

Dual-use CNS: The Civil-Military Interoperability Multiplier

The Russian invasion of Ukraine in February 2022 kicked Europe's defence spending into higher gear, accelerating plans to introduce a new generation of weapon systems. A huge number of leading-edge military assets, such as the 5th generation F-35 Joint Strike Fighter, will soon be operational in Europe, which bring with them additional airspace and infrastructure requirements. And the defence industry is lining up to introduce many other advanced weapon systems. Civil-military interoperability, therefore, has become increasingly important.

In parallel, civil aviation's communications, navigation and surveillance (CNS) infrastructure is being digitally transformed. This offers a unique opportunity to develop and deploy a dual-use CNS system that is capable of seamlessly accommodating and integrating military air operations. Such a system can only be accomplished through a new blend of innovative civil-military interoperability solutions that are tailored to the data-centric nature of modern air traffic services – and solve the avionics mismatch that many military aircraft face.

Summary

This Think Paper argues that the time has come to define a dual-use CNS system, taking advantage of new civil-military interoperability opportunities such as emerging performance-based concepts, enhanced data sharing, virtual and remote service provision, and increasing ATM/CNS avionics predominance, coupled with software-intensive technical approaches.

Main findings

- Aviation's future CNS infrastructure must have a dual-use nature to sustain particular requirements from various airspace users.
- Civil-military CNS interoperability must benefit from enhanced data sharing/ "big data", emerging ICAO performance-based CNS concepts, and cutting-edge software-based avionics.
- Innovative interoperability solutions need to be developed through pragmatic industrial research initiatives (SESAR 3 JU and others).
- A performance-based approach must be favoured to allow the military to use their own available CNS equipment when seeking compliance with civil requirements.
- The new dual-use system needs to be resilient and mitigate against security vulnerabilities, addressing data encryption, jamming protection, GNSS outages and concealment of surveillance parameters.
- Particular attention needs to be paid to the emergence of disruptive technologies and to new challenges related to spectrum efficiency and sharing.
- CNS provision must be aligned with sustainability objectives through improved flight efficiency.



Setting the scene

A new interoperability approach

Russia's aggression to Ukraine has confirmed the vital role of Europe's armed forces in protecting national security and defence interests. This relies heavily on ensuring military assets across Europe are highly mobile – with unrestricted access to airspace and aerodromes crucial in this regard.

Every year, the European aviation network managed by EUROCONTROL processes around 200,000 State military flights under General Air Traffic (GAT) status. These flights are enabled by a communication, navigation and surveillance (CNS) infrastructure that is frequently owned/operated by civil air traffic service providers.

Many of these flights are conducted by military aircraft that are non-equipped or evidence a mismatch with the required civil ATM/CNS capabilities. Hence, accommodation is based on equipage exemptions. As connectivity and automation increase, there is additional pressure for industrial research to deliver civil-military interoperability solutions that are adapted to the rapidly evolving technology context.

Civil aviation requirements are becoming technology-agnostic. There is increasing net-centricity, and modern military avionics are part of “functional integrative architectures”, leveraging a full glass cockpit (Figure 1), enhanced visual systems, electronically scanned array multi-function radars, onboard data fusion, smart antennae and software-defined radios. Cyber vulnerabilities however grow exponentially every day.

This technology context offers opportunities for new and inventive engineering solutions that support civil-military interoperability, building on the power of “big data” and performance-based approaches. Interoperability options based on the traditional “equipment-based approach” will not work anymore.

Key guidance in this regard will be offered by the CNS Evolution Plan, which is to be developed on the basis of the recommendations and action plan from the CNS Advisory Group of the High Level Group on SES, led by the European Commission.



Figure 1: F-35 JSF cockpit

A related “Military CNS Strategy” is being coordinated by the European Defence Agency (EDA), with contributions from EUROCONTROL, NATO and States, which is intended to be a fundamental source of military requirements.

A true civil-military dual-use system needs to be developed, building on work done via the SESAR 3 Joint Undertaking or other research initiatives, where EUROCONTROL will provide a substantial technical-level contribution within dedicated industry partnerships. **The focus must be to raise interoperability, avoid cumbersome retrofitting, address security vulnerabilities, face radio spectrum congestion, respect sustainability targets and respond to requirements identified by national authorities.**

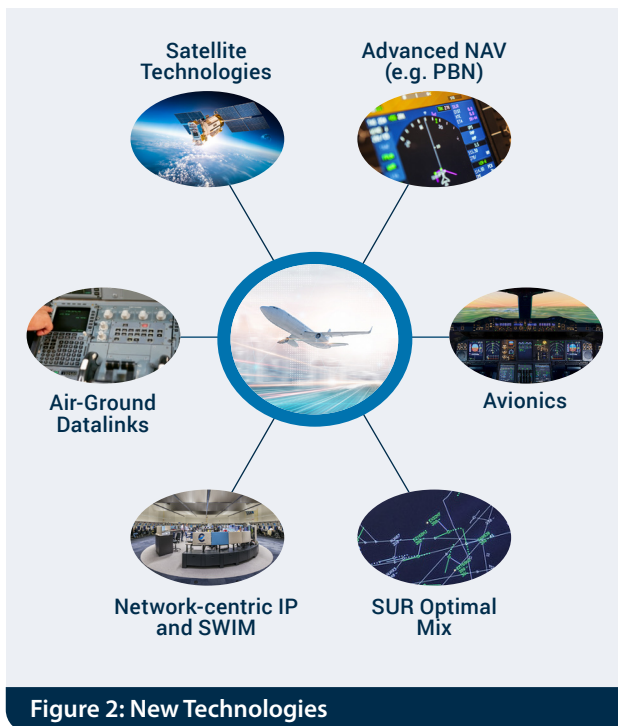
Addressing infrastructure evolution

Across Europe, the civil aviation CNS infrastructure has begun a transformational journey that will bring an exponential increase in the levels of automation, interconnectivity and data-sharing – all of which however pose new safety and security challenges.

A fully digitalised, high-bandwidth and low-latency infrastructure as per Figure 2 is expected to emerge, featuring:

- a network-centric and distributed data sharing environment
- strong reliance on satellite technologies
- a new generation of datalink-style air-ground communication technologies
- an evolution from conventional to area navigation (performance-based navigation, PBN)
- an optimal mix” of surveillance technologies (SSR Mode S, WAM and ADS-B).

Future CNS systems must be radio frequency (RF) spectrum-efficient, performance-based, highly integrated and rationalised. Performance monitoring mechanisms will be paramount.



Any interoperability initiatives need to be consistent with related national decisions with a focus on harmonisation, de-fragmentation and cost reduction.

A layer of existing technologies will be retained, designated as minimum operational networks (MON), to complement the deployment of new technologies and to make the overall ATM system more resilient.

Electromagnetic RF spectrum coordination and sharing represents a major interoperability challenge, and ensuring RF spectrum efficiency is vital whenever new systems are planned.

Technical studies are needed to address RF spectrum sharing and compatibility; to assess radio frequency interference, technical CNS performance and quality of service, surveillance detection, NAVAID coverage and integrity; as well as to ensure interfacing solutions and put in place technical security measures.

Performance-based CNS to boost civil-military interoperability

Benefits of performance-based CNS

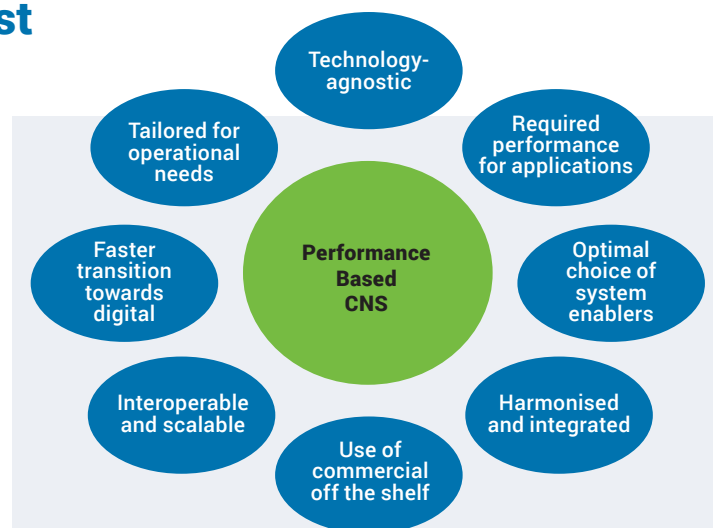
The ICAO performance-based CNS concepts allow an evolution from prescriptive equipment-based operations to the delivery of technology-agnostic performance-based services, tailored to meet operational requirements, and treating CNS as a fully integrated system (see Figure 3).

This paradigm shift will enable airspace users to rationalise airborne systems by customising the required airborne equipment, allowing potential synergies across COM, NAV and SUR.

Performance-based CNS metrics

The performance indicators to be met must be selected in accordance with the specific operational environment.

ICAO's PBN concept specifies that aircraft navigation system performance requirements should be defined in terms of accuracy, integrity, continuity and functionality,



all of which are needed for operations in the context of a particular airspace concept.

Similar metric targets have been defined under the concept of performance-based communications and surveillance (PBCS).

Performance-based CNS applied to civil-military interoperability

To overcome equipage mismatches, national authorities may decide to apply alternative performance-based processes, which would allow the use of available military equipment to comply with civil-derived ATM/CNS requirements based on performance metrics.

Research efforts must deliver technical solutions and methodologies that demonstrate the feasibility of equipment re-use and performance-based approaches for civil-military interoperability. The decision to implement resides with national authorities.

Data-sharing as a civil-military interoperability multiplier

Data context

Future aviation developments will be driven by enhanced data-sharing. Network-centricity will be another essential asset. Future air and ground systems, including those at airports, are expected to evolve into a single integrated infrastructure, enabling the network to accommodate the growth of air traffic, and raise system performance in an intermodal environment.

At the core of this integrated infrastructure will be the new EUROCONTROL Network Manager system, iNM (integrated Network Management). The iNM digital transformation programme, part of EUROCONTROL's Network Transformation 2030 roadmap, will accelerate the transition towards a digital information-rich environment supporting the full range of aviation functions.

Such data-intensive operations will rely on high speed and low latency communication systems that are highly interconnected, taking advantage of Internet Protocol technologies and air-ground connectivity. Aircraft avionics will access ground data repositories updated in near-real-time.

Enhanced data-sharing will decisively stimulate greater military operations integration into the overall aviation system.

The ADaaS is fed by remote flight data processing system services from MUAC.

Remote service provision

The extensive sharing of flight data is also the basis for ATS virtualisation and remote operations. Correlated flight plans, safety nets, Flight Data Processing System (FDPS) functionalities and other ATC information resources may be shared remotely, contributing to improved coordination, safety and infrastructure rationalisation.

Virtualisation of air navigation services, the use of common FDPS and the remote processing of operational data can be a major civil-military integration multiplier.

One example from recent years of remote service benefits for civil-military interoperability was the Shared ATS System (SAS) initiative, when the air traffic control system of EUROCONTROL's Maastricht Upper Area Control Centre (MUAC) became fully operational at the Royal Netherlands Air Force (RNLAf) Air Operations Control Station at Nieuw Milligen, and at seven air bases. In the meantime, the RNLAf has been relocated to LVNL Schiphol, as part of an integration project, and has stopped using SAS. This valuable experience can offer benefits for other organisations willing to follow similar synergies.

MUAC has been a pioneer in this domain through the development of ATM Data as a Service (ADaaS). The ADaaS project has investigated the extent to which ATM data services can be provided by the interoperable ATM system of an ATM data service provider (ADSP) to one or more civil air traffic service units (ATSUs), all of which moves closer to the concept of data centres.

The ADaaS demonstrator used local radars, tracking and safety net services, but is fed by remote flight data processing system services from MUAC. This project demonstrated how a state-of-the-art data centre could

be deployed from which an ADSP can deliver services to remote ATSUs.

If national authorities so decide, military operations can benefit from “big data” repositories, centralised common FDPS and remote provision to support air picture compilation, flight identification, surveillance data sharing, access to up-to-date flight data and

aeronautical information, as well as support to airspace management, meteorological data, etc.

Intensive data-sharing does however carry some risks, which calls for a sound security policy to be in place each time sensitive data are to be exchanged, or systems are to be interconnected.

Commercial off-the-shelf and software-based innovative solutions uplift interoperability

Interoperability reliant on commercial off-the-shelf and software-based approaches

As an extremely safety-centric environment, aviation relies strongly on highly standardised technologies – with the necessarily prescriptive standards to some degree constraining the use of cutting-edge commercial off-the-shelf (COTS) technologies, and resulting in longer procurement cycles.

Nevertheless, civil-military interoperability approaches taking advantage of COTS and software-based solutions can be important, comprising, for example:

- application programming interfaces (API), which enable compatibility with integrated modular avionics (IMA)
- reuse of legacy hardware leveraged with enhanced components
- reutilisation (rewriting) of legacy software functionalities to adapt to new processing environments
- use of software emulation to mitigate obsolete hardware
- use of model-driven architectures to allow for modular and incremental certification.

Such approaches may be crucial when adapting military avionics to emerging concepts like trajectory management, PBN and advanced surveillance.

One potential example is the future multilink environment as part of the air-ground data communications evolution. This calls for a flexible aviation radio based on software-defined radio (SDR) technology, which will drastically rationalise airborne avionics.

Greater focus on SDR technologies would facilitate military adherence to civil datalink requirements, possibly on the basis of waveform accommodation and performance-based options for compliance.

The most recent, i.e. 5th generation of fighters, like the F35 Joint Strike Fighter Lightning II, carry communication, navigation and identification (CNI) avionics suites supported by SDR technology, with conformal and adaptive (multi-frequency band) antenna arrays, which use reconfigurable FPGA (field programmable gate arrays)/RF hardware and computer processors to run software which produces the desired/selected waveform(s).

Flexible aviation radios based on SDR (as per Figure 4) could help to overcome military aircraft integration constraints by using reprogrammable software to facilitate the implementation of future communication infrastructure (FCI) datalink capabilities defined as waveforms.

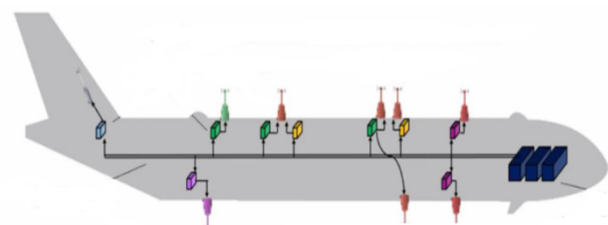


Figure 4: Flexible Software Defined Radios

This would also facilitate co-existence with other military capabilities. A flexible radio solution for military aircraft based on SDR would avoid cumbersome military aircraft retrofits, eliminating duplicated equipment and senseless architecture configurations. Again, in this interoperability domain a research gap persists.

Building a Civil-Military Dual Use CNS Infrastructure

The notion of dual use CNS

Dual-use CNS infrastructure offers the ability of one single underlying infrastructure to sustain two-way communications, navigation position-definition and tracking as well as surveillance identification and separation services, for multiple airspace user categories.

A dual-use CNS approach makes sense when national authorities, in response to the increasing trend of civil service providers handling military traffic, have determined the need for mixed service provision.

How to make it happen

The building blocks of a dual-use CNS infrastructure must be national CNS development plans. Areas of cross-border consistency between national CNS segments must be identified for trans-national harmonisation and optimisation.

At times, depending on local requirements, military operations may rely on the CNS enablers managed by civil ANSPs that retain infrastructure elements required to handle (legacy) military platforms (e.g. UHF for air-ground voice communications). Components of military CNS resources may be considered to enhance the provision of the overall common infrastructure (e.g. TACAN as part of VORTAC, PSR).

From a service provision perspective, a dual-use CNS approach (as per Figure 5), must be consistent with the judicious selection by the national authorities of one or more of the following (not mutually-exclusive) compliance approaches:

- equipage exemptions and special handling by ATC
- reuse or adaptation of military avionics to sustain civil requirements
- supplementary ground support (e.g. multilink)
- equip “as civil” (when possible).

Therefore, dual-use will consist of an optimal mix of accommodation, interoperability and integration aligned with the local CNS environment.

EUROCONTROL, the technical facilitator

EUROCONTROL offers a unique wealth of civil-military technical expertise, supported by data assets and validation platforms. As a founding member of the SESAR Joint Undertaking, EUROCONTROL is a major contributor to fostering higher levels of civil-military integration and technology convergence.

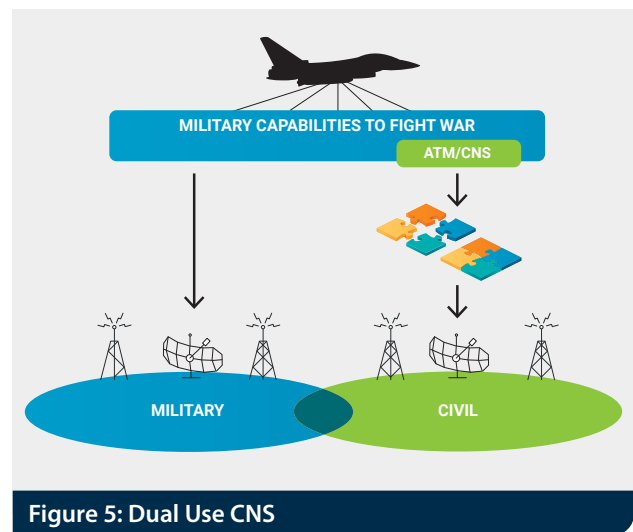


Figure 5: Dual Use CNS

EUROCONTROL plays a pivotal role in supporting harmonisation, wider architecture consistency and coordinated deployment (e.g. through support to the SESAR Deployment Manager, and through our joint work programme with the European Defence Agency).

Research incorporating civil-military interoperability needs

A dual-use CNS infrastructure depends on the availability of concrete technical interoperability solutions that have been defined, validated, standardised and industrialised in time. However, research into the area of interoperability needs to accelerate, especially as uncertainty exists as to whether there is sufficient industry buy-in for delivering solutions to improve the air-ground integration of military aircraft (see Figure 6), or increased ground-ground secure data sharing, either through the SESAR 3 JU or through other research programmes.

The concrete research proposals for SESAR 3 derive from military-related priorities identified at the 28th meeting of

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the EUROCONTROL Military ATM Board (MAB) on 13 April 2021, which proposed, inter alia, security solutions enabled by ADS-B Phase Overlay, datalink solutions for the military, and the validation of governmental GNSS suitability to support PBN specifications.

A good baseline is offered by recent technical studies commissioned by EUROCONTROL to support its contribution to SESAR 2020. Such studies produced important results in areas such as use of military inertial systems and governmental GNSS signals to support PBN specifications, as well as RF spectrum compatibility between military datalink and future terrestrial datalink used for ATM (LDACS).

The foreseeable rollout of mature interoperability solutions supporting dual-use is anticipated to be insufficient in the short to medium term. A number of other interoperability areas also remain open as research gaps. Research initiatives in this particular domain are usually impacted by the lack of industry buy-in, serious industrialisation gaps and multiple institutional and technological hurdles.

Therefore, additional research frameworks need to be identified, tackling also the most recent interoperability challenges introduced by disruptive technologies, new generations of military platforms and by fast-evolving technological environments, all of which should lead to software predominance, data-centric services and equipment-agnostic concepts.

Closing the industrialisation gap: standardisation and coordinated procurement – the harmonisation “glue”

A crucial element in meeting military mission needs is, therefore, the availability of common technical standards that properly reflect military needs.

Standardisation is a fundamental enabler to bridge the gaps between research, industrialisation and deployment. Standardisation is the glue for harmonisation, and the main facilitator of interoperability and infrastructure de-fragmentation. In addition, standardisation eases certification by providing sound and common elements to certify against.

It is imperative to link the military planning and procurement programmes with the underlying operational concepts and to synchronise them with corresponding civil programmes. A key reference in this regard is the EUROCONTROL Civil-Military CNS Interoperability Roadmap.

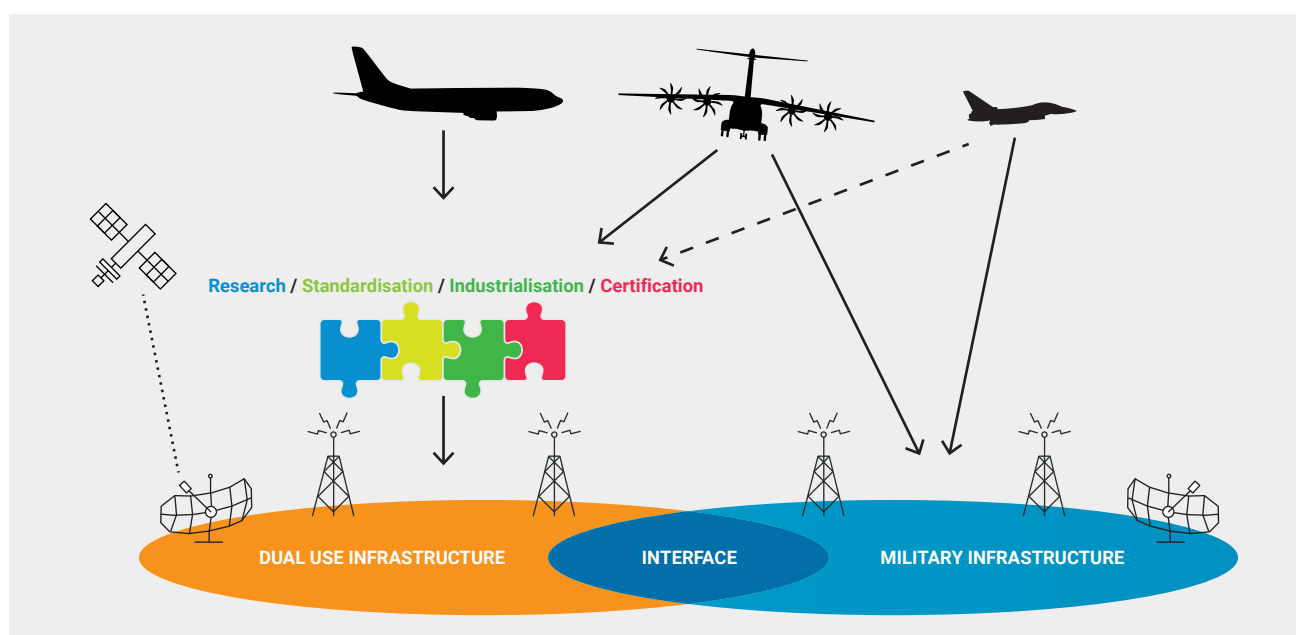


Figure 6: Dual Use Air-Ground Integration

Addressing civil-military deployment challenges

The CNS infrastructure evolution and related deployment initiatives have triggered a number of civil-military interoperability challenges, nine of which are examined below:

1. CNS rationalisation

Ongoing civil aviation plans to eliminate redundancies and replace ageing technologies cannot take place without co-ordination with all stakeholders, including national military authorities. Any decommissioning decisions must include the retention of MONs, and should be taken by the appropriate national authorities.



2. Information sharing and networking

A future dual-use infrastructure must rely on secure data-sharing based on IP technologies, standardised SWIM services, data models and technical infrastructure profiles.

IP connectivity to the NewPENS communications backbone, and the application of security interfacing measures to safeguard military-sensitive information, will be paramount.

The wider deployment of ICAO's FF-ICE (Flight & Flow Integrated Cooperative Environment) and flight data interoperability, as well as the virtual/remote provision of ATS services, offer substantial civil-military interoperability opportunities.

3. Aircraft connectivity

Air-ground interoperability will be a fundamental challenge to enable trajectory management and other advanced operational concepts. This entails, in some cases, military operators considering the use of civil datalink services (ATN/VDL-2 followed by FCI) for controller-pilot data link communications applications (see Figure 7) and, subsequently, for ADS-C/EPP services supporting real-time sharing of 4D trajectory data.



Figure 7: Datalink HMI

4. From conventional to area navigation

The move from conventional to multi-tracking area navigation (RNAV) based on ICAO's PBN concept (as per Figure 8), including the optimisation of air traffic service routes and instrument approach procedures, is a development that significantly impacts military operations.

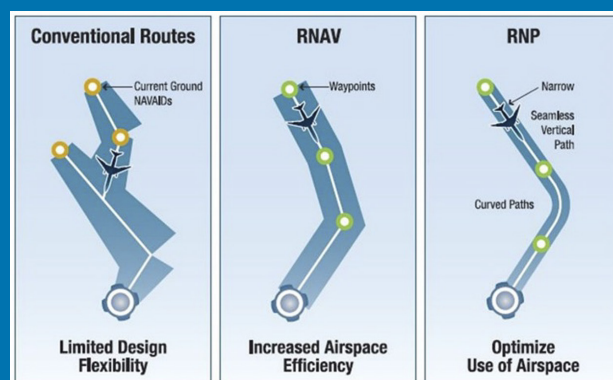


Figure 8: Area Navigation

A sufficient level of conventional means of navigation must remain in service to handle non PBN-equipped State aircraft in line with national transition plans.

Performance-based solutions will be essential for State aircraft to comply with PBN, maximising the reutilisation of military airborne capabilities (e.g. military inertials, GPS-PPS/GNSS restricted signals, TACAN, differential GPS, enhanced visual systems, etc.).

Alternative-positioning, navigation and timing (A-PNT) solutions must ideally consider TACAN (as part of a multitasking solution still to be defined) as an equivalent means of navigation to DME/DME.

5. Military in the optimal surveillance mix

Military flights conducted in a mixed environment must be integrated into the surveillance chain, providing updated aircraft identification, position and other aircraft-derived parameters for safe separation in a defined volume of airspace.

The (civil) terminal and en-route surveillance infrastructure are evolving to rely on an “optimal surveillance mix” including SSR Mode S, Wide Area Multilateration (WAM), and Automatic Dependent Surveillance–Broadcast (ADS-B). In parallel, a layer of independent and non-cooperative surveillance (primary radar) must remain available for all flight phases to track non-transponding targets.

To conceal military information and avoid the easy disclosure of SUR data tracking and flight identification by public internet platforms, many military operators have decided to revert to the operation of Mode 3/A C only. In addition, spoofing and similar threats represent a significant risk for ADS-B. Consequently, security solutions to enable the use of the surveillance infrastructure by the military are urgently needed.

An important aspect is 1030/1090 MHz RF pollution and over-interrogation, which entails strong civil-military coordination actions to maintain safety levels.

6. Spectrum - the enabler of enablers

The success of military missions depends on adequate access to RF spectrum resources, in particular to ensure the mobility and interoperability of forces. Military utilisation of RF spectrum must be safeguarded, and the mitigation of RF interference to/from the civil infrastructure ensured through civil-military coordination efforts.

The increasing reliance on satellite technologies calls for GNSS performance monitoring and coordination efforts, which are particularly important when seeking to mitigate GNSS jamming and service outages.

7. Security – A vital dimension

Security management processes and mechanisms are fundamental if we are to enable a dual-use CNS infrastructure that is trusted for military access. Sound security solutions must address CNS vulnerabilities introduced by intensive data-sharing and increasing levels of automation and connectivity. Concrete technical security solutions must be defined and brought to adequate deployment readiness level.

8. Unmanned aircraft

As a general principle, the CNS requirements for civil remotely piloted aircraft systems (RPAS) will also be applicable to military RPAS integration.

RPAS HALE/MALE (High Altitude/Medium Altitude Long Endurance) integration will entail the availability of a ground and space-based service and airborne CNS equipment that mirrors the CNS requirements applicable to manned flights.

9. Sustainability

If aviation is to achieve its ambitious decarbonisation goals, all actors need to play their part. As other EUROCONTROL Think Papers have underlined, there is considerable potential to ‘green’ the ground infrastructure of European air traffic management. Military operators are also contributors to such important goals where energy efficiency plays a major role.

An important aspect is 1030/1090 MHz RF pollution and over-interrogation, which entails strong civil-military coordination actions to maintain safety levels.

Key conclusions

Russia's ongoing aggression against Ukraine has put the need for military aviation to be able to promptly deploy military assets throughout Europe under the spotlight. This calls for a future **CNS infrastructure with a dual-use nature** to sustain particular requirements from military and other airspace users.

Enhanced data sharing / "big data", emerging ICAO performance-based CNS concepts and cutting-edge software-based avionics are trends that will facilitate civil-military CNS interoperability objectives. Interoperability initiatives will indeed benefit from the exponential increase of information exchanges, new requirements defined on the basis of equipment-agnostic approaches and software-based technologies supporting new waveforms in opposition to cumbersome hardware evolution.

A future dual-use infrastructure, and related interoperability imperatives, can only become a reality if research initiatives to deliver military integrative solutions are intensified. Current research remains insufficient, and in many cases is not adapted to the emerging technology paradigms. Innovative interoperability solutions need to be intensified and developed through pragmatic industrial research initiatives (SESAR 3 JU and others).

Performance-based approaches must be favoured to allow the military to use their own available CNS equipment when seeking compliance with civil requirements. Equipment retrofits are no longer viable when civil-military interoperability is at stake (glass cockpits, lack of integration space, etc.).

An optimised and technologically advanced CNS infrastructure with a dual-use nature will feature higher automation and connectivity levels which raise additional security concerns, and its net centricity and distributed nature poses new resilience challenges. Such a new dual-use system needs to be resilient and mitigate against cyber vulnerabilities, addressing data encryption, jamming protection, GNSS outages and concealment of surveillance parameters.

Future civil-military initiatives must pay close attention to the specific nature of new disruptive technologies (e.g. the emergence of artificial intelligence, quantum computing, etc.) **and to the new challenges related with spectrum efficiency and sharing.** The aviation technology paradigm is evolving quickly. A fully digitalised and high-bandwidth new generation of air-ground data communications, reliance on satellite signals and distributed Internet Protocol connectivity relying on harmonised protocol stacks and standardised data models will severely influence interoperability with military systems. Fierce competition for spectrum bands will intensify as other sectors compete for spectrum.

The CNS infrastructure must evolve to offer energy efficiency gains and also improved flight efficiency that contribute to aviation decarbonisation objectives. Military operators have taken already concrete measures in that domain, and must remain as contributors to such important goals.

The new dual-use system needs to be resilient and mitigate against cyber vulnerabilities, addressing data encryption, jamming protection, GNSS outages and concealment of surveillance parameters.

Glossary

ADaaS	ATM Data as a Service	SAS	Shared ATS System
ADS	Automatic Dependent Surveillance (C - Contract, B – Broadcast)	SDR	Software Defined Radio
ADSP	ATM Data Service Provider	SES	Single European Sky
A-PNT	Alternative Positioning Navigation and Timing	SESAR	Single European Sky
ATC	Air Traffic Control	SSR	Secondary Surveillance Radar
ATM	Air Traffic Management	SWIM	System-Wide Information Management
ATN	Aeronautical Telecommunications Network (ICAO concept)	TACAN	(UHF) Tactical Air Navigation Aid
ATS	Air Traffic Services	UHF	Ultra High Frequency
ATSU	Air Traffic Services Unit	VDL	VHF Data Link
ATSP	Air Traffic Service Provider	WAM	Wide-Area Multilateration
CNI	Communications, Navigation and Identification		
CNS	Communications, Navigation and Surveillance		
COTS	Commercial Off The Shelf		
EDA	European Defence Agency		
FCI	Future Communications Infrastructure		
FDPS	Flight Data Processing System		
FF-ICE	Flight & Flow Integrated Collaborative Environment		
FPGA	Field Programmable Gate Array		
GNSS	Global Navigation Satellite System		
GPS	Global Positioning System		
HALE	High Altitude Long Endurance		
ICAO	International Civil Aviation Organisation		
IFPS	Initial Flight Plan Processing System		
IMA	Integrated Modular Avionics		
IP	Internet Protocol		
LDACS	L-Band Digital ATM Communications System		
MAB	Military ATM Board		
MALE	Medium Altitude Long Endurance		
MON	Minimum Operational Network		
MUAC	Maastricht Upper Area Control Centre		
PBN	Performance Based Navigation		
PENS	Pan-European Network Services		
PPS	Precise Positioning Service		
PSR	Primary Surveillance Radar		
RF	Radio Frequency		
RNLAF	Royal Netherlands Air Force		
RPAS	Remotely Piloted Aircraft System		



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