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On the Potential of Public Network Dual-Use for Medium Altitude Long Endurance Remotely Piloted Aircraft Systems (MALE RPAS)

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Summary: Medium Altitude Long Endurance (MALE) Remotely Piloted Aircraft Systems (RPASs) operate at an altitude of approximately 12 km with a long operational life up to 40 h. In Terms of efficiently transmitting sensor and situation information, a robust and broadband communication link is crucial for enabling new applications such as transmission of high-definition ISR (Intelligence, Surveillance, Reconnaissance) data. Traditional tactical data links offer high robustness but deliver low data rates and incur high costs per node, making scaling distributed sensor networks difficult. This work aims to assess whether the civilian communication technologies can meet the requirements of MALE RPASs in a tactical environment, using the NATO *Anglova* scenario as a representative example. To this end, we analyze the extent to which the European Aviation Network and 5G-Non-Terrestrial Networks can be used and represent an open, cost-effective alternative to open up new operational possibilities – in particular through the dual use of civilian technologies with applications in sensor and communication relay payloads. Our results indicate significant potential for civil-driven technologies, although further detailed modeling and field testing are required.

Keywords: MALE RPAS, UAV, Dual Use, 5G-NTN, SATCOM, European Aviation Network (EAN)

1. Introduction

Medium Altitude Long Endurance (MALE) Remotely Piloted Aircraft Systems (RPASs) are systems that can operate at an altitude of 12 km with long flight times over long ranges. But can tactical communication links cover the current use cases of MALE RPAS? The type of communication with autonomous systems such as MALE RPAS significantly determines their purpose and possible applications. Widely available, reliable broadband communication enables MALE RPASs to gain new operational relevance. This could be achieved through suitable sensor or communication payloads. Tactical data links often have the characteristic of being highly robust in tactical scenarios, but they have a lower data rate [1] and usually generate high monetary costs per node and in operation. This also has an impact on distributed sensor networks with a high number of nodes that may be located on the ground or at sea, for example, and need to be connected via flying relay nodes. If, in the future, a large number of sensors can be quickly integrated into a situational picture in a tactical environment, new capabilities in the field of communication can be created through the dual use of civilian technologies.

The EAN and 5G-Non-Terrestrial Networks (NTN) are promising technologies for MALE RPASs. These are mainly based on the 3GPP mobile communications standard, which can be used both terrestrial and via satellite. The mobile communications sector is a growing market in which technology is developing rapidly [2] and advancing into new areas such as satellite communications.

Because EAN and 5G-NTN are open, standardized technologies with a large market [2], they are widely used and less expensive than tactical links. The aim of this Paper is to present the two technologies EAN and 5G-NTN in connection with their use in a MALE RPAS using the *Anglova* scenario as an example. The NATO IST-124 *Anglova* [3] scenario provides the tactical context in which a MALE RPAS can operate. **Sec. 2** focuses in particular on the technical differences between the systems in terms of data rate and frequency, as well as the effects of the different satellite positions of the two systems. The MALE RPAS is also presented in order to derive the parameters for a tactical scenario. The parameters for radio links resulting from the use of the MALE RPAS are presented in **Sec. 3** and compared with the radio systems presented. **Sec. 4** then presents a tactical use case. The use of civilian communication technologies in a heterogeneous communication system can result in MALE RPAS payloads whose communication requirements exceed what can be achieved with existing communication solutions. A summary with an outlook can be found in the conclusion (**Sec. 5**).

2. Commercial Mobile Systems for Aviation Application

The EAN [4] is widely used in civil aviation, offering broadband Internet access to aircraft. Passengers can connect to the Internet via onboard Wi-Fi, assuming the aircraft is equipped for EAN. The advent of 5G introduces new possibilities, including standardized non-terrestrial deployment. The 5G-NTN standard includes satellite coverage, allowing standard

5G devices to connect via satellite to the 5G network. This enhances coverage in previously underserved areas, such as maritime and aerial regions.

2.1. Properties of MALE RPASs

The MALE RPAS, an EU PESCO project development [5], is a tactical remote-controlled flight platform. It operates at altitudes up to 12 km with speeds between up to 500 km/h and a flight duration up to 40 h and can carry payloads of up to 2300 kg [6]. Systems that meet this definition are the Airbus Eurodrone and the U.S. MQ-9 Reaper drone by General Atomics [7].

2.2. Scenario

The *Anglova* scenario, defined by the NATO IST-124 Research Task Group, involves Vignette 1, where fixed-wing UAVs (Unmanned Aerial Vehicles) are connected via satellite and Ultra High Frequency (UHF) links, s. **Figure 1**. The Harvest UAV's goal is to gather sensor data and centrally deliver it to the headquarter (HQ). This scenario employs multiple radio systems, including High Frequency (HF), Very High Frequency (VHF), UHF, and Satellite Communication (SATCOM), with plans to incorporate 4G and 5G [8].

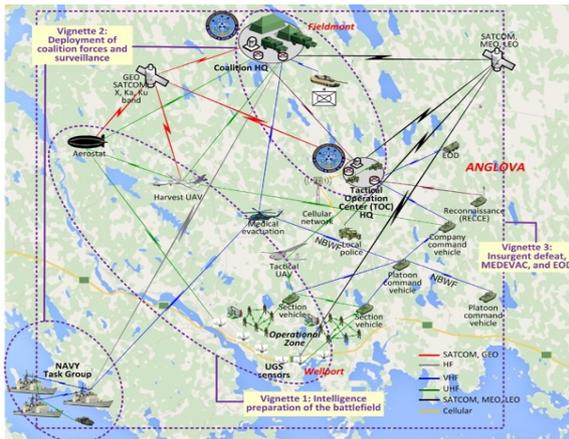


Fig. 1. NATO IST-124 reference scenario *Anglova* (cf. [3]).

In this paper, the *Anglova* scenario serves as the foundation for enhancing it with extra communication systems. In Vignette 1, sensor nodes are intended to gather monitoring data. The network gateways feature a Beyond Line-of-Sight (BLOS) channel. The majority of data is relayed via the harvesting UAV to the coalition headquarter (CHQ).

2.3. European Aviation Network (EAN)

The EAN offers Internet access to commercial aircraft across Europe using two communication technologies: a terrestrial Long Term Evolution (LTE) network and a satellite system. The LTE network, operated by Deutsche Telekom AG, consists of over 300 ground base stations, providing coverage up to 150 km per cell [9]. The satellite system, supported by the Viasat “Hellas Sat 3” satellite, ensures connectivity in maritime and remote areas. Aircraft are equipped with separate terminals for LTE and SATCOM [10].

Figure 2 illustrates the EAN network structure, showing how the aircraft connect via the Complementary Ground Component (CGC) and Mobile Satellite Service (MSS). The CGC includes onboard transponders and ground base stations linked to a core network. The satellite terminal facilitates communication with a ground station through the satellite relay. Both networks integrate at the “Meet Me Point,” establishing the link to the Internet and the Internet Service Provider (ISP).

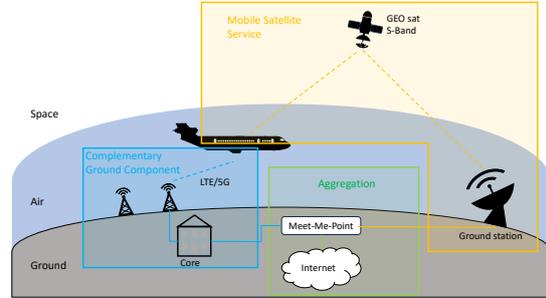


Fig. 2. EAN architecture (cf. [11]).

a) Terrestrial Communication: As mentioned before, the terrestrial components of the EAN use LTE technology. Adjustments to the Radio Access Network (RAN) are necessary to accommodate aircraft speeds up to 1200 km/h, causing frequency shifts up to about 2.4 kHz. CGC terminals on the aircraft must compensate for these shifts. For the communication, LTE Band 65 is used. At an altitude of 8000 m, the network achieves full coverage. Base stations operate with a transmission power of 80 W, and antennas are directed upwards [12].

The CGC system consists of over 300 base stations, covering the European area as illustrated in **Figure 3** [13]. Key features of the EAN include a data rate peaking at 75 Mbit/s, latency under 100 ms (typically 20–70 ms), seamless availability over land and water due to SATCOM, and a range of 150 km per cell under the CGC system connection.

The terrestrial network’s capacity can be increased by densifying cell deployment, reducing the cell size to maximize bandwidth. CGC terminals onboard aircraft have enhanced transmission power of 5 W, compared to typical terminals at 0.2 W [12], [14]. The CGC terminal antenna is mounted under the aircraft to maintain a Line-of-Sight (LOS) connection with ground base stations.

b) Satellite Connection: The Viasat “Hellas Sat 3” satellite provides EAN with satellite access via MSS. It is an S-band multi-beam satellite in geostationary orbit at 39 °E [15], [16], launched in 2017 [17]. Bandwidths for S-band communication are allocated as 2×15 MHz. The “Hellas Sat 3” operates within the frequency ranges of 1980–1995 MHz for Earth-to-Space communication and 2170–2185 MHz for Space-to-Earth communication [18]. A detailed overview of the satellite characteristics can be found in [17]. Regulations specify that frequencies may be used for in-flight communication from a minimum altitude of 1000 m [18]. The “Hellas Sat 3” covers the European area, as illustrated in **Figure 3**. Satellite connections

are primarily utilized in regions not covered by the CGC, mainly maritime zones. The satellite is connected to a ground station via a feeder link. The data can then be forwarded to the meeting point via the ground station. The aircraft are connected to the satellite via an onboard terminal, mounted on the aircraft's roof.

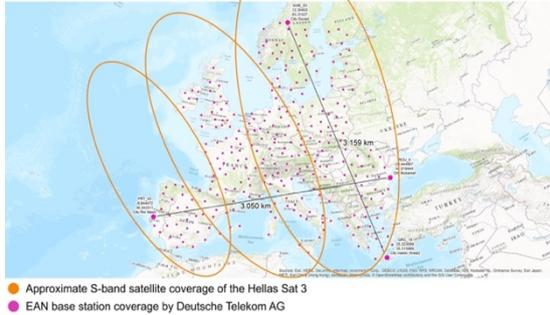


Fig. 3. EAN coverage by Deutsche Telekom AG and Viasat (cf. [10], [13]).

2.4. 5G-NTN

5G-NTN, part of the 3rd Generation Partnership Project (3GPP)'s 5G standard specification, aims to provide global 5G services by connecting earth-based devices via NTN infrastructure. As defined by 3GPP, NTN includes space-borne (Geosynchronous Equatorial Orbit (GEO), Medium Earth Orbit (MEO), Low Earth Orbit (LEO)) or airborne nodes (Unmanned Aircraft System (UAS), High-altitude Platform System (HAPS)) integrated into the network either as transparent or regenerative payload architectures [19]. Using the NTN node as a relay between the device and satellite gateway denotes a transparent payload architecture, whereas if the node has its own base station, it is a regenerative payload architecture. The standard specifies that commercial devices can operate within these networks. 5G-NTN debuted with initial studies in Release 15, while requirements for transparent payload architecture were specified in Releases 17 and 18 [20]. The most recent 3GPP Release, Release 19, finalized in October 2025, specifies the requirements for regenerative payload architectures in 5G-NTN systems.

a) Specifications: Initial frequency ranges for 5G-NTN were specified in Releases 17 and 18. FR1-NTN spans 410–7125 MHz, and FR2-NTN covers 17,300–30,000 MHz. The complete list of 5G-NTN bands can be found in [21].

In terms of coverage, 3GPP's report TR23.737 calculates the number of satellites needed for global coverage from a geographical point of view [22]. At 800 km altitude, 80 LEO satellites can achieve continuous global coverage. Satellite beam diameters vary between 100–1000 km for non-GEO satellites and 200–3500 km for GEO satellites [19], requiring regulatory and operational adjustments, also addressed in TR23.737 [22].

3GPP defines target data rates for scenarios like "Airplane connectivity," where up to 360 Mbps downlink and 180 Mbps uplink should be avail-

able [23]. The authors of [24] simulated 5G-NTN-LEO throughput for S-band and Ka-band connections using 30 MHz and 400 MHz bandwidths, respectively, yielding maximum rates of 16 Mbps (S-band) and 190 Mbps (Ka-band) per cell user.

Delay and Doppler shift are critical due to satellite distances and speeds, also addressed in the 3GPP standard. In the 3GPP report [23], the Round-Trip Time (RTT) for 5G-NTN-LEO and 5G-NTN-GEO is calculated as the sum of the individual signal propagation times over the channel, with an additional 5 ms added for each direction. These 5 ms are defined in the report as one-way network latency. Consequently, the maximum latency for a 5G-NTN-LEO transmission is 70 ms, while the minimum latency is 22 ms. In contrast, 5G-NTN-GEO experiences significantly higher latencies, ranging from 490 ms to 570 ms, due to much greater distances.

Maximum Doppler shift values are detailed in report [19], specified in parts per million (ppm). Maximum frequency shift depends on satellite altitude, with 24 ppm at 600 km and 21 ppm at 1200 km for LEO links, translating to 48 kHz and 42 kHz shift at 2 GHz. GEO-satellite links have a lower maximum shift of 0.93 ppm, equating to 1860 Hz at 2 GHz.

b) 5G-NTN Implementations: Initial 5G-NTN implementations prioritize continuous connectivity and seamless coverage. The transparent architecture approach is being adopted as it is independent of signal type, allowing existing satellite technology to remain unchanged [27]. Following the first successful 5G connectivity tests in 2023, during which Vodafone and AST SpaceMobile established a 5G voice call via the low-orbit satellite BlueWalker 3, both companies have formed a joint venture named SatCo to act as a dedicated satellite service provider for mobile communications. **Table I** lists the existing frequencies ranges of BlueWalker 3 and provides a comparison with the 5G bands they would match. SatCo is planning the launch of the satellite-based communication service in early 2026. The planned European constellation will incorporate a comprehensive command switch functionality to ensure operational control and compliance with European oversight and security requirements. In addition to supporting commercial mobile broadband, the system will provide capabilities for Public Protection and Disaster Relief (PPDR), thereby enhancing communication and coordination among European emergency services in line with the EU Critical Communication System (EUCCS) framework [28].

3. Radio Links for MALE RPAS

To effectively use communication systems for MALE RPAS, they must meet key requirements outlined in **Sec. 2.1:** Maintain connectivity at UAV speeds up to 500 km/h, ensure seamless handovers in networks with multiple base stations or relays, and guarantee continuous coverage in the operational area. These criteria are crucial for reliable communication in MALE RPAS operations.

Table 1. Bluewalker 3 frequency ranges, cf. [25].

Service Description	Frequency Range	NR-band [26]
Service Links (Earth-to-Space)	846.5–849 MHz	n5
	845–846.5 MHz	n5
	788–798 MHz	n14
Service Links (Space-to-Earth)	891.5–894 MHz	n5
	890–891.5 MHz	n5
	758–768 MHz	n14
Gateway/Feeder Links (Earth-to-Space)	47.2–50.2 and 50.4–51.4 GHz	n262
Gateway/Feeder Links (Space-to-Earth)	37.5–42.0 and 42.0–42.5 GHz	n260

3.1. Communication Requirements

A distinction must be made between terrestrial and satellite-based communication for a MALE RPAS-type UAV communication system. Key parameters to evaluate include:

- **Distance/Coverage:** In general, the drone must have the necessary equipment to meet the link budget requirements for a successful link between satellite or ground stations [29]. Seamless coverage is necessary in the drone’s operational area, achievable through a heterogeneous approach that combines multiple technologies to increase coverage. Available infrastructure and the size of the area to be covered depend on the scenario.
- **Data Rate:** The data rate is crucial to the application for which the drone is being considered. High data rates are essential for many sensors and should be ensured through high-bandwidth communication technologies.
- **Delay:** In satellite communication, the signal propagation time between the drone and the communication node is significantly affected by the satellites’ varying orbital altitudes [19]. This can lead to particularly long signal propagation times, which are examined in detail in **Sec. 3.2**. **Figure 4** provides a general overview of signal propagation time as a function of distance, with the propagation speed of the signal equivalent to that of light.
- **Velocity:** Besides long signal propagation times in satellite communication, Doppler effects are also critical for communication requirements. The system must accommodate the drone’s, the base station’s, and the satellite’s relative velocity to each other to maintain a stable connection. The frequency shift f_d is given by **Equation (1)** and is presented in [30]. Let c denote the speed of light, f_0 the original (carrier) frequency, and v_r the velocity.

$$f_d = \frac{c}{c - v_r} f_0 - f_0 \quad (1)$$

- **Reliability:** Network reliability is crucial in a tactical context, as availability directly impacts the operational capability of systems and the reliability of information. Civilian network systems, with their centralized structure, present a single point of failure despite technical redundancies. They have a centralized core that makes them vulnerable.

EAN and 5G are designed for speeds up to 1200 km/h [19]. Techniques for compensating fre-

quency shifts in these technologies are essential [31]. EAN, especially with CGC, has adjusted the LTE air interface to facilitate speed compensation.

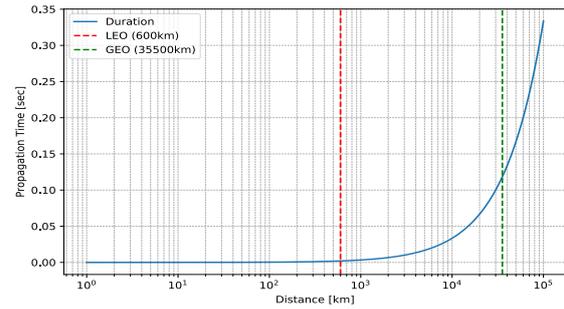


Fig. 4. Signal propagation time vs. distance.

3.2. Comparison of Communication Systems

Both 5G-NTN and EAN provide terrestrial components and satellite-based parts that have been used in civil applications or have been successfully tested. It is conceivable to use only the terrestrial components to supplement a tactical satellite system, as terrestrial use offers scaling advantages over satellite systems. System performance can be enhanced by adding more cells on the ground.

In addition to weighing up which technology can be used by the EAN, a comparison is also made between the EAN CGC, 5G-NTN-LEO, and 5G-NTN-GEO. **Figure 5** compares the RTT of CGC, 5G-NTN-LEO, and 5G-NTN-GEO satellite communication technologies. The lower edge of the color-coded blocks indicates the minimum RTT, and the upper edge represents the maximum RTT. 5G-NTN-LEO and GEO refer to the transparent payload architecture defined by 3GPP, with RTT values derived from 3GPP definitions [23]. For 5G-NTN-LEO, including an additional 5 ms per direction, maximum latency reaches 70 ms, while minimum latency is 22 ms. The CGC system exhibits similar latencies, ranging from 20 ms to 70 ms. In contrast, 5G-NTN-GEO experiences significantly higher latencies from 490 ms to 570 ms. EAN also uses satellite technology with latencies exceeding 500 ms in GEO orbit [32]. Notably, latency in GEO satellite transmissions is mainly due to signal propagation time, with processing latencies having less impact. Initial performance tests with OpenAirInterface (OAI) Core and RAN for 5G-NTN-GEO transmission runtimes have been conducted, establishing a connection between two Software-Defined Radios (SDRs) and a GEO satellite, measuring average latencies around 553 ms [33].

4. Use Case for Civilian Cellular Networks in Military Operations

The EAN systems and 5G-NTN technology can complement MALE RPAS systems by enabling broadband, low-latency connections. In the *Anglova* scenario Vignette 1, a MALE RPAS can serve as a harvester, assuming sensor network communications are integrated as a payload into the system, allowing sensor data to be collected and sent to the CHQ. EAN and 5G-NTN can act as a redundant link alongside

tactical data links, enabling the transmission of more data over time and ensuring lower latencies for data fusion purposes if needed. Unlike tactical waveforms, civilian communication technologies are not particularly resistant to jamming and are comparatively more vulnerable [34]. **Figure 6** illustrates the connection of these systems with MALE RPAS, utilizing EAN through terrestrial mobile radio and a satellite connection in the S-band, together with 5G-NTN as a second SATCOM. Communication is routed to service providers via a gateway, facilitating data transfer to the CHQ [35].

Large distance variations lead to increased Free Space Loss (FSL) [36], [37], affecting components in various communication technologies and causing runtime differences. Signal propagation can reach several hundred milliseconds, as shown in **Figure 4**, with the shortest latency achievable via EAN-CGC. Fast communication methods enable swift transmission to the CHQ, accessible via a gateway for quicker data availability. High-speed data transmission allows the interconnection of multiple sensors, enhancing situational awareness. MALE RPASs have versatile applications, serving as flying communication nodes or sensor payloads, with the possibility of a combined payload. EAN offers advantages with its compact CGC terminal design.

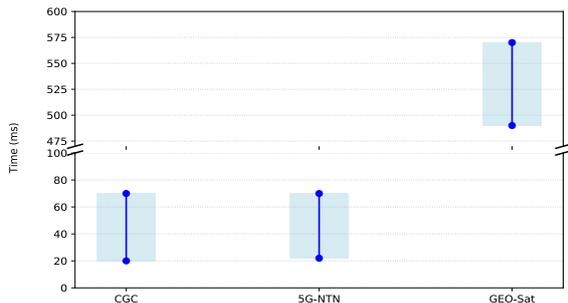


Fig. 5. RTT comparison of the signal delay between EAN-CGC, 5G-NTN and GEO SATCOM [23], [32].

4.1. Sensors as a Payload Concept

A sensor payload can include various sensors, such as a radar sensor. The sensor specifies the communication requirements, such as latency and data rate. The sensor data can also be processed at a network edge integrated into the MALE RPAS and transmitted cyclically rather than continuously. The payload can then be connected using 5G-NTN and EAN.

4.1. Communication as a Payload Concept

To supplement the communication needed for MALE RPAS operation, it can act as a communication node. Its high flight altitude enables broader communication coverage, enhancing ships or buoy nodes at sea with MALE RPAS payloads [38], thereby extending terrestrial system ranges [37]. Delay Tolerant Networking (DTN) mechanisms [39] can transport large data volumes, utilizing various cyclic systems [40], [41]. Other communication systems can also be integrated here, making 5G-NTN and EAN part of a heterogeneous network.

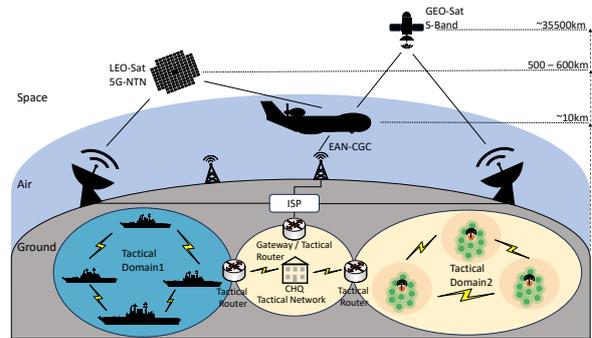


Fig. 6. EAN and 5G network concept with MALE RPAS in *Anglova* context.

5. Conclusion

This paper explores the potential use of EAN and the new 5G-NTN standard with the MALE RPAS, detailing their characteristics. Terrestrial connections with the EAN CGC offer high data rates and low latency, with performance enhanced by additional base stations. EAN's integration in the near future with 5G is expected to increase capacity even further. The 3GPP is standardizing 5G-NTN to enable satellite communication with standard mobile devices, aiming to globally expand mobile networks through satellites, enhancing connectivity in underserved regions. Despite high attenuation in satellite communication, these systems are effective in LOS conditions. Successful initial 5G-NTN tests were conducted using AST's BlueWalker 3 satellite. The commercial satellite service is scheduled to launch in early 2026. The current and future availability of broadband technology is promising for UAV operations, with standardizing and expanding civil technology allowing terminal compactness to complement tactical data links. Using the example of the *Anglova* scenario in combination with MALE RPAS, we were able to show that dual use of civil technologies as a supplement to tactical functions enables new applications. Large sensor networks can thus be implemented economically. Both the connection of payloads with sensors and the connection of communication payloads in heterogeneous networks could be realized in this way. These broadband communication networks build the basis for UAV swarm applications [39]. Once the first 5G-NTN satellite service becomes commercially available, further research and field trials can be conducted to gain deeper insights into the performance of 5G-NTN with unmanned systems.

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