



# Nav-IC Guided AI-based Autonomous Drone System For Intelligent Disaster Response

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## Abstract

UAVs are increasingly used in these emergencies, delivering supplies or assessing damage [2]. But there's a catch: most of them still rely a lot on GPS to get around [1]. If the satellite signal cuts out or gets weak—and it happens, especially if you're only using one system—those UAVs can't always finish their jobs or avoid dangerous areas [1].

That's why this project takes a different approach, one that is effective for disaster zones in India [5]. It mixes NavIC with GPS for navigation [5], uses an adaptive A\* routing method [4], and reverts built-in geofencing checks, all inside a single mission loop [3]. We tested it out by distorting with the signal strength on purpose [1]. Even then, the new system kept UAVs on course and stopped them from drifting into restricted zones—a big improvement over GPS by itself [1, 3]. In short, this setup actually handles real-world problems, making UAV navigation tougher and smarter when everything's falling apart [5, 6].

**Keywords:** NavIC, Autonomous UAV, Disaster Response, Artificial Intelligence, Sensor Fusion, Regulatory Compliance, Geofencing

## 1. INTRODUCTION

When natural disasters hit—floods, cyclones, earthquakes, landslides—responders need fast, accurate information and quick logistics support [2]. But this remains a limitation in current UAV systems: roads often get blocked, washed out, or just disappear under water. So, more and more teams are turning to unmanned aerial vehicles (UAVs) [2]. They use drones to scout the damage, help locate survivors, and even deliver emergency medicine [2].

Yet, most of these UAVs still depend on GPS to get around [1]. That's a problem. In real disaster zones, GPS isn't always reliable [1]. You get signal loss from collapsed buildings, jumbled signals bouncing off city structures, or interference from the weather [1]. Flights can get interrupted, and that's the last thing you want in a crisis.

In India, there's a homegrown solution: NavIC [5]. It's a regional satellite system built to give better coverage over the Indian subcontinent [5]. Sounds perfect, right? But even now, only a handful of UAVs designed for disaster response actually use NavIC, and most don't combine it with GPS for extra reliability [5].

separately, outside the drone's main navigation workflow [3]. In an emergency, this split makes things messy and forces teams to keep a closer eye on every flight.

This study tackles those gaps. We're building a disaster-response UAV system that brings it all together. Here's what's inside: dual NavIC-GPS navigation [5], adaptive path planning using A\* algorithms [4], real-time obstacle detection and avoidance [4], and geofencing checks built straight into the drone's main control system [3].

The goal is to make drone navigation tougher, smarter, and more aware of regulations—even when satellites go flaky—so that teams on the ground can actually count on these UAVs when disaster strikes [1,6].

## 2. RESEARCH METHODOLOGY

This disaster-response UAV framework uses a layered setup where navigation reliability, adaptive routing, and regulatory checks all run together in a single loop [1,3]. Instead of splitting these functions into separate silos, the framework lets routing and compliance work hand in hand, reacting to each other in real time while the UAV's in the air [3,4].

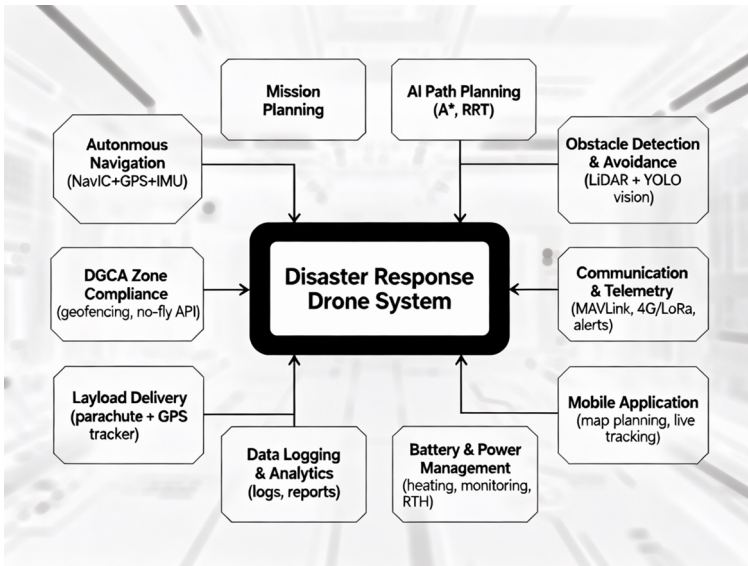


Figure 1: Integrated architecture of the proposed disaster-response UAV framework highlighting navigation, AI routing, compliance validation, and communication modules.

Look at Fig. 1. Here, mission planning, navigation fusion, AI-powered routing, and compliance checks all work together in a single system—ready to jump into action when emergencies hit [3,4].

### 2.1. Dual Navigation Architecture

For better positioning during disasters, the UAV pulls data from both NavIC and GPS satellites [5]. Using more than one satellite network means the system keeps working even when buildings, debris, or damaged infrastructure block signals [1]. NavIC, in particular, gives stronger coverage across the Indian subcontinent [5].

Instead of sticking to just one satellite network, the UAV keeps an eye on the signal strength from both [1]. If one signal dips below a set level, it automatically switches to the other network to keep navigation on

track [1, 5]. With this setup, the odds of losing navigation completely—even when GNSS signals get spotty—drop way down [1].

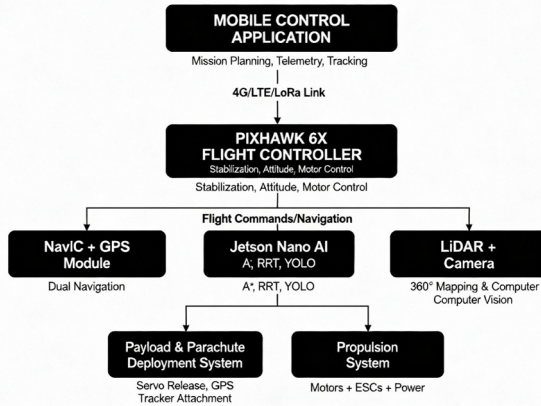


Figure 2: Hardware and AI-integrated block diagram of the NavIC-guided disaster-response UAV system.

2 shows how everything fits together on the UAV: the flight controller, navigation system, AI module, sensors, and the payload release mechanism all interact [4].

**2.2. Adaptive Path Planning Strategy**

For global route planning, we use a search method inspired by A\*. It weighs up two things: the cost you’ve racked up so far getting to a node ( $g(n)$ ), and a guess at how much farther you have to go ( $h(n)$ ), just like in [4]. The evaluation function is expressed as:

$$f(n) = g(n) + h(n) \tag{1}$$

Inside our simulated disaster zone, we give blocked areas a higher travel cost [4]. The UAV picks up on these and automatically finds a new route when it hits an obstacle or restricted area [3]. That way, the system handles path changes on its own, so there’s no need for someone to jump in and fix the route mid-mission [4].

**2.3. Local Obstacle Adaptation**

While the UAV’s flying, its sensors—like LiDAR and cameras—keep an eye on the surroundings [4]. If they spot something too close for comfort, the drone tweaks its path on the spot but sticks to the big-picture route [4]. This way, the UAV can handle sudden changes in the landscape without having to rethink the whole route from scratch [4].

**2.4. Automated Geofencing and Compliance Mechanism**

Rules and regulations aren’t just an afterthought—they’re baked right into the navigation [3]. The drone checks its position using geometric boundary checks, a lot like what you see in recent geofencing research [3].

Restricted zones are modeled as circular constraints defined by:

$$(x - x_c)^2 + (y - y_c)^2 \leq r^2 \tag{2}$$

Here,  $(x_c, y_c)$  marks the center of any no-go area, and  $r$  is the radius of that zone.

The UAV constantly checks its planned path against these boundaries [3]. If it looks like it's about to cross the line, the drone's routing system quickly finds a different way around before it gets too close [3]. By building these checks into the main navigation loop, the UAV doesn't need someone watching over it all the time, even in urgent situations [3].

### 2.5. Mission Execution Workflow

The mission kicks off by setting the target coordinates, marking out restricted areas, and configuring the payload [2]. Once the airspace is cleared automatically, the drone heads out, adjusting its route as needed [4]. When it reaches the destination, it drops off the payload using a servo, then heads back home to wrap up the job safely [2].

## 3. RESULTS AND DISCUSSION

### 3.1. Comparative Evaluation with Existing Approaches

Most disaster-response UAV systems out there focus on aerial monitoring and carrying payloads [2]. They work, sure, but almost all of them lean heavily on GPS for navigation [1]. When it comes to making sure these UAVs follow regulations, people usually handle that outside the system, using separate mission planning tools—not something built right into the drone's core decision-making [3].

This new framework takes a different approach. It brings together dual-constellation navigation [5] and compliance checks [3] right into the actual flight operations. So, instead of handling navigation and airspace validation as separate chores, both happen together and shape the route in real time [3]. That means the system doesn't need to keep checking in with outside supervisors, and it keeps running smoothly even in fast-moving emergency situations [1].

The table below lays out how this framework stacks up against other well-known disaster-response UAV systems [2].

Table 1: Comparison with Representative Disaster-Response UAV Systems

Study	Navigation Source	Adaptive Routing	Compliance Integration	Payload Capability
Conventional Search UAVs [2]	GPS	Limited	External validation	No
GPS-Denied Navigation Studies [1]	GPS / Sensor Fusion	Partial	Manual	No
Geofencing-Based Planning [3]	GPS	Static planning	Pre-validation	No
Proposed Framework	NavIC + GPS	Dynamic A*-based routing	Embedded geofencing	Controlled deployment

The comparison indicates that while prior systems focus on either navigation robustness or compliance planning independently, the proposed model integrates both within a unified mission structure.

### 3.2. Simulation-Based Evaluation

Earlier systems usually tackled navigation robustness or compliance planning on their own [1, 3]. This new model pulls both together into one mission framework, so you don't have to choose between them [3].

To see how steady the navigation stayed, we ran a bunch of simulations where GNSS signals weren't perfect [1]. We dropped GPS confidence but kept NavIC running [5]. Even after repeating the experiment several times, the missions kept going and routes stayed mostly stable.

When the system relied on GPS alone, missions broke down more often—especially when the signal got shaky [1]. But with both NavIC and GPS working together, navigation held up much better [5]. The redundancy really helped, which matches what other multi-constellation studies have seen [1].

### 3.3. Practical Implications and Limitations

We also set up restricted zones in the simulation. When geofencing checks weren't built in, the system sometimes plotted paths right through these no-go areas during quick reroutes [3]. Once we added compliance checks directly into the navigation loop, it started picking alternate routes before crossing any boundaries [3]. That cut down on violations in the tests.

Sure, these results are just from controlled simulations, but it's clear: combining redundancy in navigation with compliance-aware routing makes the whole mission more reliable [1, 3].

This approach—blending regional satellite navigation [5], adaptive routing [4], and built-in compliance checks [3]—really matters in disaster zones, where regular infrastructure can't be trusted and GNSS signals might be spotty [1]. Having geofencing baked into the routing means you don't need someone constantly watching over the operation during emergencies [3].

Still, this study sticks to simulations. In the real world, things get messier: you've got to deal with communication delays, noisy sensors, unpredictable weather, and getting multiple agents to work together [2]. Next up, we'll push the system into hardware and field tests to see how it handles real-life conditions.

## 4. CONCLUSION

This study introduces a NavIC-assisted autonomous UAV system built for disaster response, even when GNSS signals get patchy [1, 5]. The main goal? Make navigation more reliable and keep regulatory compliance right in the mission loop, not as an afterthought [3].

Here's how it works. The system combines dual NavIC-GPS positioning [5], adaptive routing with a heuristic A\* algorithm [4], and geofencing checks—all in one place [3]. By doing this, the UAV doesn't just rely on one navigation system or need outside help to stay in bounds [1]. Instead of handling routing and airspace validation separately, everything runs together inside the same framework [3].

When put through simulations with degraded signals, the system kept missions going more smoothly than setups that use only GPS [1]. These results line up with what's been seen in other studies on multi-constellation navigation [1]. Plus, having compliance checks built in helped cut down on restricted-zone violations during reroutes [3].

Testing so far happened in simulations, but the way these pieces fit together sets the stage for real-world use in disaster zones [2]. Next steps include testing with real hardware, running field trials, and seeing how it holds up in unpredictable conditions [2].

This framework gives UAV-based disaster response a more resilient, compliance-focused backbone [6].

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