

Abstract

The Siam Photon Source II (SPS-II) is Thailand's next-generation 3 GeV synchrotron light source, currently undergoing detailed design and preparation for the construction of the accelerator facility. The facility comprises a 270 MeV linear accelerator, a 3 GeV booster synchrotron, a 3 GeV storage ring designed to achieve an electron beam emittance of less than 1 nm·rad, and beamlines. A robust alignment network is essential for achieving high-precision component installation, accurate verification, long-term positional stability, and reliable future realignment.

This paper presents the design of the SPS-II alignment network developed to support the installation, alignment, and maintenance of the accelerator complex. The proposed system comprises a three-level hierarchical reference network: the Ground Control Network, the Primary Network, and the Alignment Network. These networks are established using floor and wall monuments distributed throughout the accelerator tunnels and experimental areas to achieve the required positioning accuracy of ± 0.1 mm.

A laser tracker system is employed as the primary instrument for high-precision three-dimensional measurements of the alignment network. The measurement data are subsequently processed, and the network is adjusted using the Unified Spatial Metrology Network (USMN) algorithm implemented in Spatial Analyzer (SA) software. This integrated measurement and adjustment approach enables the establishment of a consistent, accurate, and reliable three-dimensional coordinate reference system.

The proposed network supports the installation process, including pedestal positioning and installation, girder-magnet assembly installation, alignment, and periodic verification of component positions. In addition, the network serves as a reference frame for integrating survey data throughout the installation, commissioning, operation, and future maintenance phases, enabling the synchrotron light source to maintain the required positioning accuracy and long-term operational stability.

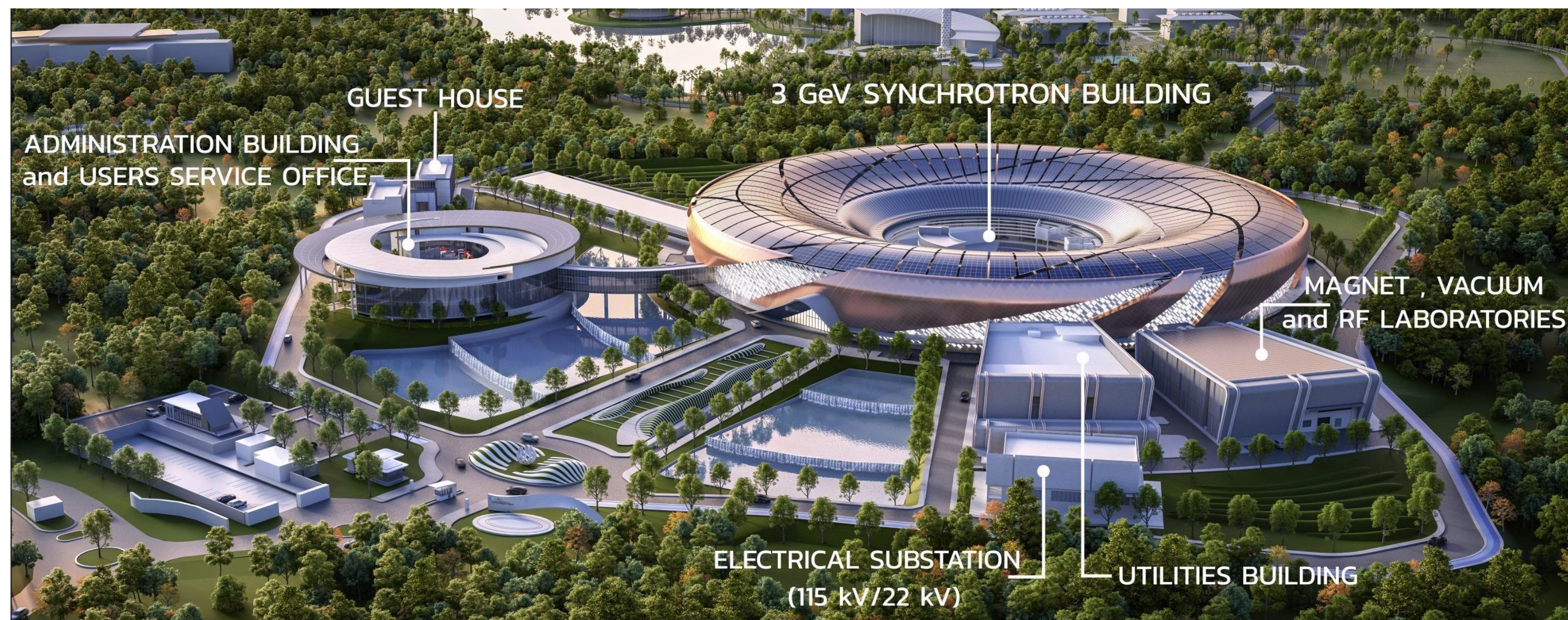


Figure 1: Overview of the Siam Photon Source II facility

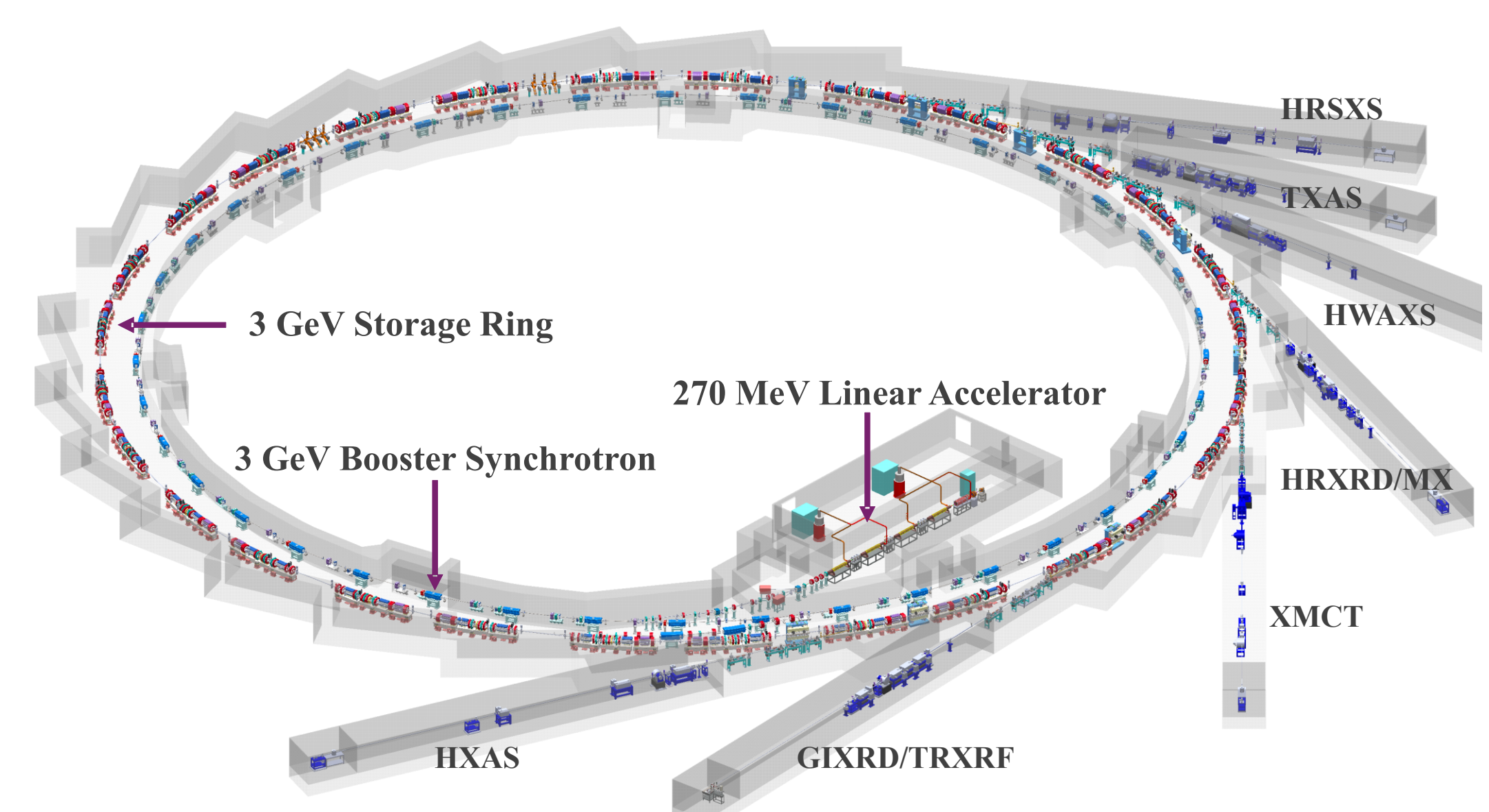


Figure 2: Overview of the SPS-II accelerators Complex

01 Alignment Network Design

The 327.6 m circumference storage ring, which comprises 14 DTBA cell, errors introduced during individual alignment stages may propagate and accumulate. A hierarchical network of permanent floor and wall monuments (see Figure 3) therefore provides a common 3 level reference framework, with the Alignment Network at the highest precision. Common points between adjacent stations maintain coordinate consistency and provide sufficient redundancy for uncertainty evaluation.

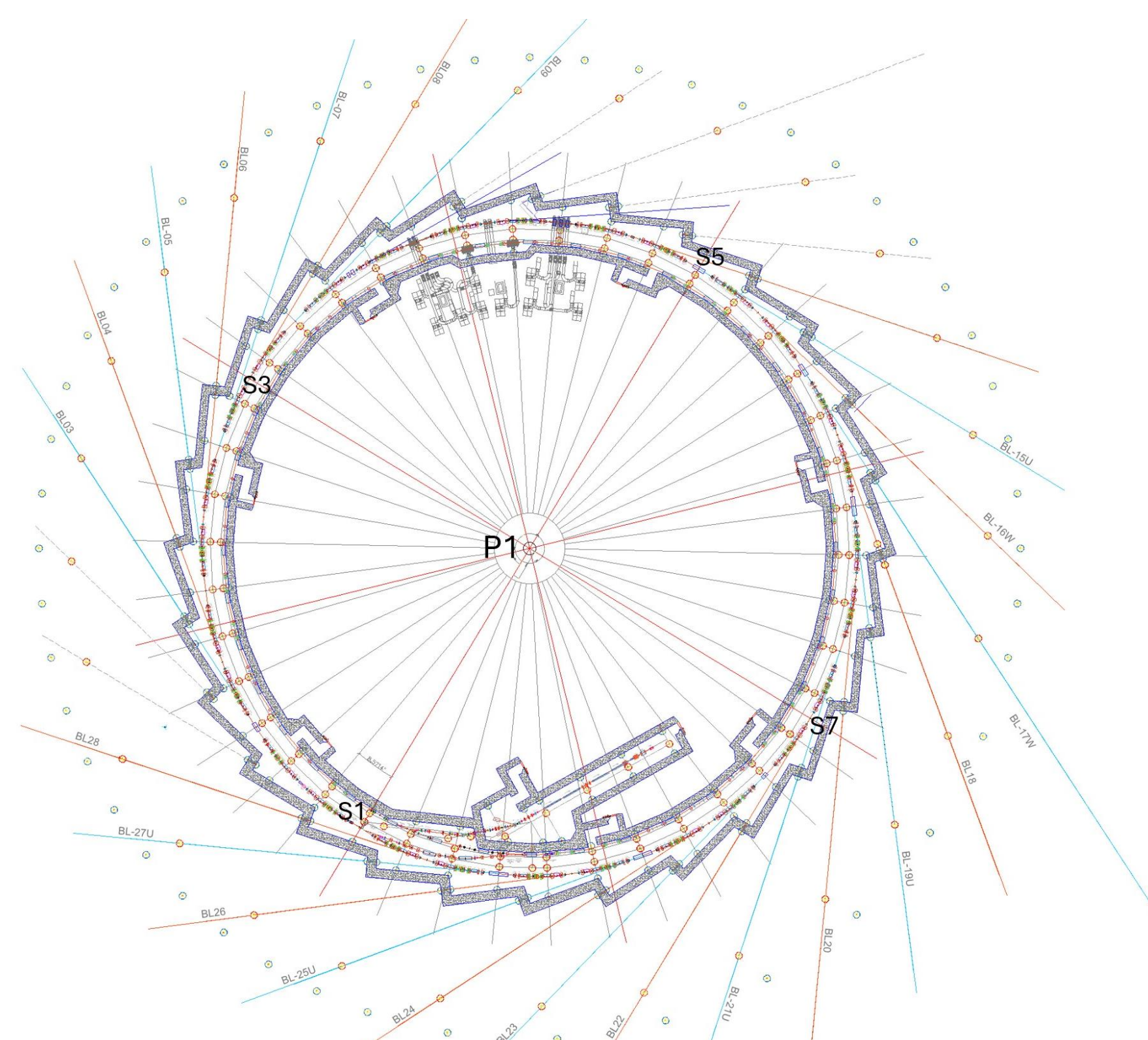
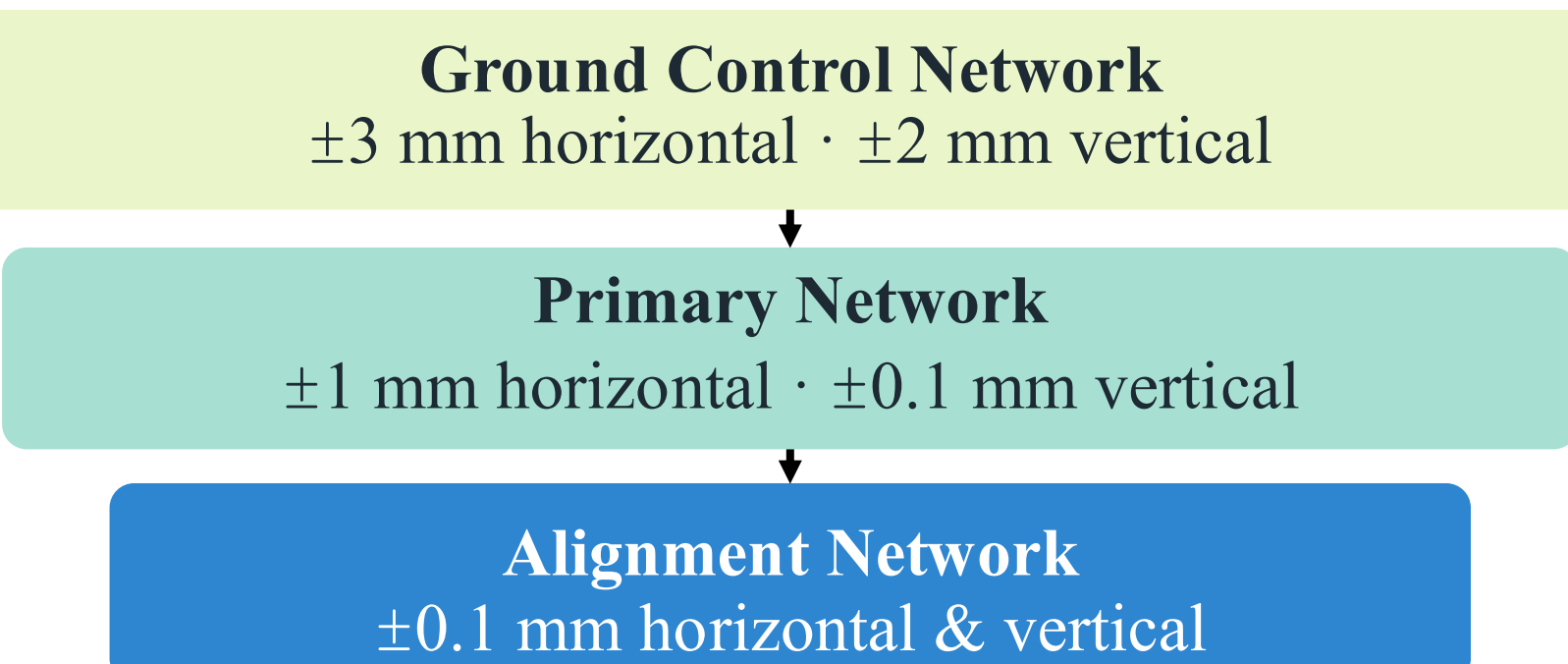


Figure 3: Layout of alignment network design

02 Uncertainty Simulation

A Storage ring simulation in SA/USMN (Weighted Least-Squares) compared four measurement-station configurations (see Figure 4, Table 1). Stations were arranged sequentially with overlapping common points, including instrument uncertainties and line-of-sight constraints.

Case 1 Free station **U_{mag} (max) 0.1526 mm**

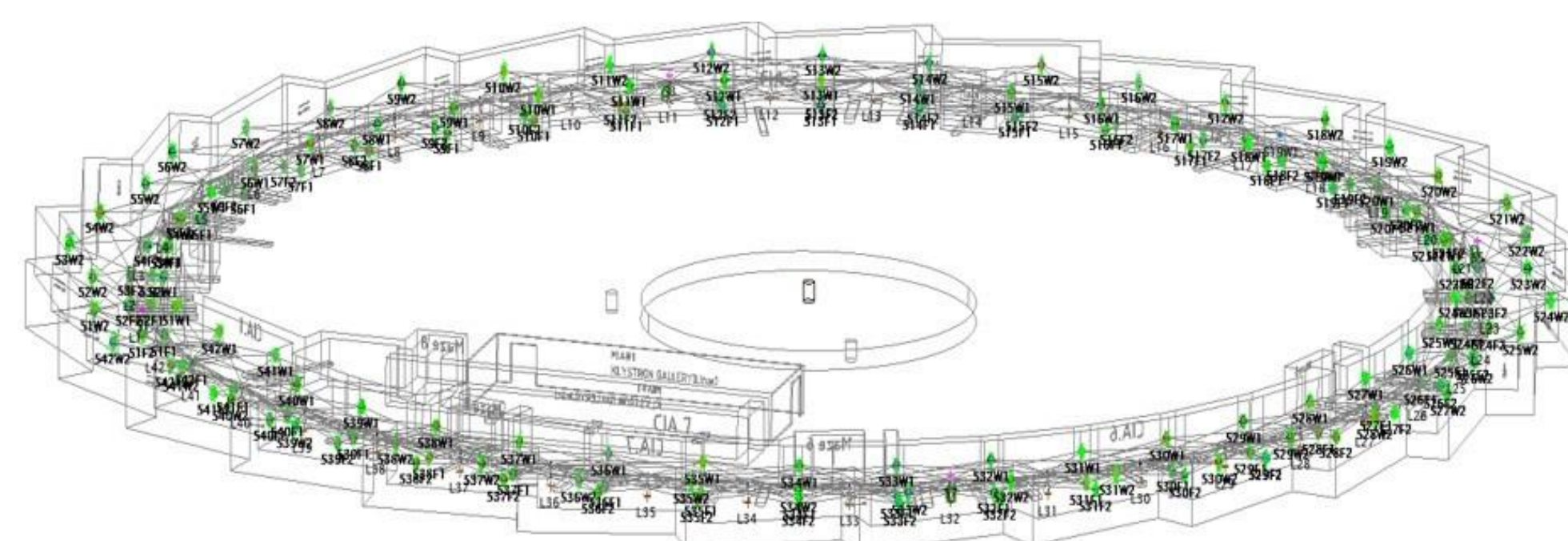


Figure 4: Simulated uncertainty of the Alignment Network

Table 1: Simulation Results Uncertainty for Alignment Network

Case	Fix Station	U _{mag} (Max), mm
1	Free station ★	0.1526
2	Station Fix: S1	0.9228
3	Station Fix: P1	0.3920
4	Station Fix: S1, S3, S5, S7	0.0905

Case 1 (Free Station): maximum uncertainty of 0.1526 mm.
Cases 2 and 3: a single constrained station, resulting in higher uncertainties of 0.9228 mm and 0.3920 mm.
Case 4: four stations (A:S1, S3, S5, S7) at 90° intervals limit error accumulation, achieving the lowest uncertainty (0.0904 mm) within ± 0.1 mm; any station disturbance would propagate as a systematic bias.
Case 1 is more robust: free-network adjustment distributes residuals across the whole network, although it exceeds ± 0.1 mm.
Decision: limited to a one-cell prototype, Case 1 was adopted as the baseline for methodology validation, with refinement planned for full scale (see Fig. 4).

03 Prototype & Field Measurement

DTBA cell prototype was built in the Pilot Plant (see Figure 5), with reference points and stations defined according to the simulated configuration (see Figure 6). Measurements used a laser tracker Leica AT500, with emphasis on common points shared with adjacent stations, and were processed in SA/USMN. The procedure was repeated at three different time periods (see Table 2).



Figure 5: DTBA cell prototype and laser tracker setup in the pilot plant

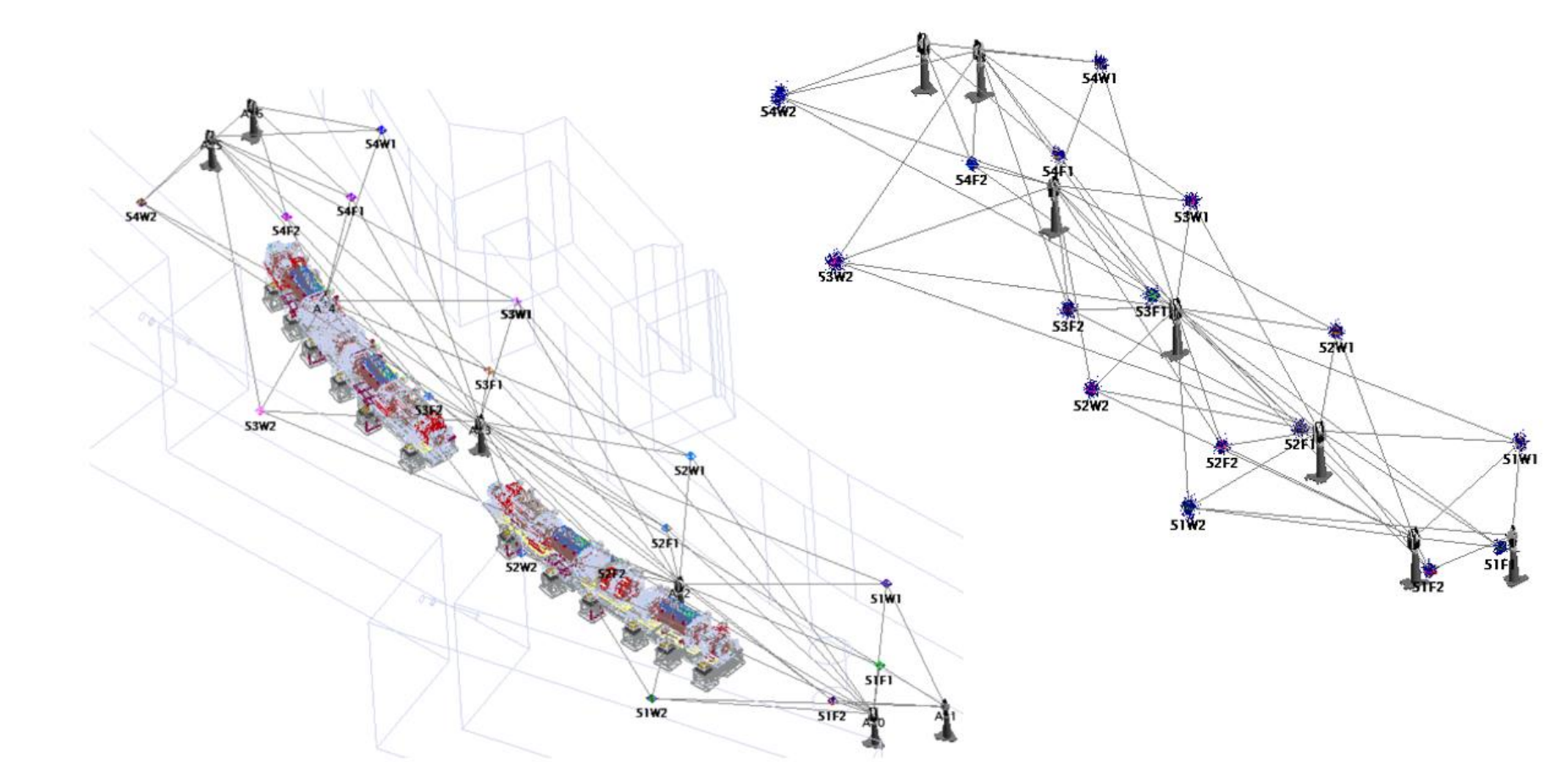


Figure 6: Measurement station configuration and reference point connectivity in the DTBA cell prototype

04 Simulation & Measurement

Tables 2 : Prototype Simulation and measurement

Parameter	Sim. (mm)	Meas. 1 (mm)	Meas. 2 (mm)	Meas. 3 (mm)
Overall RMS	0.0262	0.0968	0.1090	0.1017
Avg. Point Error	0.0171	0.0571	0.0675	0.0621
Max. Point Error	0.1093	0.4049	0.5160	0.4714
Avg. Uncertainty	0.0260	0.0188	0.0191	0.0175
Max. Uncertainty	0.0332	0.0251	0.0261	0.0233

As summarized in Tables 2, field RMS and point error exceeded the idealized model, while uncertainty stayed consistently below the simulation: the simulation is a conservative estimate. Larger field point errors did not translate into proportionally larger coordinate uncertainty.

05 Conclusion

- The SPS-II Alignment Network has been developed as a three-level hierarchical reference framework, integrating a Laser Tracker system with the **USMN algorithm in Spatial Analyzer (SA)** for network adjustment and uncertainty evaluation.
- The four-station constrained configuration achieved **0.0904 mm, satisfying ± 0.1 mm**. Although the Free Station configuration's uncertainty of **0.1526 mm** exceeds the specified tolerance, it was selected for field implementation for its flexibility to site and line-of-sight constraints, robustness to localized point instability, and freedom from fixed-station systematic bias.
- Three independent measurement sessions on the prototype yielded maximum uncertainty magnitudes of **0.025, 0.026, and 0.023 mm**, all substantially below the specified tolerance and showing strong consistency.
- The proposed Alignment Network provides a stable and reliable three-dimensional coordinate reference framework. Future work will extend the network to larger sections and investigate the effects of temperature variation and structural vibration on long-term stability.