# STEP INBOARD SYSTEM – ARCHITECTURE AND TECHNOLOGY DEVELOPMENT OVERVIEW

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## 1. INBOARD DESIGN

The design of inboard build is a fundamental challenge for the STEP Prototype Plant (SPP). The spherical tokamak geometry of the SPP means the inboard radius drives the size, and hence overall cost, of the machine [1]. The SPP Inboard System, shown in Fig. 1, protects the central column magnets from heat, particle, and neutronic loads while using this captured energy for power generation. Innovative designs and novel technologies are needed for the SPP Inboard System to fit within stringent spatial constraints, particularly considering the complex integration with magnet systems.

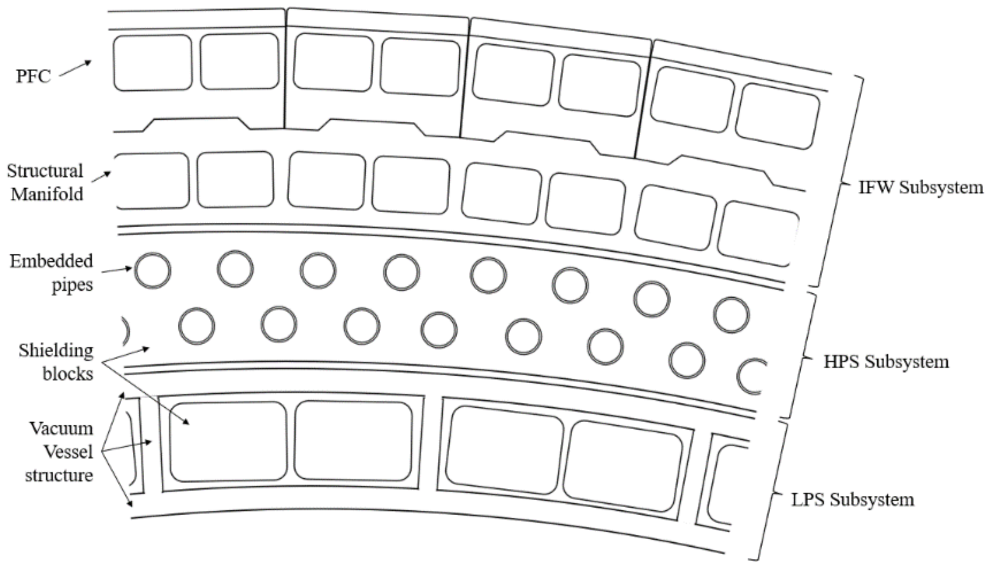


*Figure 1: Cross-sectional view of the STEP Inboard System architecture*

The design approach addresses these challenges through three subsystems. The Inboard First Wall (IFW) manages plasma heat and particle loads using long, slender Plasma-Facing Components (PFCs) supported by a Structural Manifold. A High-Pressure Shield (HPS) system surrounds the IFW, employing shielding blocks with embedded cooling pipes to attenuate neutrons and manage volumetric heating. The Low-Pressure Shield system provides additional neutron attenuation through shielding blocks housed within the vacuum-vessel structure's cooling channels, working to meet magnet lifetime requirements. Detailed analysis continues to refine the design, balancing structural performance with shielding requirements. The established spatial allocations undergo evaluation through a developing parametric workflow, with particular attention to magnet protection requirements. This work explores opportunities to optimise shielding materials and configurations while maintaining structural integrity and cooling effectiveness throughout the system.

Design integration considerations include thermal management, structural integrity, and maintenance accessibility. The design accommodates differential thermal expansion between components while maintaining precise geometric tolerances. Assembly sequences and maintenance procedures influence key design features, particularly at system interfaces. This holistic approach ensures operational requirements are met while enabling practical implementation of the complete system.

## 2. INBOARD TECHNOLOGY DEVELOPMENT

The SPP Inboard System design includes a number of low TRL aspects. Successful realisation of the SPP Inboard System requires technology development activities to addressing these aspects. Key technology develop challenges include characterisation of relevant materials, development of reliable manufacturing and joining methods and high heat flux testing of PFCs. Recent technology developments with industrial partners have addressed some of these challenges and increased confidence in the engineering design.

Results from manufacturing trials will be presented regarding forming of both metallic and ceramic shielding blocks (Fig. 2), embedding steel pipes into shielding blocks, tungsten tile to CuCrZr joining and fabrication of thick-walled vacuum vessels. Results from materials activities on synthesising novel shielding material compositions and characterising the behaviour of shielding materials, including under irradiation, will also be presented. Work has also been done on research collaboration with non-fusion radiation shielding applications. An overview of planned future technology development activities will also be presented.

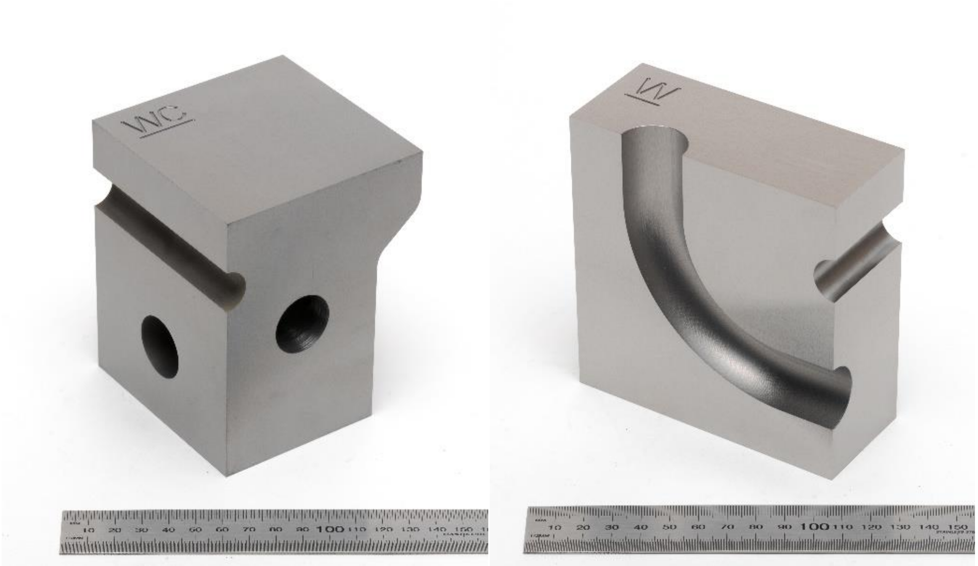


*Figure 2: STEP inboard tungsten shield manufacturing demonstrator parts*

## ACKNOWLEDGEMENTS

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## REFERENCES

[1] BAKER, A., "The Spherical Tokamak for Energy Production (STEP) in context: UK public sector approach to fusion energy", Philosophical Transactions A 382, no. 2280 (2024): 20230401