

Hardware and Software for Location Computation Workshop (WIPHAL 2026): Preface

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Abstract

Positioning, Navigation, and Timing (PNT) technologies are undergoing rapid transformation driven by the emergence of Low Earth Orbit (LEO) constellations, signals of opportunity, advanced sensor fusion techniques, resilient navigation architectures, and novel application domains ranging from intelligent transportation to autonomous robotics. These developments create new opportunities for improving positioning accuracy, robustness, scalability, and availability while also introducing significant technical challenges. The Workshop on Work-in-Progress in Hardware and Software for Location Computation (WIPHAL 2026), co-located with the International Conference on Localization and GNSS (ICL-GNSS 2026), provides a venue for researchers and practitioners to present ongoing work, early-stage results, experimental platforms, and emerging concepts in localization and navigation systems. The workshop particularly encourages the discussion of innovative hardware and software approaches that have the potential to shape future PNT solutions. The 2026 edition received nine submissions, each evaluated through a peer-review process involving three independent reviewers. Following the review process, seven papers were accepted for publication and presentation. The accepted contributions address a broad range of topics, including cellular signals of opportunity for navigation, LEO-based PNT systems, mitigation of GNSS spoofing and multipath interference, distributed monitoring architectures, reconfigurable radio-frequency front-ends, robotic wilderness navigation, and high-accuracy smartphone positioning for intelligent transportation systems. Collectively, the papers included in this volume illustrate current research trends and emerging technological directions at the intersection of localization, navigation, wireless communications, and signal processing, highlighting both ongoing challenges and promising opportunities for future research and development.

Introduction

Welcome to the 2026 edition of **WIPHAL: Work-in-Progress in Hardware and Software for Location Computation**, held in Rome, Italy, as a workshop co-located with both the **International Conference on Localization and GNSS (ICL-GNSS 2026)** and the **International Conference on Indoor Positioning and Indoor Navigation (IPIN 2026)**. By bringing together the communities represented by these two leading conferences, WIPHAL provides a unique venue for exchanging ideas across satellite navigation, terrestrial positioning, indoor localization, and emerging hybrid positioning technologies.

WIPHAL serves as a forum for researchers, practitioners, and industry experts working on localization, navigation, and positioning technologies. The workshop particularly emphasizes work-in-progress research, enabling participants to present early-stage results, novel concepts, experimental platforms, and emerging system architectures that may not yet be sufficiently mature for larger conference venues but nevertheless offer significant potential for future scientific and technological impact. Through open discussion and constructive feedback, the workshop aims to accelerate the development and maturation of innovative positioning solutions.

WIPHAL'26: *Work-in-Progress in Hardware and Software for Location Computation, co-located with the International Conference on Localization and GNSS (ICL-GNSS 2026), October 5–8, 2026, Rome, Italy*

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The workshop brings together contributions addressing both hardware and software aspects of location computation. Topics of interest include Global Navigation Satellite Systems (GNSS), Low Earth Orbit Positioning, Navigation, and Timing (LEO-PNT), Signals of Opportunity (SoOP), wireless localization, sensor fusion, resilient navigation, positioning security, localization algorithms, environmental monitoring, autonomous systems, and emerging applications requiring accurate and reliable positioning capabilities. Particular attention is given to interdisciplinary approaches that integrate advances in wireless communications, signal processing, embedded systems, robotics, and artificial intelligence.

The growing demand for accurate, resilient, and trustworthy Positioning, Navigation, and Timing (PNT) services continues to drive innovation across both satellite-based and terrestrial infrastructures. Modern applications such as autonomous vehicles, intelligent transportation systems, environmental monitoring, unmanned platforms, smart cities, and industrial automation increasingly depend on precise location information that remains available even in challenging operating conditions. At the same time, the emergence of alternative navigation technologies, including LEO satellite constellations and signals of opportunity, is reshaping the broader PNT landscape and creating new opportunities for research and innovation.

In this context, WIPHAL aims to promote discussion of emerging concepts, novel architectures, experimental platforms, and practical implementations that contribute to the next generation of location-aware systems. By fostering interaction among researchers from academia, industry, and public-sector organizations attending both ICL-GNSS and IPIN, the workshop seeks to strengthen collaboration across traditionally separate research communities and support the development of robust, accurate, and scalable positioning technologies for future applications.

Review Process

For the 2026 edition, the workshop received 9 submissions. Each submission underwent a peer-review process involving three independent reviews. Editorial decisions were based on the scientific quality of the contributions, technical soundness, novelty, relevance to the workshop topics, and reviewers' recommendations.

Following the review process, 7 papers were accepted for publication and presentation, corresponding to an acceptance rate of approximately 78%.

Overview of Accepted Contributions

The accepted papers cover several emerging directions in positioning, navigation, and timing, ranging from alternative navigation signals and Low Earth Orbit systems to resilient localization architectures, robotic navigation, and smartphone-based high-accuracy positioning.

The paper *Design of a Custom 5G and 4G Signal of Opportunity Navigation Radio Receiver* by Morrison and Sokolova [1] presents the design and implementation of a compact software-defined radio platform tailored for the exploitation of 4G and 5G Signals of Opportunity. The proposed receiver emphasizes multi-channel operation, independent channel control, synchronization capabilities, and a reduced size, weight, power, and cost footprint, enabling practical deployment of cellular-based navigation and synchronization solutions.

In *Pseudorange Error Modeling for LEO-PNT Systems*, Bianconi *et al.* [2] investigate the role of Low Earth Orbit satellites in future positioning systems. Through stochastic modeling and estimation techniques, the authors analyze the impact of major error sources in MEO, LEO, and hybrid constellations and demonstrate the potential of LEO-based systems to improve positioning performance.

The contribution *Joint Spoofing and Multipath Suppression Using MEDLL and GNSS/5G/INS Consistency Check* by Li *et al.* [3] addresses the combined challenge of spoofing attacks and multipath interference. The proposed method integrates MEDLL signal processing with consistency checks across GNSS, 5G, and inertial sensors, demonstrating improved resilience of integrated positioning systems under adverse signal conditions.

In *CHAGALL: An Adaptive Distributed GNSS Architecture for Autonomous Geodetic and Environmental Monitoring*, Consoli *et al.* [4] introduce a distributed monitoring framework for long-term autonomous operation. The architecture supports multiple acquisition strategies and separates measurement collection from application-specific processing, enabling flexible deployments for geodetic monitoring, environmental sensing, and GNSS reflectometry applications.

The paper *Development of a Universal RF Front-End for Next-Generation LEO-PNT Systems* by Consoli *et al.* [5] presents a modular radio-frequency front-end platform designed to support emerging LEO-PNT and Signals of Opportunity technologies. The proposed architecture combines multi-band RF acquisition, coherent digitization, and scalable processing interfaces, creating a flexible platform for developing future navigation solutions.

In *ROBOSAT: Towards an Integrated Robotic Platform for Large-scale Multimodal Wilderness Navigation*, Matey-Sanz *et al.* [6] describe a framework for collecting large-scale multimodal navigation data in natural environments. The project combines robotics, GNSS, geographic information systems, and contextual sensing to support improved localization performance and reproducible research in challenging outdoor conditions.

Finally, *Smartphone RTK for C-ITS: Architecture and PPK-Based Field Evaluation* by Zerafa and Scerri [7] explores the use of commodity smartphones for high-accuracy positioning in Cooperative Intelligent Transport Systems. Using real-world experiments, the authors demonstrate the potential of smartphone GNSS observations combined with RTK and PPK processing techniques for future intelligent transportation applications.

Together, these contributions illustrate the diversity of current research directions in positioning and navigation technologies, including GNSS modernization, LEO-PNT architectures, signals of opportunity, resilient navigation, environmental monitoring, autonomous robotics, and mass-market positioning solutions. They reflect the workshop's objective of fostering discussion on innovative hardware and software approaches that will shape future location computation systems.

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Declaration on Generative AI

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