Robotics Science & Technology for Burning Plasma Experiments

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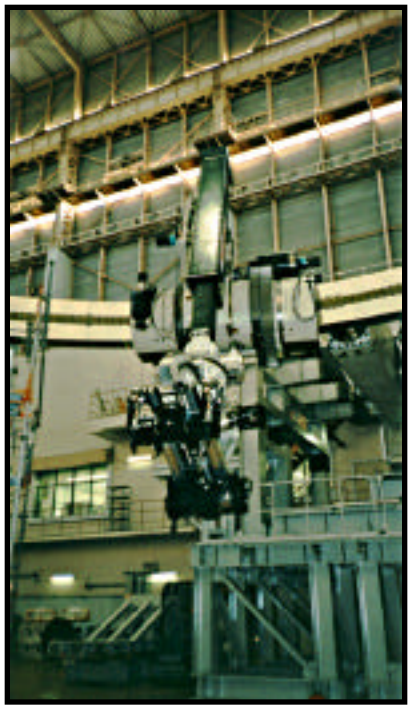
Robotics Challenges in Burning Plasma Experiments

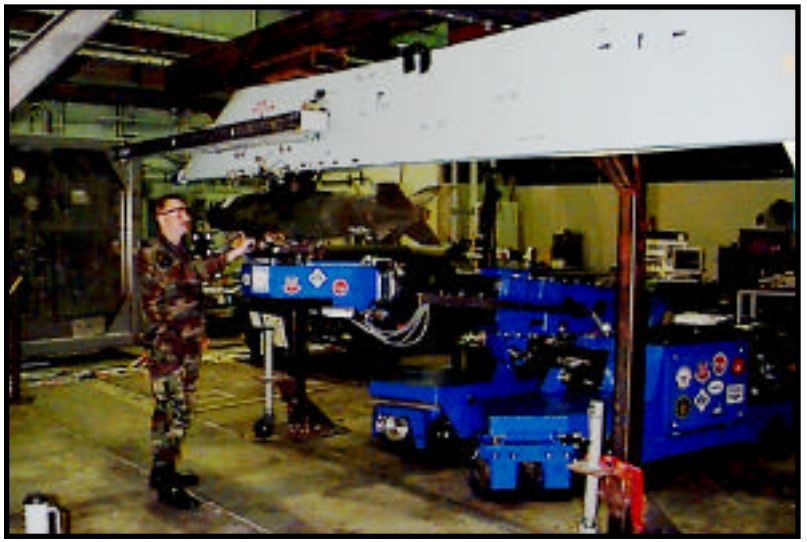
- ***Control and manipulation techniques for precise transportation and positioning of massive (both mass & volume) in-vessel and port mounted components.***
- ***Remote measuring techniques for high precision alignment and damage assessment of plasma facing components.***
- Remote viewing techniques 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

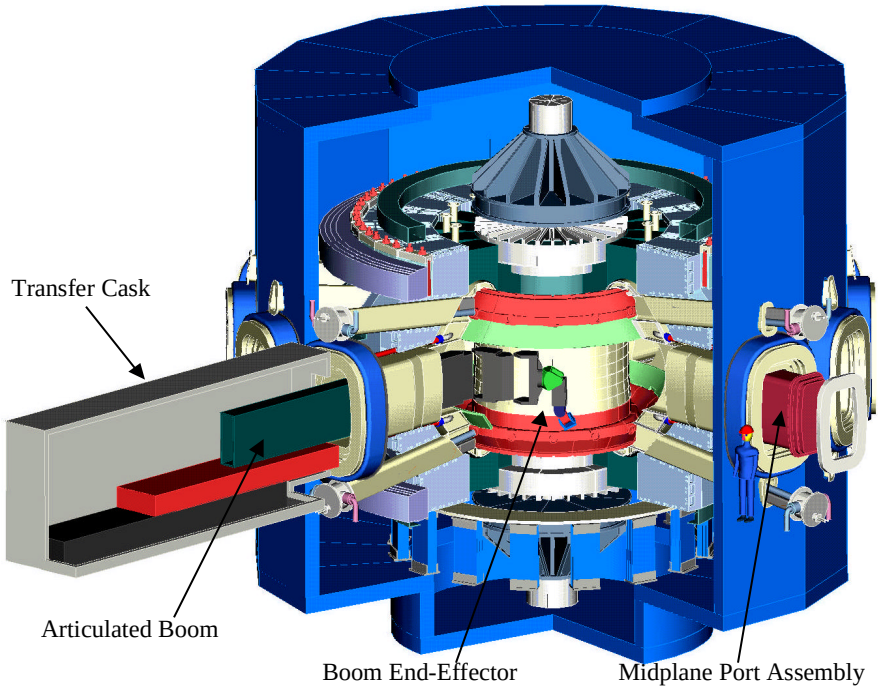
JAERI In-Vessel Transporter/Blanket Module Demo





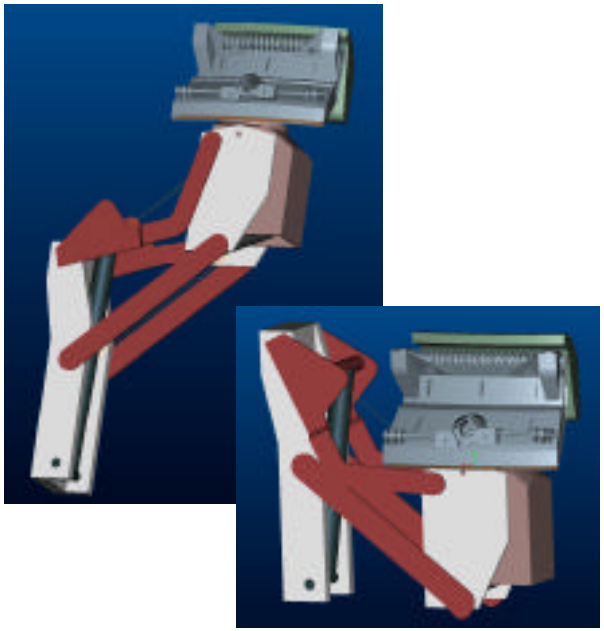
ORNL Next Generation Munitions Handler

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



Divertor end-effector

- Module weight ~ 800 kg
- Positioning accuracy of millimeters required

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

Manipulation of massive payloads involves significant scientific and technical challenges

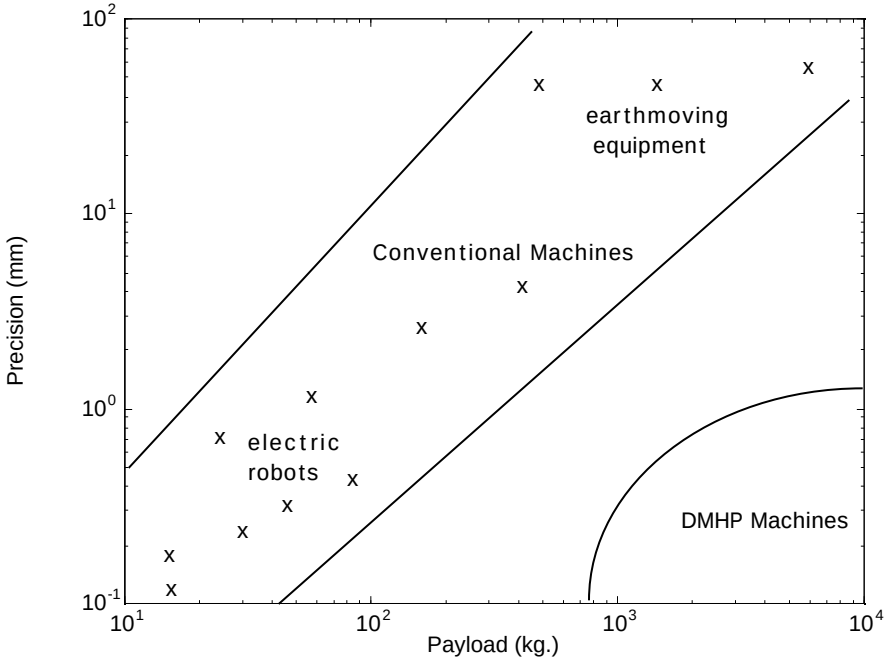
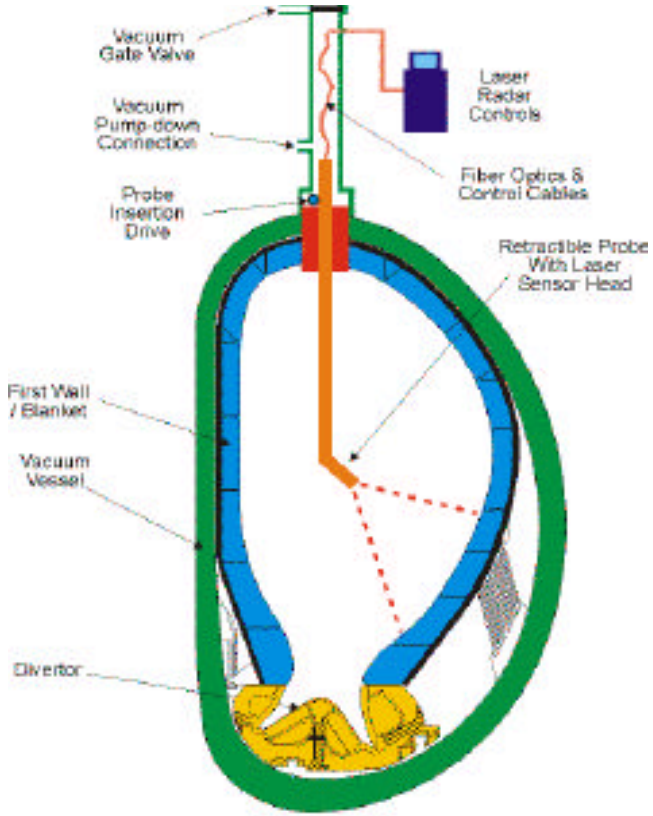


Figure showing the DMHP (dexterous manipulation Of heavy payloads)

- 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.



Schematic of the CLR Inspection Scheme

A technique using frequency modulated coherent laser radar (FM CLR) shows promise

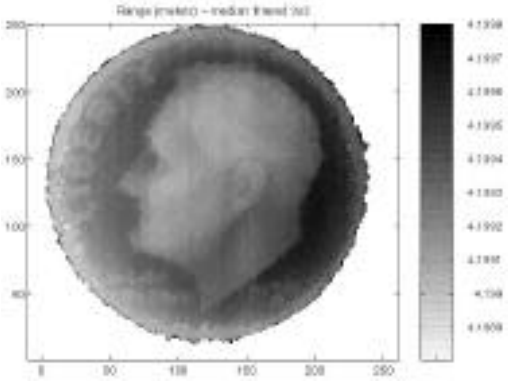
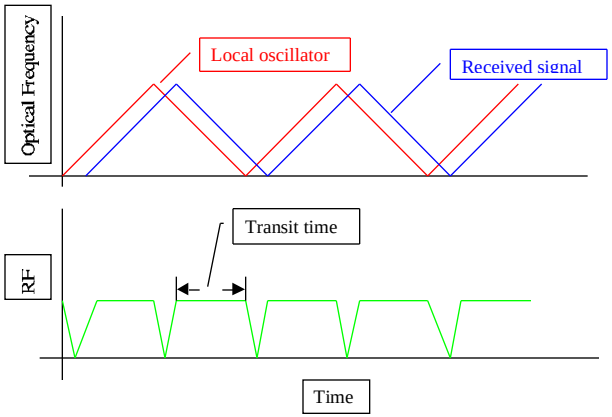
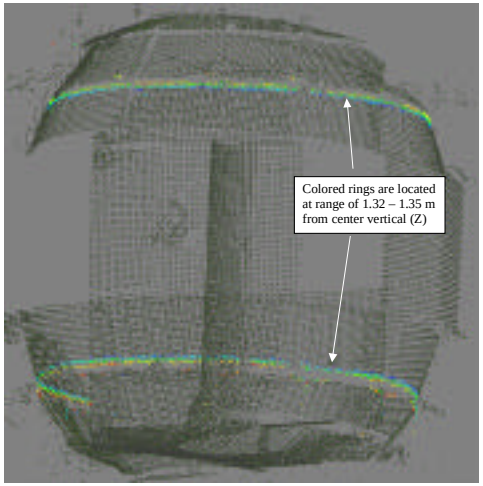


Image of a dime rendered using range data obtained by laser scanning the surface from a distance of 4.2 m



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



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