A Comprehensive Design of the Upper Port #18 Interspace Support Structure for the ITER Diagnostic Port

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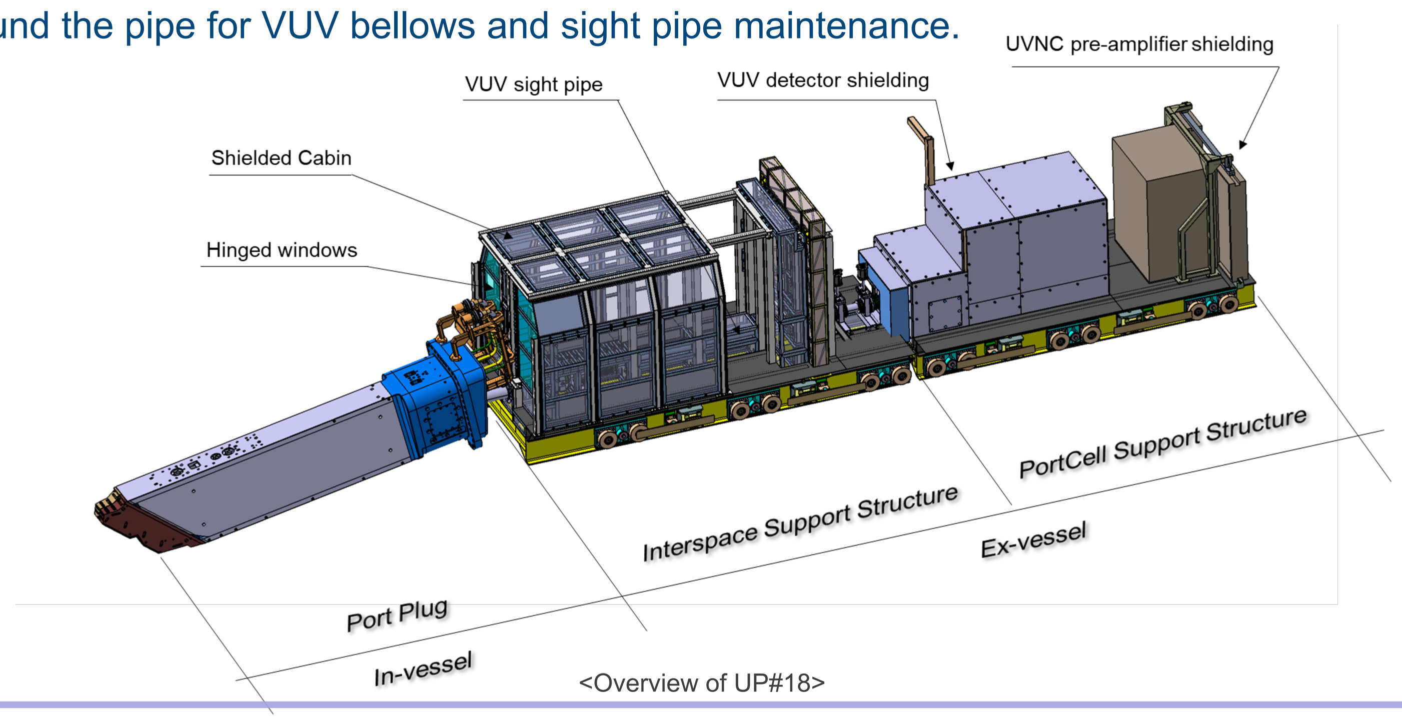
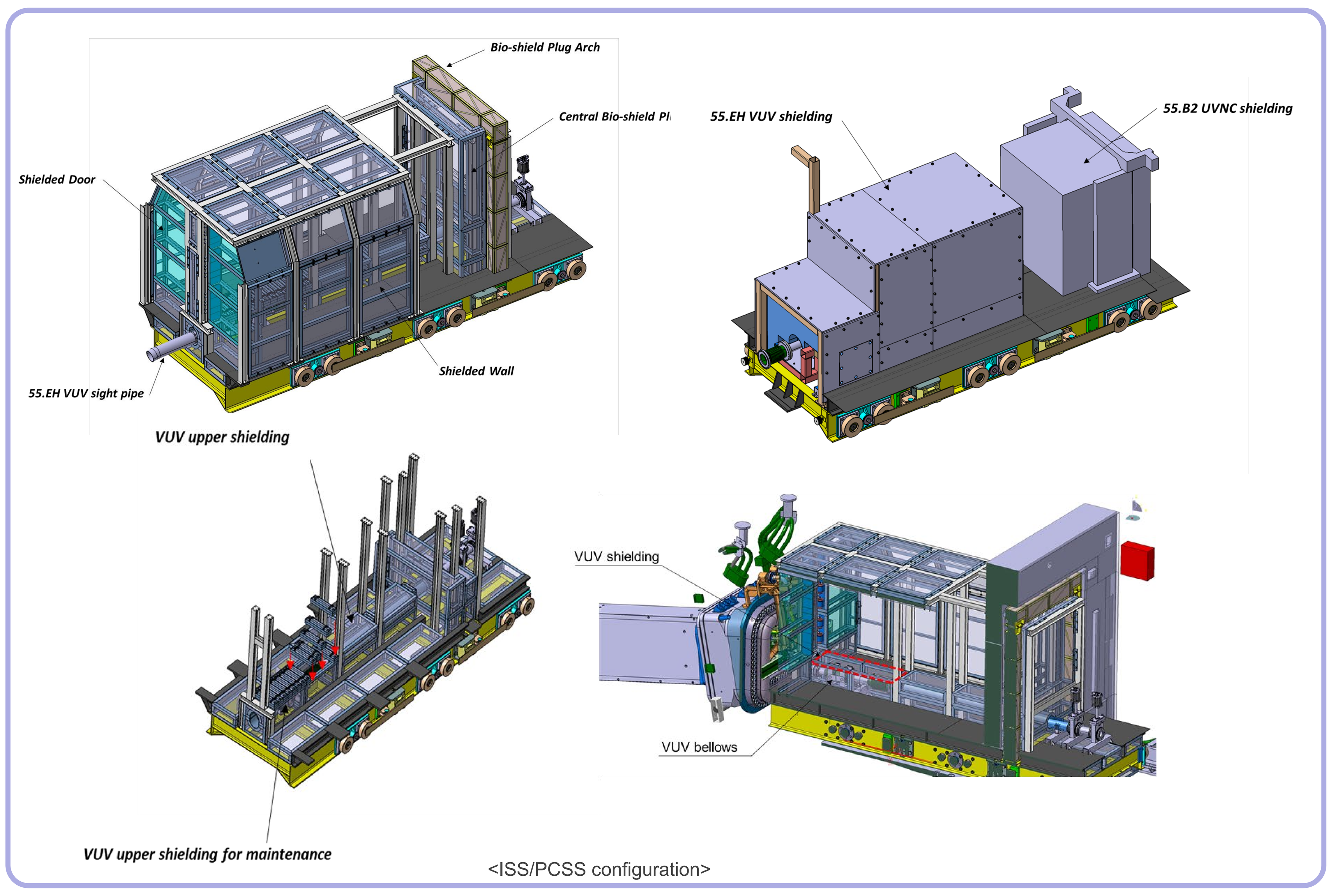
ABSTRACT: The paper describes the design strategy and results for the ex-vessel components of Upper Port #18 (UP #18) for ITER diagnostics to integrate tenant diagnostics and to ensure overall design considerations. The ITER diagnostic port is divided into two main areas. One is the integrated port plug, in-vessel component, is equipped with diagnostic first wall (DFW) and diagnostic shield module (DSM) which has a role of neutron shielding and of diagnostic safety. The other area is interspace and port cell which is located at the outside of the vacuum vessel. Interspace support structure (ISS) and port cell support structure (PCSS) are installed in the area. The diagnostic electronics and detectors are also located in this area, away from the plasma, to protect the equipment from nuclear radiation. During the maintenance phase, the shut-down dose rate (SDDR) should be controlled to check the diagnostic status or to replace the diagnostic by hand. The ISS/PCSS structures are mounted on permanent remote handling rails. The ISS/PCSS structures are detached from the rails and each structure is removed with a trolley when maintenance is required. Therefore, the final design of the ISS needs to be done from the perspective of neutron and gamma shielding for the human passage area, structural integrity, cooling performance, and maintainability.

Design Strategy

- To meet the ITER SDDR requirements of 100 μSv/hr after 10^6 seconds from shutdown in the interspace area, a shielded cabin concept has been adopted for the UP #18 ISS.
- Borated heavy concrete panels will be installed on the ISS frame. The human passage is fully shielded to minimize SDDR. This provides access to the interior of the shielded cabin for maintenance of diagnostics. The front-hinged windows can be opened to access the port plug components. These can be opened separately to minimize occupational radiation exposure when handling the port closure plate components. Removable shield blocks are installed around the pipe for VUV bellows and sight pipe maintenance.



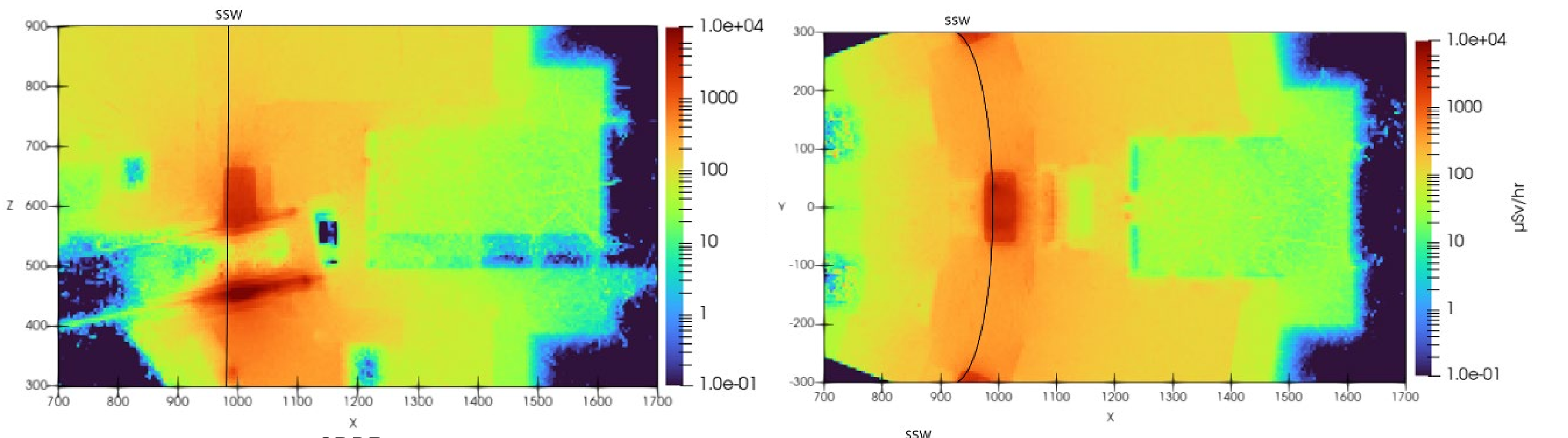
<Overview of UP#18>



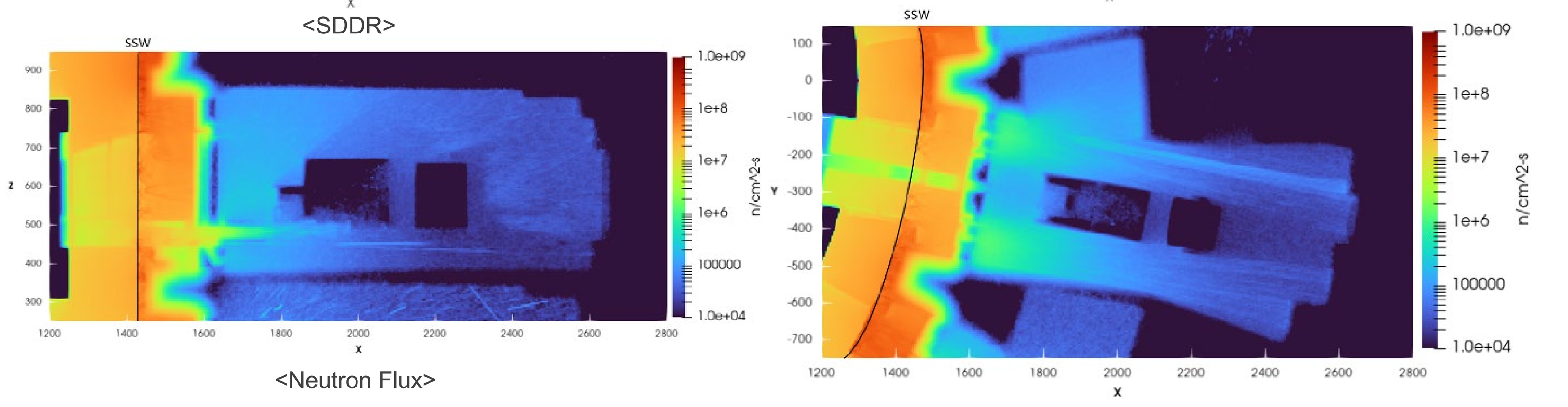
<ISS/PCSS configuration>

Neutronics

- A neutronic analysis was conducted to estimate the SDDR at the human passage inside the shielded cabin. The neutron source employed in this study was a standard plasma source with a fusion power of 500 MW, as described in the MCNP ITER C model. Neutron analysis was conducted using D1S-UNED v3.1.4 with the FENDL 3.1 cross-section library.
- The SDDR distribution of Interspace. It shows that the SDDR is less than 100 μSv/h which meets the ITER requirement. The flux and SDDR were calculated in Interspace and Port Cell. The SDDR in the maintenance for VUV double bellows in Interspace are 42.5 μSv/h and 42.1 μSv/h.
- the neutron flux distribution in Port Cell area of UP #18. The neutron streaming is observed in a gap of the central shielding and VUV sight pipe. The neutron streaming is also observed within the bio-shield plug. The maximum neutron flux in the Port Cell is ~ 10^6 n/cm²/s, and the neutron flux is decreased as the distance from the bio-shield increases.



<SDDR>

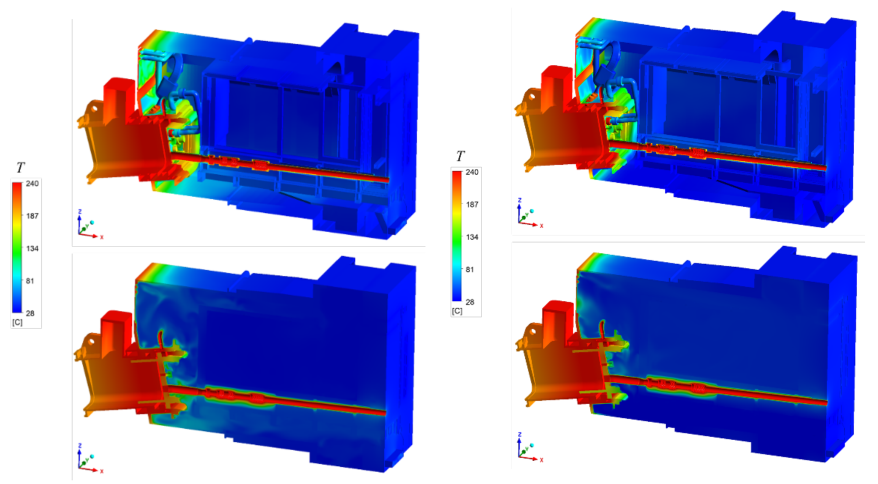


<Neutron Flux>

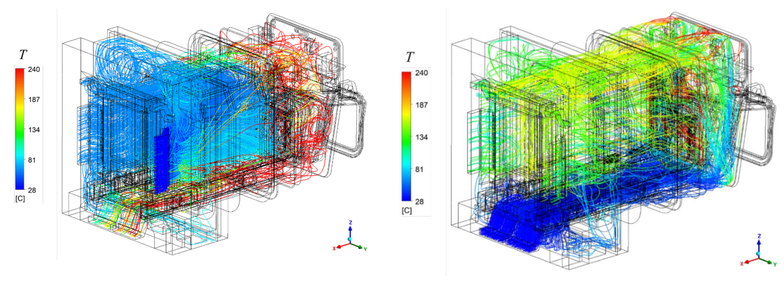
Thermal Fluid Dynamics

- CFD analysis has been performed to estimate the thermal–hydraulic characteristics in the Interspace area, including mean velocity, total pressure, temperature, heat flux and wall heat transfer coefficient. The considered loads are the flow rate and the temperature at inlet face.

	Total pressure Drop	Total heat transferred	Outlet temperature	ISS temperature
Case 1	55.5 Pa	7,330 W	34.3 °C	33 °C
Case 2	26.4 Pa	12,205 W	42 °C	38.3 °C



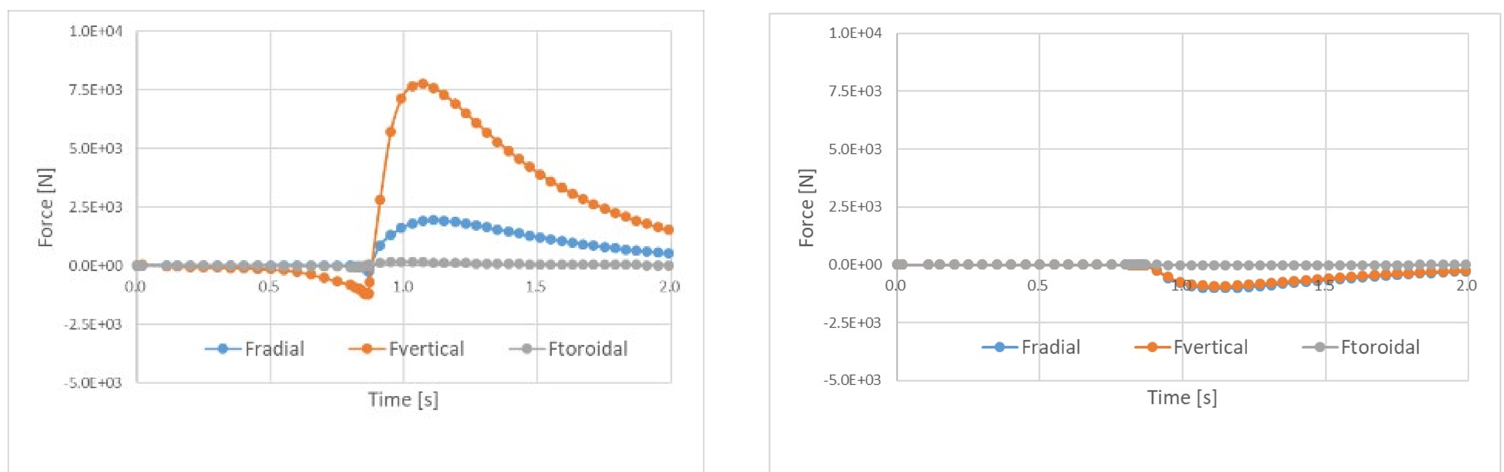
<Temperature Distributions>



<Stremline>

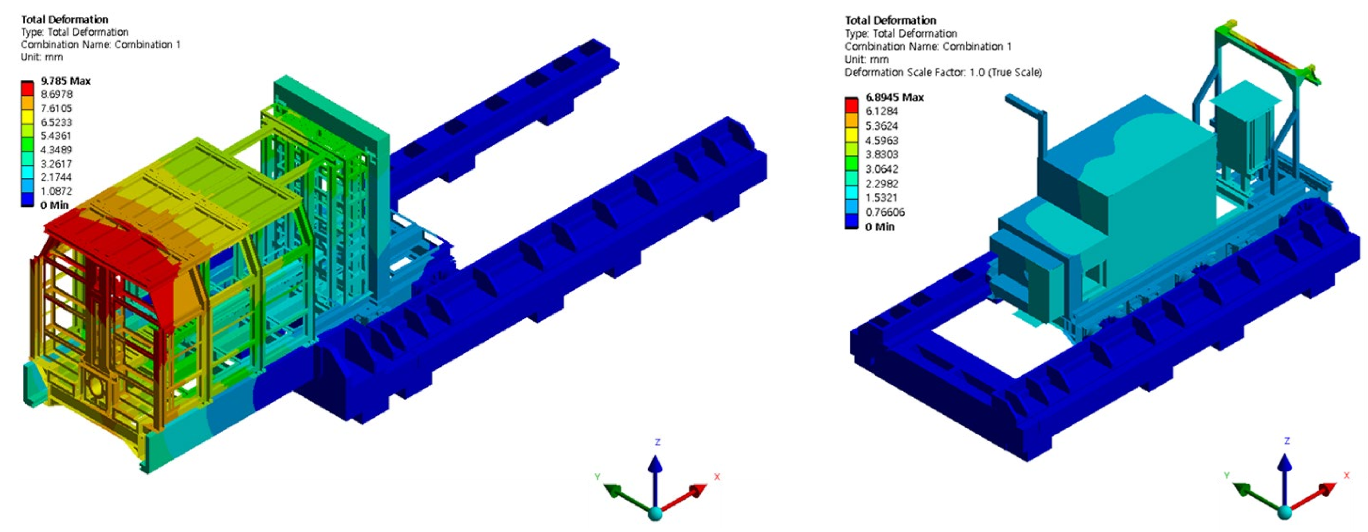
Electromagnetic

- In order to calculate the electromagnetic load on the ISS/PCSS, a detailed analysis has been performed using Ansys Emag solver. The subsequent results are displayed under the VDE UP 36ms scenario (Upward Fast Vertical Disruption Event with linear 36ms current decay), representing the worst disruption scenario.



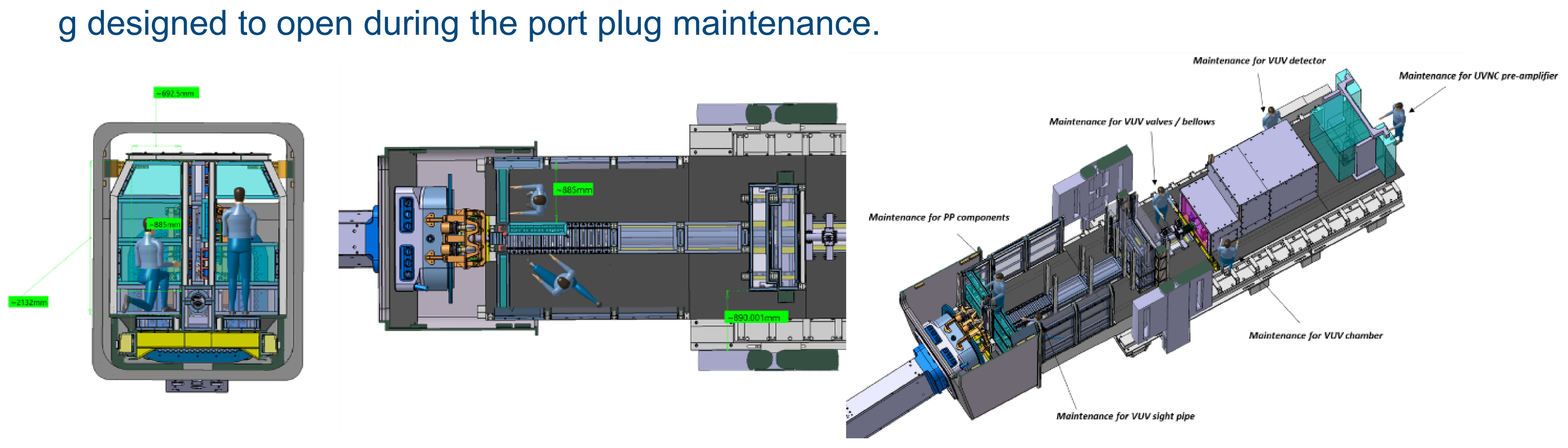
Structural Integrity

- The structural analysis presented in this paper aims to assess the structural evaluation of the shielded cabin with ISS. This evaluation was carried out in accordance with the RCC-MR (2007) code. The integrity of structures using the H-beam meets the design allowable stress under the ITER's severe load conditions.



Maintenance

- The implementation of the maintenance corridor in the Interspace and Port Cell zone is demonstrated. In order to gain access to the diagnostic components during maintenance operations, it may be necessary to remove the ISS shielding panels. It is evident that the shielding panels have been permanently installed on the ISS frame. It is, therefore, the case that the front hinged doors are being designed to open during the port plug maintenance.



ACKNOWLEDGEMENTS: This work was supported by the Ministry of Science and ICT of Korea, through the ITER project contract (RS-2022-00154842). The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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