Robotics Science & Technology for Burning Plasma Experiments

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Robotics Challenges in Burning Plasma Experiments

- Control and manipulation techniques for precise transportation and positioning of massive (both mass & volume) in-vessel and port mounted components.

- Remote measuring techniques for high precision alignment and damage assessment of plasma facing components.

- Remote viewing techniques for examination and troubleshooting of in-vessel components (in an environment of radiation, vacuum, high temperature, magnetic field, etc.).

- Cask-based transport systems with double-seal door for effective transfer of massive contaminated components for refurbishment.

- Remote tools for specialized applications such as lip-seal cutting and welding of port interfaces, cutting and welding by means internal to the pipe, cutting and welding vacuum vessel sectors, and hot-cell refurbishment of first-wall components.

*Items in italics are first order issues*
Examples of manipulation of massive payloads

JAERI In-Vessel
Transporter/Blanket
Module Demo

ORNL Next Generation
Munitions Handler
Burning Plasma Experiments require manipulation of massive components that is beyond state-of-the-art

**FIRE in-vessel transporter**
- Complete in-vessel coverage from 4 midplane ports
- Conflicting requirements: long reach, limited cross-section, high payload, high precision

**Other examples** include port assembly handling and VV / TF coil sector handling

**Divertor end-effector**
- Module weight ~ 800 kg
- Positioning accuracy of millimeters required
Manipulation of massive payloads involves significant scientific and technical challenges.

- The precision with which certain components in burning plasma experiments need to be manipulated is beyond the realm of the state of the art.
- R&D in non-linear mathematical modeling and advanced telerobotic control architectures are needed to advance into the DMHP domain.
- Development and implementation of human-in-the-loop control and remote manipulation of heavy payloads will be quite challenging.
Remote metrology and inspection of in-vessel components is another challenging area.
A technique using frequency modulated coherent laser radar (FM CLR) shows promise.

With linear modulation, frequency shift during round trip transit time is proportional to range.

Image of a dime rendered using range data obtained by laser scanning the surface from a distance of 4.2 m.

Range-based image of NSTX plasma facing surfaces.
Significant R&D issues remain before FM CLR can be used in burning plasma experiments

- Development and integration of scanning techniques compatible in burning plasma environment (particularly, high radiation, ultra-high vacuum, high temperature and high magnetic field).

- Higher measuring speeds (from the current rate of hundreds of points/s to several thousand points/s).

- Integrating techniques that are compatible with burning plasma in-vessel conditions for remote focussing and position sensing of the laser optical components.
Summary

• Efficient and reliable robotic techniques are crucial to the successful operation and for improved reliability and maintainability of a burning plasma experiment.

• Good progress has been made in connection with ITER and FIRE related robotics R&D in several areas.

• Dedicated R&D is needed at least in two areas of robotics science and technology to meet the needs of burning plasma experiment in a timely manner:
  – Dexterous manipulation of massive payloads
  – Remote metrology and viewing