

Building the Future of Autonomous Mobility: Inside TiHAN-IITH's Journey from Testbeds to Real-World Solutions

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Autonomous mobility is often imagined as a distant future—self-driving cars navigating cities, drones flying without pilots, and air taxis transporting people above congested roads. At the Technology Innovation Hub on Autonomous Navigation Foundation at IIT Hyderabad (TiHAN-IITH), that future is being developed through a very practical approach: building, testing and validating autonomous systems in real-world conditions. Established under the National Mission on Interdisciplinary Cyber-Physical Systems, TiHAN

IITH brings together autonomous systems, intelligent connectivity, advanced engineering and safety-focused solutions to address the complex mobility challenges of India. What makes this work particularly significant is its emphasis on Indian conditions. Autonomous systems cannot simply be developed for ideal roads, perfect weather and predictable environments. They must cope with unstructured roads, diverse traffic, poor visibility, GPS-denied environments, industrial sites and difficult terrain. TiHAN-IITH's work brings together testing infrastructure, multimodal datasets, autonomous vehicles, drones, connected mobility and aerial systems to create technologies that are designed for these realities.

From the Laboratory to the Real World

One of the central ideas behind TiHAN-IITH is that autonomy must be validated beyond simulation. The TiHAN Testbed provides a dedicated environment for testing aerial and terrestrial autonomous navigation, combining road infrastructure, intersections, test tracks, hangars, ground control stations, simulation tools and a dedicated aerial test zone, the facility as a 10-acre integrated testbed with multiple multimodal tracks and scenarios.



Figure 1. TiHAN Autonomous Navigation Testbed

This infrastructure allows researchers and technology developers to investigate how autonomous systems behave under controlled but realistic conditions. Signalized and unsignalized intersections, smart poles, V2X communications and environmental emulators create opportunities to reproduce situations that autonomous vehicles are likely to encounter outside the laboratory.

The philosophy is simple but important: an autonomous system is only as useful as its ability to operate safely when conditions are imperfect. That philosophy extends to TiHAN IITH's advanced testing facilities. The Rainfall Simulator can reproduce varying rainfall intensities, while the Wind Shaper Facility enables controlled dynamic wind testing for UAVs and eVTOL platforms. The Control Drone Navigation Testing Centre provides an indoor environment for testing navigation in GNSS-denied and obstacle-rich conditions. The eVTOL Propulsion and Motor Testing Lab support evaluation of electric propulsion systems, including thrust, efficiency and endurance. Together, these facilities create something more valuable than an individual laboratory: an ecosystem in which autonomous technologies can be tested across multiple dimensions of real-world operation.

TiHAN-IITH addresses this through TiAND—the TiHAN-IITH Autonomous Navigation Dataset.

Autonomous systems depend on data. A vehicle or drone must recognize its surroundings, understand what is happening and make decisions based on that understanding. But a major challenge is that much of the world's autonomous navigation research has been built around datasets collected in environments that do not fully represent India's roads, traffic patterns and operating conditions. TiAND is described as a multimodal dataset designed for autonomy on unstructured Indian roads and includes terrestrial, aerial, underwater and agricultural data. It combines information from cameras, LiDAR, RADAR, GNSS and other sensing systems.

The breadth of the dataset is particularly noteworthy, more than 250 hours of recorded data across multiple weather conditions and more than 50 cities, together with 125,000 images and 45,000 point-cloud files. The data covers 26 object classes and synchronized multisensor information.

This creates an important foundation for researchers developing perception, localization, planning and autonomous decision-making systems specifically for Indian environments. The significance goes beyond the size of the dataset. Diverse data makes it possible to study the unusual and unpredictable situations that often determine whether an autonomous system succeeds or fails. In autonomy, the difficult cases—the sudden obstacle, unusual road user, poor lighting or unexpected interaction—can matter more than thousands of routine examples.

Autonomy Beyond the Road

While autonomous cars are an important part of the work, TiHAN-IITH's vision extends across multiple modes of transportation. Its autonomous campus shuttle demonstrates how autonomous mobility can

be deployed in controlled environments. The system integrates perception, navigation and control and includes LiDAR-enabled perception, prediction and detection, multisensor fusion, fail-safe mechanisms and an in-house drive-by-wire system. The shuttle has been operational since August 2023 and reports more than 30,000 passengers served, with a 95% satisfied-user figure. Connected mobility is another important part of the ecosystem. TiHAN-IITH's C-V2X communication platform connects vehicles, roadside infrastructure, traffic signals and cloud systems. Applications include pedestrian detection, collision avoidance and emergency-vehicle green corridors.

The system is designed around low-latency communication, high reliability, real-time data exchange and secure connectivity. This reflects a broader understanding of autonomy: the future vehicle will not operate as an isolated machine. It will increasingly communicate with infrastructure, other vehicles and digital services.



Figure 2. TiHAN Autonomous Campus Shuttle

Taking Autonomy into the Air

The aerial portfolio demonstrates perhaps the widest range of operating challenges. TiHAN-IITH has developed surveillance, precision-delivery, GPS-denied navigation and heavy-payload platforms.

Ti-Shadow is an autonomous surveillance UAV designed for real time aerial surveillance and situational awareness. It can be equipped with thermal and advanced surveillance payloads for day-and-night operations. Its autonomous capabilities enable reliable, intelligent and secure surveillance missions with minimal human intervention.

For environments where satellite navigation cannot be relied upon, TiHAN-IITH has developed an outdoor and Indoor GPS-denied autonomous navigation drone to operate inside industrial plants, warehouses, tunnels, boilers and mines. These systems demonstrate an important transition: drones are moving from remotely operated machines toward autonomous platforms capable of perception, localization, navigation and mission execution.



Figure 3. TiHAN SHADOW – Surveillance Drone

From Small UAVs to Heavy Payloads and Human Transport

The same technological foundation is being extended to much larger aerial systems. Ti KALA is presented as a precision air-drop platform with autonomous navigation and high accuracy payload release.

It is intended for applications ranging from defence and disaster response to delivery in remote areas. At the heavier end, Ti-Chakravayuh is a higher altitude UAV designed to transport more than 100 kg of payload with redundant communication capabilities.



Figure 4. TiHAN GPS Denied Drone

Its applications include defence logistics, industrial transportation, emergency services and remote-area cargo delivery. The most ambitious application is Ti-Palyanka, a personalized aerial vehicle designed for human transport, emergency response and urban air mobility.

The platform is presented with a 100 kg payload capacity, safety redundancy and autonomous/manual operating modes. The drone specifically highlights emergency landing decision-making and fail-safe mechanisms designed to tolerate single and dual motor failures.

This progression—from surveillance drones to heavy-payload aircraft and ultimately human-carrying aerial mobility—illustrates how autonomous navigation technologies can scale across increasingly demanding applications.



Figure 5. Ti CHAKRAVYUH on Flight

Building an Ecosystem, Not Just Products

Perhaps the most important aspect of TiHAN-IITH's work is that these technologies are not presented as isolated products. They form part of a larger ecosystem involving datasets, test infrastructure, connectivity, simulation, autonomous vehicles, UAVs, propulsion systems and software. The Software Defined Vehicle initiative further reflects this systems-level approach. By separating vehicle intelligence from hardware through modular software architectures, the platform aims to enable continuous feature development, secure over-the-air updates, connectivity and AI-ready capabilities. Similarly, the indigenous Ti-Circle flight controller and TiHAN Fly Ground Control Station point toward greater control over the software and hardware stack for autonomous UAV operations, capabilities including autonomous navigation, fail-safety, BVLOS and swarm operations.

Communication resilience is another critical piece. TiHAN-IITH's anti-jamming telemetry system addresses the vulnerability of single-frequency links by incorporating adaptive frequency hopping, secure encryption, replay protection, long-range communication and onboard intelligence.

What Comes Next?

The future of autonomous mobility will not be defined by one vehicle, one sensor or one algorithm. It will depend on how well different technologies work together—and how reliably they perform outside controlled laboratory conditions. TiHAN-IITH's approach points toward that future: collect representative data, build intelligent systems, test them in increasingly demanding environments, validate their safety and then translate the results into deployable solutions. The opportunities are equally broad.

Urban air mobility, autonomous logistics, disaster response, industrial inspection, agricultural monitoring, connected transportation and human aerial mobility all require reliable autonomy. The challenge is to transform technological capability into systems that people can trust. That is ultimately what makes TiHAN-IITH's work important. It is not simply about imagining a future filled with autonomous vehicles. It is about building the infrastructure, data, engineering capability and validation ecosystem required to make that future possible.

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The journey is about experiencing innovation and embracing tomorrow. Its growing portfolio suggests that tomorrow's mobility will not belong to a single mode of transport. It will be connected, autonomous, intelligent—and increasingly designed around the realities of the world in which it must operate.

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