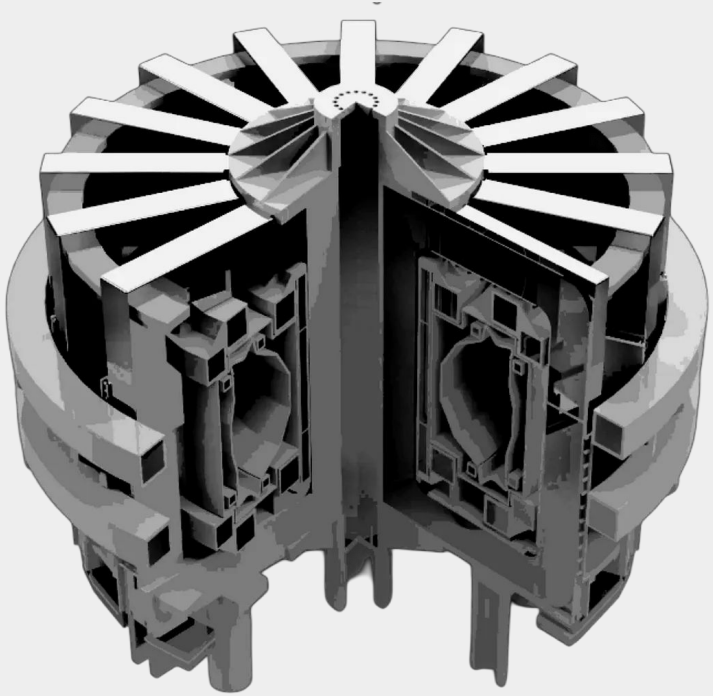
High-Quality Professional Solutions

Tokamak Integrated Modeling

Tokamak Integrated Modeling

We specialize in tokamak design with a focus on advanced plasma control:

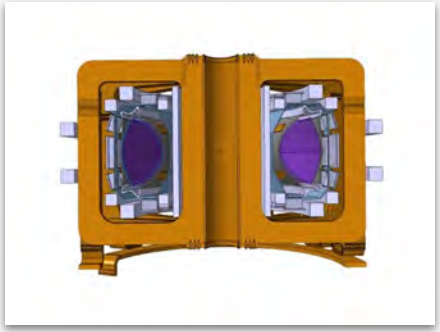
- **New tokamak preliminary design** for specific operational goals
- **Validation and optimization** of existing tokamak design
- **Automated discovery and optimization** of tokamak operational parameters



NTT Case Study

Negative Triangularity Tokamak Design with Columbia University

COLUMBIA ENGINEERING



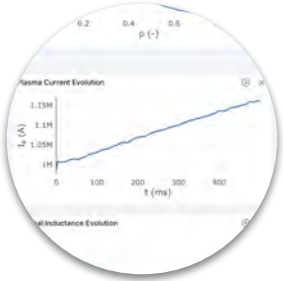
As a result of a year-long collaborative project, we have completed the preliminary design of the NTT, fully paving the way for the next stages:

- **Tokamak-as-a-Service** for external researchers
- **Design and plasma operation scenarios** informed by NSFsim
- **Optimized magnetic system configuration**
- **Comprehensive assessment** of plasma stability, mechanical and electromagnetic loads, power supply system, and other

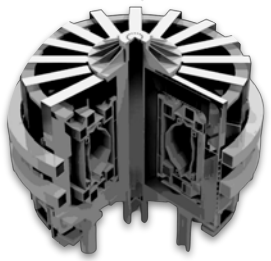
See the paper and posts for more details!

Let’s Shape the Future of Fusion Together!

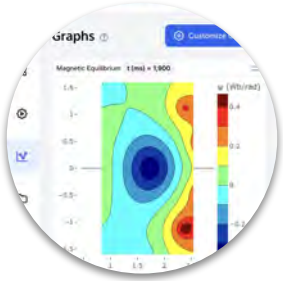
Summary



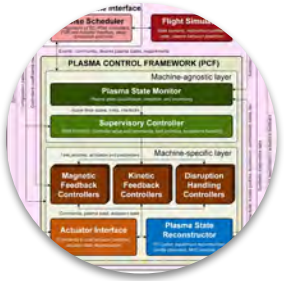
Advanced Simulation Services



Tokamak Integrated Modeling



Fusion Twin Platform
FusionTwin.io



Plasma Control System