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NSTX-U Milestone R(18-1)

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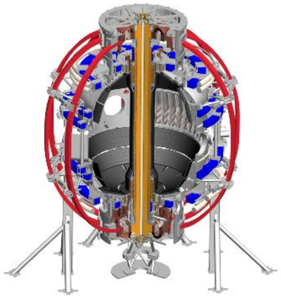
NSTX-U FY18 Milestone Meeting
5/25/2017

PPPL



"When in the Course of Tokamak Events…"

FY18-1: Develop and Benchmark Operations-Focused Reduced Heat Flux and Thermo-Mechanical Models for use in PFC Monitoring

The NSTX-U Recovery Project will deploy new plasma facing components (PFCs) to meet updated heat exhaust requirements driven by a narrower scrape-off-layer width, increased heating power and longer pulse durations relative to NSTX. Inter-shot monitoring or intra-shot control of heat flux to PFCs is anticipated for a range NSTX-U operating space, necessitating reduced models that can be run between shots or even in real-time. Monitoring requires a reliable instrumentation suite which can support or contradict model predictions and confirm PFC integrity. The goals of this milestone will be accomplished in three major components: 1) Develop tools for pre-shot planning and confirmation of post-shot PFC thermal observations which use reduced models to predict time-evolving heat fluxes to shaped PFCs and estimate distances from engineering limits. Assess additional effort needed for implementation of reduced models in PCS. 2) Where feasible, benchmark reduced models against boundary physics (e.g. SOLPS, UEDGE) and finite element analysis (e.g. ANSYS) tools, and validate using experimental data from relevant tokamaks and results from FY18-2. 3) Evaluate examples of discrete monitoring systems that are sufficient to capture the evolution of the PFCs relative to engineering limits. Compare the ability for different techniques (e.g. thermocouples vs. imaging) and technologies (e.g. near vs. long-wave infrared cameras) to achieve NSTX-U PFC monitoring objectives.

Mission Statement

Inter-shot monitoring or intra-shot control of heat flux to PFCs is anticipated for a range NSTX-U operating space, necessitating reduced models that can be run between shots or even in real-time. Monitoring requires a reliable instrumentation suite which can support or contradict model predictions and confirm PFC integrity.

- requirements for a monitoring system have yet to be specified by the Recovery Project or NSTX-U Operations
- R[12] response from Recovery to EoC #2:
  - "IR cameras will be deployed to monitor the tile temperature and as a minimum provide guidance for the execution of the subsequent shot."
  - "It is anticipated a PFC inter-shot monitoring system will be required for full-performance operations and the need for real-time PFC protection will depend on the design of the PFCs and on future operational experience."
- milestone will start building necessary computational tools and contribute to conceptual design of a instrumentation suite

Goal #1: Develop Reduced Models

Develop tools for pre-shot planning and confirmation of post-shot PFC thermal observations which use reduced models to predict time-evolving heat fluxes to shaped PFCs and estimate distances from engineering limits. Assess additional effort needed for implementation of reduced models in PCS

build PO's/SL's tools to reliably plan and run experiments within PFC limits without having to be boundary physics experts

- develop, or consider adapting existing community solutions (PFCFlux, SMARDDA), to predict heat fluxes to 3D surfaces
  - handle features like: shaped tiles, leading edges, bolt holes
  - ensure modeling can handle NSTX-U equilibrium needs: LSN/USN, SFDs, including power to all divertor legs, time evolution of sweeping
- develop simple engineering models of limits including surface/edge temperatures and thermal stresses ($T < T_{crit}$?, $\sigma < E\alpha\Delta T$?)

model will include values which we may not know or are extrapolating from NSTX, MAST, etc. (λ_q, S, pow. sharing)

Goal #2: Benchmark Reduced Models

Where feasible, benchmark reduced models against boundary physics (e.g. SOLPS, UEDGE) and finite element analysis (e.g. ANSYS) tools, and validate using experimental data from relevant tokamaks and results from FY18-2.

- verify reduced models for PFC heat fluxes against edge-plasma codes such as UEDGE, SOLPS (might need EMC3)
  - match input assumptions, confirm PFC heat loads and explore P_{RAD} estimates
- verify reduced models for PFC stress against engineering finite element analysis results used in the NSTX-U PFC design process.
- validate reduced models against experimental data available from relevant machines (e.g. NSTX, NSTX-U, MAST, or MAST-U) and from FY18-2
  - reduce uncertainties in key model parameters (e.g. λ_q, S, P_{RAD}, power splits),
  - specify power sharing for snowflake divertor legs based on those results, as well as TCV and/or DIII-D experimental results
  - not expected to support running experiments on other devices, but support effort to integrate results explored by team (i.e. separate MAST-U proposal, DIII-D work)

Goal #3: Scope Monitoring Systems

Evaluate examples of discrete monitoring systems that are sufficient to capture the evolution of the PFCs relative to engineering limits. Compare the ability for different techniques and technologies to achieve NSTX-U PFC monitoring objectives.

- compare thermocouple and IR based monitoring approaches
  - can we get away with just a LOT of TC's?
- compare NIR/MWIR/LWIR approaches for detecting hot spots and leading edges and what coverage is necessary
- compare limited resolution bolometry configurations to approximate total radiated power and 'zone' radiated power (core, edge, x-pt, strike points)

do necessary work to bring monitoring system to CDR assuming conventional diagnostic approaches

Milestone Activities Map to PFCR-WG Charges

FY18-1: Develop and Benchmark Operations-Focused Reduced Heat Flux and Thermo-Mechanical Models for use in PFC Monitoring

The NSTX-U Recovery Project will deploy new plasma facing components (PFCs) to meet updated heat exhaust requirements driven by a narrower scrape-off-layer width, increased heating power and longer pulse durations relative to NSTX. Inter-shot monitoring or intra-shot control of heat flux to PFCs is anticipated for a range NSTX-U operating space, necessitating reduced models that can be run between shots or even in real-time. Monitoring requires a reliable instrumentation suite which can support or contradict model predictions and confirm PFC integrity. The goals of this milestone will be accomplished in three major components: 1) Develop tools for pre-shot planning and confirmation of post-shot PFC thermal observations which use reduced models to predict time-evolving heat fluxes to shaped PFCs and estimate distances from engineering limits. Assess additional effort needed for implementation of reduced models in PCS. 2) Where feasible, benchmark reduced models against boundary physics (e.g. SOLPS, UEDGE) and finite element analysis (e.g. ANSYS) tools, and validate using experimental data from relevant tokamaks and results from FY18-2. 3) Evaluate examples of discrete monitoring systems that are sufficient to capture the evolution of the PFCs relative to engineering limits. Compare the ability for different techniques (e.g. thermocouples vs. imaging) and technologies (e.g. near vs. long-wave infrared cameras) to achieve NSTX-U PFC monitoring objectives.

1. ~~define which (additional) parameters need to be specified in an updated requirements document for the NSTX-U PFCs~~
2. facilitate generation of updated requirements utilizing:
   a) available reduced models, empirical scalings, boundary simulations
   b) ultimately, a validated model for specifying heat loads to all plasma facing components for arbitrary NSTX-U scenarios
3. in preparation for operations, develop:
   a) instrumentation plan for intra and inter-shot PFC monitoring
   b) a reduced model for heat loading for pre-shot planning
   c) guidance on how to best integrate monitoring with operations
   d) control, diagnostic requirements for real-time heat-flux control
4. work closely with engineers and analysts to develop and implement requirements

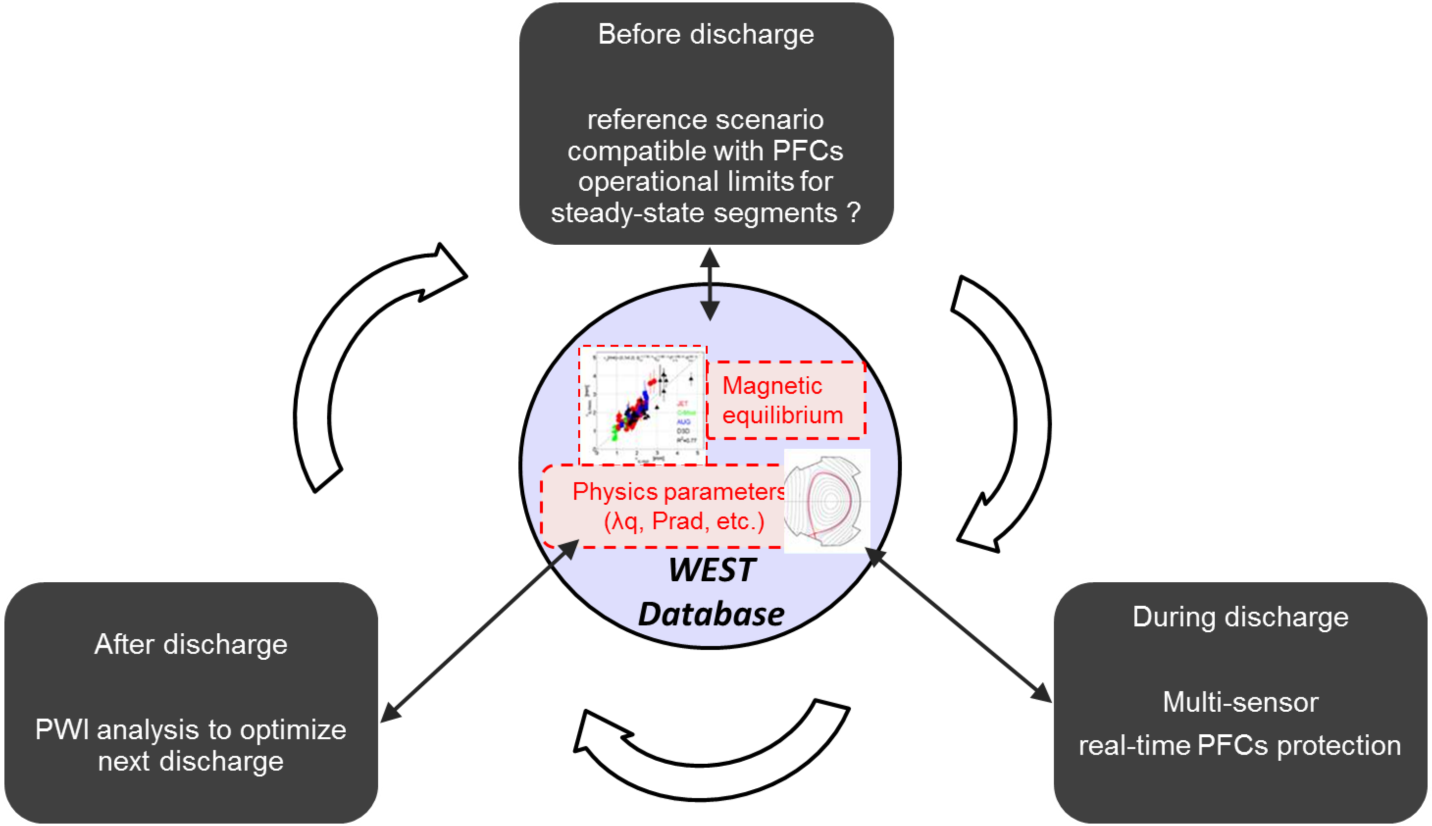
Initial Resource/Skill Estimates

- GOAL #1: Develop Reduced Models (45%)
  a) > 50%: code development/deployment, integration w/ CAD
  b) ~ 20%: plasma scenarios expert, NSTX-U physics operator
  c) ~ 20%: engineering analysis, design*
  d) < 10 % PCS expert
- GOAL #2: Benchmark Reduced Models (30%)
  a) ~35%: computational boundary modeling
  b) ~45%: engineering analysis*
  c) ~20%: boundary physics (involved w/ collaborations)
- GOAL #3: Scope Monitoring Systems (25%)
  a) ~30%: comparison of IR/TC approaches
  b) ~40%: diagnostician (imaging systems, IR)
  c) ~30%: diagnostician (bolometry)

**engineering need not be PPPL or be 'Engineering Department'*

EXTRA SLIDES

WEST “Wall Monitoring System”



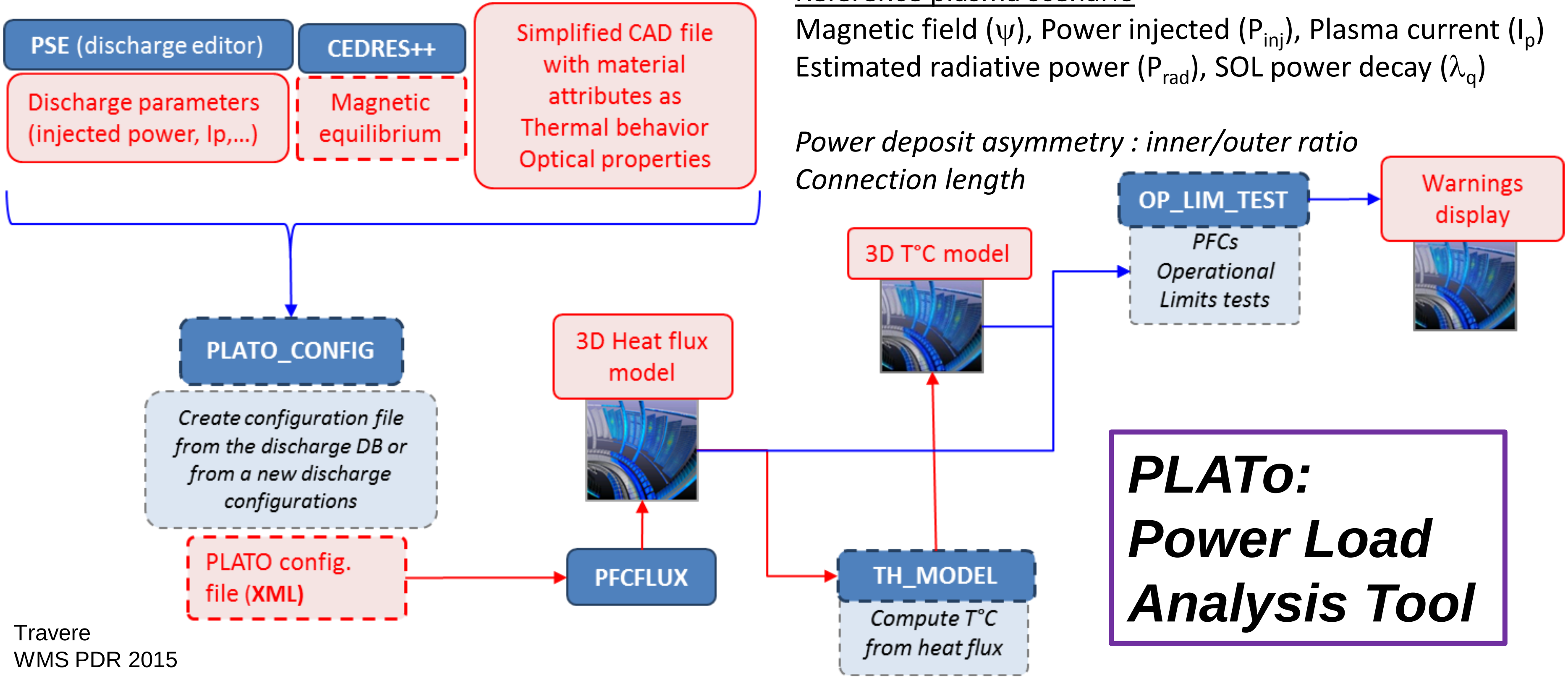
Travere
SOFT 2016

Pre-Pulse Check Against Material Limits: PLATo

<u>Reference plasma scenario</u>

Magnetic field (ψ), Power injected (P_{inj}), Plasma current (I_p)
Estimated radiative power (P_{rad}), SOL power decay (λ_q)

Power deposit asymmetry : inner/outer ratio
Connection length



PLATo: Power Load Analysis Tool

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WMS PDR 2015