

White paper

Active smart labels in air logistics

Active smart labels eliminate the fundamental blind spots of legacy tracking systems. By transmitting autonomously and actively over existing cellular networks, they provide continuous cargo intelligence from the shipper's dock to the consignee's door.



Executive summary

Air logistics is one of the most time-critical and compliance-intensive industries in the global economy. Shipment success for goods such as pharmaceuticals, perishables, and high-value electronics can depend on knowing exactly where a shipment is, what condition it is in, and who has handled it, at any moment throughout its journey.

Active smart labels are emerging as the defining technology for air cargo intelligence. Unlike passive Radio Frequency Identification

(RFID) or barcode labels that yield data only when scanned at fixed points, active smart labels transmit location, environmental sensor readings, and custody events continuously and independently over the global mobile networks or Wi-Fi signals that connect smartphones, without requiring dedicated reader infrastructure.

This white paper examines how active smart labels work and why their characteristics make them particularly well-suited to air logistics.

The visibility gap in air logistics

Modern air freight moves with impressive physical speed, but the information about the freight has historically moved far more slowly and far more unreliably than the cargo itself.

Traditional cargo tracking in the air logistics industry is event-based. A shipment generates a status update when it is physically scanned at pickup, at the origin cargo terminal, at departure, on arrival, at the destination terminal, and on delivery. Between these events, which typically span hours or even days, including dwell time at transit hubs, the shipment is effectively invisible.

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A shipment carrying a barcode or RFID label is only visible when someone or something reads it. However, a shipment carrying an active smart label is visible all the time.”

Shreya Mehta
Global Air Logistics
Product Innovation
Manager

What are active smart labels?

An active smart label is a self-powered electronic label that integrates sensors, microchips and IoT direct to cloud connectivity. The label continuously collects data about the shipment's condition (such as temperature, humidity, shock, tilt and light) and transmits that data over the cellular network or via GPS to a cloud platform, where it is processed and made available to authorised parties in real (or near real) time.

Unlike passive RFID tags or barcodes, which have no power source and no independent communication capability, active smart labels are self-contained telematics devices. They are typically single-use, thin adhesive labels that are easily attached directly to any cargo or waybill pouch, making them the most convenient tracking solution on the market and very effective for mass deployment.





Why cellular is the right technology for air logistics

Multiple tracking technologies, such as barcodes, RFID, and Bluetooth Low Energy (BLE), have been applied to air cargo over the decades. Each of these technologies has real value in specific contexts. But due to the structural characteristics of the air logistics environment, cellular smart labels are better suited as a primary tracking device.

GPS, like cellular, would also provide the required coverage, but to do this, GPS receivers must continuously lock onto signals from multiple satellites to calculate position, which drains battery life. The second issue with GPS is environmental coverage; the technology depends on line-of-sight reception of signals from satellites orbiting at approximately 20,000 kilometres altitude. This works well in open-sky conditions, but air cargo spends the majority of its dwell time inside cargo terminals, warehouses, aircraft holds, and customs facilities. In these environments, GPS signal acquisition is unreliable or impossible.

Risk lives between the milestones

Risks to shipments occur during transitions, handovers and dwell time. Air cargo shipments routinely pass through 8 to 15 different handling environments: the shipper's dock, multiple trucking legs, origin cargo terminal, transfer sheds, aircraft hold, transit hub, customs examination facility, destination cargo terminal, and last-mile delivery. Each of these environments is managed by a different operator with different technology investments.

RFID and BLE tracking work well in facilities that have invested in reader infrastructure. But, for example, a shipment moving from a pharmaceutical manufacturer in India, through a regional airport in South Asia, via a hub in the Middle East, to a hospital distribution centre in Central Europe, will pass through environments where RFID reader coverage ranges from comprehensive to non-existent. However, an active smart label is indifferent to these variations in the infrastructure: if there is a cellular signal, the label transmits.

Data security and privacy

The continuous transmission of shipment location and condition data raises legitimate concerns about competitive intelligence exposure. A carrier's cargo loading patterns, a shipper's supply chain relationships, and a freight forwarder's customer network can all be inferred from smart label data streams.

Enterprise-grade cellular smart label platforms address this through end-to-end encryption of all transmissions (TLS 1.3 or equivalent), role-based access controls that limit data visibility to authorised parties, data residency options that ensure compliance with GDPR and equivalent privacy frameworks, and SIM-level authentication that prevents unauthorised devices from accessing the platform.

The cellular network itself provides a fundamental security advantage over open Wi-Fi or BLE-based tracking: transmissions occur over licensed, carrier-managed spectrum with built-in SIM authentication, making eavesdropping and signal injection attacks significantly more difficult than on unlicensed frequency bands.

Real-time alerting without infrastructure

Because active smart labels push data proactively, they can generate real-time alerts without any action by the receiving party. If, for example, a pharmaceutical shipment's temperature exceeds the tolerated range while sitting in a cargo terminal at a transit hub, the cloud platform immediately sends an alert to the shipper, the freight forwarder, and the airline, allowing corrective action to be undertaken before the temperature excursion becomes a regulatory event.

This proactive alerting capability represents a qualitative change in cold-chain and shipment condition monitoring, not merely an incremental improvement. The shift is from first discovering problems at destination to being aware of an issue, and intervening, while the shipment is still in transit.



Use case: How Kuehne+Nagel is deploying cellular smart labels

Semicon supply chains handle some of the highest-value equipment in commercial logistics and operate under demanding reliability and handling requirements. A single undetected shock event, handling error, or misrouting can damage critical hardware, delay ramp-up of a semiconductor fab and result in substantial operational and financial losses.

How Smart labels saved a high value semicon shipment

A semiconductor capital equipment shipment that consisted of two oversized crates, containing the capital equipment main machine and its components, was being transported under strict shock and tilt conditions from Bangkok to Chicago via Taipei. To provide end-to-end visibility, cellular smart labels with sensors for geolocation, shock and tilt, and humidity were placed on the outside of each of the crates, which were consolidated onto one dedicated ULD for the initial leg of the journey.

Misloaded at the transit station

Upon arrival in Taipei, the two crates of capital equipment were unloaded and processed for transfer to the connecting flight to O'Hare International Airport. During cargo sorting operations, one crate was correctly staged for the Chicago transfer dolly, while the other one was inadvertently placed in the wrong ULD build-up area.

The situation if cellular smart labels had not been attached

Although both crates would have been recorded as received at the transit station, a missed or incorrect scan during the transfer process means the misrouted crate would not have been operationally flagged. As a result, the shipment would have been assumed to be intact and would have been loaded for onward carriage without further exception handling.

If smart labels had not been placed on each crate, the issue would only have been identified during arrival scanning in Chicago, when one crate would have been found to be missing, potentially delaying fab ramp-up and disrupting production lines.

With cellular smart labels

As cellular smart labels had been used, the deviation was detected in near real time, enabling corrective action before one crate was misrouted.

The monitoring team received two independent signals showing something was wrong:

- Real-time location mismatch: one crate was reporting a different location than the other crate.
- Flight-status divergence: One label stopped transmitting (flight mode) while the other label continued sending regular data indicating it was still on the ground.
- The monitoring team immediately notified the airline, and the misplaced shipper was pulled back before it departed to the wrong location, thus preventing a major service failure.

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Traditional airfreight processes, although robust, contain several blind spots where it is difficult to capture risks in real time.”

Shreya Mehta
Global Air Logistics
Product Innovation
Manager





Conclusion

Shipment visibility in air logistics has historically relied on:

- Event-driven data capture (e.g. barcode scans at key milestones)
- Limited or no direct visibility between milestones
- Fragmented data across systems operated by different stakeholders

Before active smart labels:

- Shipment-level visibility was not consistently available across the end-to-end journey

With active smart labels:

- Each shipment becomes a live, self-reporting entity
- Labels connect autonomously to global cellular networks
- Cargo conditions can be managed in real time rather than assessed after the fact
- Exceptions trigger immediate interventions instead of post-event investigations
- Chain of custody becomes a continuous electronic record rather than manual entries
- Automated milestone visibility

About us

Kuehne+Nagel is about making logistics work smarter for our customers. With a global network and deep industry expertise, we help businesses navigate complexity and unlock growth through reliable, digital services, advanced technologies and data-driven insights.

As the logistics partner of choice for companies worldwide, we deliver tailored, end-to-end supply chain solutions across Air, Sea, Road, and Contract Logistics.

Discover the future of logistics.

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