National Spherical Torus eXperiment Upgrade

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SUBJECT: INITIAL GUIDANCE FOR EXAMINING UPGRADES NECESSARY FOR NSTX-U TO SUPPORT IMAGING SYSTEMS FOR REAL TIME CONTROL

Background
As part of the Recovery Project, NSTX-U will be designing new plasma facing components. These are expected to be a combination of temperature-limited and stress-limited designs, and temperature limited tiles may have a small margin before reaching allowable stress limits. As outlined in PCRF-MEMO-001, responding to Extend of Condition committee recommendations, the PFCR-WG suggested that "An intra-shot, PCS-based control system using real-time PFC temperature data should be considered only if tile designs in high heat flux areas remain stress-limited". The working group R18-1/1-G5 (see PFCR-MEMO-014) has a goal to "Determine necessary PCS enhancements for doing real-time control from imaging systems".

This MEMO outlines more detailed information to allow that activity to be carried out. The deliverable should be a written report, to be submitted as a PFCR-WG MEMO in mid/late August 2018. It should be assumed that any real-time imaging systems that will be developed for NSTX-U are to be used for plasma control purposes and are not protection systems.

There are two primary objectives for this work:
1) Review literature from existing examples of image-based real-time monitoring systems. Comment on whether their methods of integrating imaging data is compatible with NSTX-U PCS and operations environment (e.g. do we need to innovate or adapt?). Links are given below to begin this, please request more information as necessary if it is unavailable publically. I have some internal presentations that could be shared.
    a. JET: [1] [2] [3]
    b. WEST: [1]
    c. ASDEX Upgrade: [1] [2]
    d. W7-X: [1] [2] [3]

2) Outline upgrades necessary for PCS to be able to integrate two methods of data collection from the imaging system (defined below) for real-time control algorithms
    a. 'region of interest': Scalar information (e.g. maximum in a region, average, median) is delivered for a finite number (assume < 256) of sub-domains. Use of this data is expected to be simple, e.g. if scalar exceeds a set point, do pre-determined PCS action.
    b. 'full image': All imaging data is collected and available for use for PCS algorithm decision making. Use of data is expected to be

more intense and require shot-to-shot configurable image processing.

The level of rigor and detail should be such that a CDR would be possible with minimal additional research in FY19 (although likely a lot more paperwork!). Please comment on whether these solutions for image-based control for PFCs could be used for other diagnostic systems, e.g. spectroscopy.

A secondary goal, if sufficient time is available is to consider what near-term or emerging technology or data analysis methods may be available when NSTX-U resumes operations that would provide a substantial advancement beyond existing demonstrations of real-time control from imaging on tokamaks and stellarators.

Working Requirements for Imaging System
If NSTX-U decides to develop an image-based control solution, a full requirements document will be developed which will drive the design of the front-end optics and camera system(s). To drive decisions regarding how data from such a system could be integrated into NSTX-U, the scale and magnitude of possible imaging system must be defined. These represent possible requirements resulting system design choices.

A. To view all of the plasma facing components should require 4-8 distinct cameras
B. To observe surface temperature rises these cameras should frames rates of at least 60 Hz, but should not be greater than 240 Hz
C. To observe surfaces with sufficient resolution these cameras will have no less than 320 x 240 pixels but may have up to 1280 x 1024 pixels.
D. USB 3.0, Camera Link and GIG-E may be considered as possible mechanisms for data transfer from the camera. Cameras should assume to be connected to DAQ system by fiber-optic link.
E. Measurements should be available to PCS in less than 1/60 seconds (due to the relatively slow evolution of thermal 'problems').
F. All camera information must be able to be stored and available after the shot similar to standard image-based NSTX-U diagnostics (e.g. Plasma TV).
G. Calibration or configuration (e.g. hot pixel maps) information for the camera may evolve on a shot-to-shot basis and should be stored in MDSPlus.

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Record of Changes

Rev.	Date	Description of Changes
0	5/3/2018	Initial release for review
1	5/4/2018	Added clarifying details after discussion w/ K.E. and added links to literature for the machines.