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Radio spectrum: Safety-critical for aviation – but urgent action needs to be taken to avoid channel saturation & interference from other users such as 5G networks

5G, the latest generation network technology for broadband cellular networks, is an essential part of Europe's digital transformation, delivering higher speed data with ultra-low latency. However, that comes at a price: new so-called midband 5G networks are introducing high-power terrestrial services among low-power radio spectrum users (satellite and aviation services). In the US, that has seen spectrum catapulted into the policy limelight, with highly-publicised delays to wireless broadband deployment of C-band 5G due to concerns about radio spectrum interference with signals vital to the safe operation of aircraft. This Think Paper explains how the scarcity of radio spectrum is leading to increasing pressure on aviation from other sectors, in particular 5G networks; argues that aviation must urgently improve its use of spectrum by dedicating more resources to technological enhancements; and suggests how policymakers could help aviation improve its use of spectrum and avoid operational problems on the scale of the ones encountered in the US.

Specifically, this 'Think Paper' looks to assess:

- could Europe struggle with 5G interference issues like the US now or in the future?
- how spectrum-efficient is aviation right now – and how should it evolve to ensure compatibility with quickly evolving adjacent band users?
- what steps need to be taken by policymakers and all aviation actors for improvements to happen – and to avoid possible interference between very different spectrum users?

The paper concludes that the impact of widespread 5G deployment is likely to be less in Europe compared to the US taking into account current 5G plans, because the European Commission plans to dedicate the band closest to radio altimeters to so-called "verticals" (company and factory-internal networks operating at lower power levels). However, there are no grounds for complacency: radio spectrum is a scarce resource, and aviation must improve how it uses it to avoid costly problems in the years ahead.

KEY FINDINGS OF THIS THINK PAPER

1. **Spectrum is a scarce resource that** aviation and telecommunications are competing for. **Policymakers need to balance conflicting demands of these two similarly-sized sectors** especially when auctioning high-value spectrum in or near frequency bands currently assigned to low power users like aviation.
2. While aviation has no difficulty to innovate in other areas, current business models inherently fail at creating incentives for improving aviation spectrum efficiency.
3. **Spectrum disruption could threaten aviation safety, and entail significant financial costs for airlines – a year of diversions triggered by 5G disruption to operations on low-visibility condition days could amount to €180M and impact 1.2 million passengers.** While 5G interference potential may be higher in the US mainly due to higher levels of radiated power, there is **a real risk that spectrum inefficiency will hold aviation back in coming years** as current systems increasingly struggle to meet evolving operational requirements.
4. While the telecoms industry pays huge sums for its use of spectrum compared to aviation and is a spectrum competitor, nevertheless **both industries are comparable in importance to global GDP (€3.6 trillion & €3.1 trillion, or 4.7% % 4.1% respectively), serving similar numbers of users (5.2 billion subscribers, 4.5 billion passengers).**
5. Coordinated efforts must be made to modernise aviation communication, navigation and surveillance (CNS) systems: more resources need to be devoted to tackling spectrum inefficiency to prevent **channel saturation, which will make it difficult to transition to more modern, capable systems.**
6. EUROCONTROL has identified 3 strategies to improve spectrum use: **improving adjacent band filtering** as much as possible; **improving aviation equipment standards maintenance for legacy systems, and getting the balance right between coordinated deployments** of new CNS radio systems, including 'settling for less' if this aids global implementation.
7. **However, to effect real change, incentives may be required to coordinate deployment of CNS radio systems in a mature aviation business environment.** This would help convince all actors to equip with new technology, especially as the **cost of development and safety certification continues to provide a high barrier to innovation.**

How essential is spectrum to aviation – and could ongoing 5G rollouts affect operations in Europe?

Aviation relies on spectrum for aircraft to take off, fly en-route and land safely, making radio spectrum safety-critical. **Without spectrum, CNS systems could not operate, and most civil and military aviation would simply come to a stop.** Aircraft, ground and space systems are connected through a wide range of CNS – communication, navigation and surveillance – systems. These provide navigation guidance, separation from other air traffic, and terrain clearance, and they do this globally in all weather conditions. To do their job effectively, they rely on allocations of radio frequency (RF) spectrum established many decades ago. Spectrum allocations for aeronautical use are protected by international agreements established through two specialised United Nations agencies, ITU (the International Telecommunications Union, responsible for global spectrum allocation) and ICAO (the International Civil Aviation Organization, supporting ITU on aviation aspects).

Allocations supporting the "safety and regularity of flight" enjoy specific protections including "safety margins", which recognise the safety-critical nature of aeronautical CNS systems and are normally not shared with non-aeronautical systems. **These essential aviation spectrum allocations have been maintained by governments despite increasing commercial pressure for greater spectrum access.** Aviation conducts extensive safety assurance and certification efforts dedicated to ensuring that equipment on the ground, in space and in the air has been tested in all possible operating conditions, including possible fault modes, to prove that they will not cause any unsafe situations. Furthermore, if aviation safety spectrum is shared between several such aeronautical systems, normally using frequency-separated operating channels, an extensive effort goes into ensuring signal compatibility and mutual interference-free operations.

Despite all these aviation safety efforts linked to the scarce resource of spectrum, **aviation has no privileged right to indefinite access compared to other spectrum users,** in particular the telecommunications and mobile phone industries. Lately, governments have recognised that the

"Without radio spectrum, CNS systems could not operate, and most civil and military aviation would simply come to a stop."

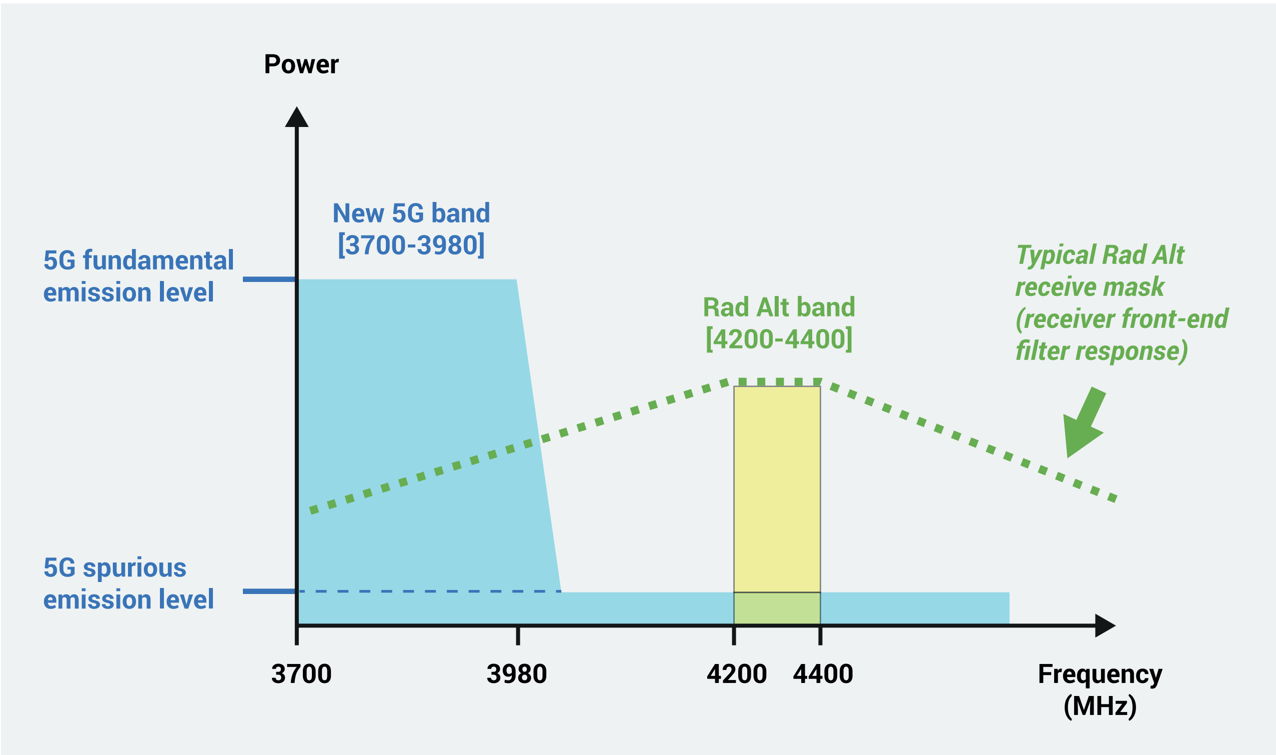
latter is an essential enabler for the digital economy and future growth. **Furthermore, the telecom industry also provides significant government revenues through spectrum auctions**. While new technologies can expand the usable range of spectrum to some degree, often there is a desirable spectrum range in terms of frequencies used for a given application. This means that there is significant competition for spectrum, in particular for the most desirable portions of spectrum.

This competition is arbitrated through the ITU World Radio Conferences every four years. While so far, aviation has been able to maintain its spectrum allocations with only minor release or sharing of spectrum, **recent years have seen an increasing dynamic in adjacent band spectrum allocations,** meaning that aviation must recognise that the spectrum neighbourhood in which it operates can change significantly, and that such changes can easily outpace the ability of aviation to adapt to such radio frequency environment changes.

The current 5G/aviation debate has for the first time thrust potential spectrum interference from other spectrum users into the spotlight with one of aviation's most safety-critical operations, automatic landings. Aircraft radio altimeters, or RADALT for short, enable aircraft to land on the runway in all weather conditions while meeting highly demanding safety requirements. RADALT use the 4.2-4.4 GHz frequency range. The band allocated in the US to 5G (3.7-3.98 GHz) is closer to the RADALT band than in Europe, where it is 3.4-3.8 GHz. Furthermore, the US permits higher maximum power compared to what is generally implemented in Europe. **Taken together, this has created a real risk of interference in the US that, for now, is not considered to be a problem requiring immediate safety mitigations in Europe;** nonetheless, the interference risk remains also in Europe, which is why studies on this topic continue.

The spectrum above and below RADALT had so far been used mainly for satellite applications, which operate also with low power levels (or with very concentrated radio beams). However, introducing a high-power terrestrial service led to a clear risk of RADALT being subject to interference despite a large separation in frequency of 200 to 400 MHz, as the RTCA (Radio Technical Committee for Aeronautics) flagged in October 2020, as per Figure 1:

FIGURE 1: 5G AND RADALT SPECTRUM INTERACTION UNDER EVALUATION [1]



[1] Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations", RTCA Paper No 274-20/PMC-2073, from rtca.org. RTCA, Inc, Washington DC, USA

"There is a desirable spectrum range, and significant competition for it, particularly for the most desirable portions of spectrum"

Avoiding any erratic disturbance or sudden loss of RADALT is vital for aviation as such a situation could have severe consequences for a wide variety of aircraft and its occupants, including military aircraft and helicopters, operating at low altitudes and in low visibility. Safety is always aviation's first priority, and as soon as there is a reasonable possibility that 5G signals could impact RADALT, operations need to be stopped [2].

Stopping or diverting operations because low-visibility conditions (LVC) landing capability is not available poses a huge financial headache for airlines: EUROCONTROL calculates that **each LVC diversion** to an alternative airport ranges between **€20-€80K** in extra costs [3].

The number of LVC varies geographically, seasonally and during the day, but in a normal year, EUROCONTROL estimates that a major European hub with Atlantic connections may see around 9,000 flights performing LVC approaches.

Losing LVC landing capability on a given day would see some flights diverted and others cancelled on the day of operation, with airlines classically bearing the brunt of costs in the form of delays and passenger compensations. But a year of LVC diversions with knock-on delay effects would be disastrous for Europe's airlines, **rising as high as €180M and impacting 1.2 million passengers.** In the US, where about 4% of 345,000 passenger flights a year (2019) use LVC approaches, the figure would be even higher [4]. And this is before factoring in financial impacts on cargo operations, rescue and military readiness, etc.

[2] Aviation safety requires positive proof that an operation is safe, taking into account all possible failure modes, including RF interference. If there is any doubt, the operation must be stopped. On the other hand, issuing an "airworthiness directive" is aviation's most severe regulatory instrument, which can only be used if specific conditions are met, including associated evidence. This is what is meant by "reasonable possibility" – which is of course the subject of significant expert debate currently.

[3] EUROCONTROL Standard Inputs for Economic Analysis. Accessed at: https://www.eurocontrol.int/publication/eurocontrol-standard-inputs-economic-analyses

[4] "US airlines warn 5G wireless could wreak havoc with flights". Accessed at: https://www.reuters.com/business/aerospace-defense/us-airlines-warn-5g-wireless-could-cause-havoc-with-flights-2021-12-15/

Competition for spectrum is heating up: How aviation and telecoms' needs shape up

The telecoms industry covets aviation's spectrum, and telecoms companies often accuse aviation of failing to use its spectrum efficiently – as indeed aviation is obliged to do, under the ITU Radio Regulations (RR). Article 4.1 of these calls on States to *"endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end they shall endeavour to apply the latest technical advances as soon as possible"* (our emphasis).

To continue to enjoy the special safety protection (provided by ITU RR Article 4.10), aviation must strive to meet all ITU regulations, including Article 4.1. But is aviation doing its best to apply the latest technological advances as soon as possible? The answer is, as we will see, not exactly.

Aviation can and does adopt new technology rapidly – however, this is only true for areas which are directly business relevant in terms of operating cost, such as fuel efficiency. For CNS systems, however, this tends to be a painstaking process. In the aviation CNS industry, system development and standardisation tend to take somewhere between 10 and 20 years, while deployment into the full global fleet of aircraft and CNS facilities can add another 20+ years.

This is based on a "forward-fit" strategy to equip only new aircraft with a new capability, rather than retrofit as well – retrofitting normally has a clearly negative business case associated with it, including losses from taking the aircraft out of operation, and is therefore normally only done to fix an urgent safety problem.

From a spectrum point of view, switching to a new technology is doubly problematic as it typically involves a period in which the spectrum needs for the new technology have to be met concurrently with the pre-existent spectrum needs for the older technology. Since today there is no new suitable and unused spectrum available, accommodating a transition over such long timescales is very challenging. **This long timescale contrasts starkly with telecoms' use of spectrum, which is directly driven by commercial imperatives.**

"A year of diversions caused by interference in low-visibility conditions would have disastrous knock-on delay effects for Europe's airlines, costing up to €180M, and impacting 1.2 million passengers"

To achieve a "minimum essential" use of spectrum, aviation needs to operate radio systems as efficiently as possible. So how does aviation shape up against telecoms in terms of spectrum efficiency? Figure 2[5] provides a series of quick comparisons. They are based on economic indicators because a discussion of technical measures is beyond the scope of this paper.

FIGURE 2: TELECOMS VS AVIATION SPECTRUM USAGE

	Telecoms	Aviation
Spectrum allocation		
Global spectrum allocation in 2019	2.38 GHz	2.15 GHz
Industry contribution to the economy		
Revenues 2019	€910BN	€714BN (612BN PAX + 102BN cargo)
Investment average for last 5 years	€152BN	€80BN
Contribution to GDP (absolute and % of total)	€3.6TN or 4.7%	€3.1TN or 4.1%
Direct jobs created	16M	11M
Tax revenues generated (excluding fees)	€433BN	€129BN
Estimated market size		
Users	5.2BN unique subscribers	4.5BN passengers transported
Approximate price of device	~ €200	€20-100,000
Approximate number of devices	5-10+BN	~ 1 M
Lifetime of devices	1-5 years	15-30 years
Environment		
Annual emissions (absolute and % of total)	220 $MTCO_2$ or 0.4%	914 $MTCO_2$ or 2.1%

Note: This comparison makes the assumption that without suitable spectrum, aviation passenger and cargo revenues could not take place. However, many other things are required to generate these revenues, which is why other spectrum-economic assessments apportion only some reasonable share of total revenues to the availability of spectrum. For telecommunications, a larger part would likely be allocated to the availability of spectrum (compared to aviation).

[5] Amount of spectrum used from ITU radio regulation, article 5. Total spectrum bands for mobile are not allocated in all ITU regions, however, WRC2019 also saw a lot of new allocations for mobile spectrum. Financial values are for 2019 (last pre-pandemic year) and sources are GSMA and ATAG. USD have been converted into EUR using Jan 22 exchange rate published by ECB as recommended in EUROCONTROL Standard Inputs for Economic Analyses. The number of CNS avionics is estimated as 35'000 air transport aircraft x 30 CNS devices per aircraft and not taking into account the associated ground facilities. 30 CNS devices are assumed as 15 different types of CNS avionics with dual redundant installations. While this is an upper bound approximation based on industry expert estimations, the point is simply that it is a lot less than the number of mobile phones. Sources used in figure:

- GSMA (2020). The Mobile Economy. Accessed at: https://www.gsma.com/mobileeconomy/europe/
- Air Transport Action Group (2020). Aviation Benefits Beyond Borders global factsheet. Accessed at: https://aviationbenefits.org/
- European Central Bank (2022). Reference exchange rate USD to EUR. Accessed at: http://sdw.ecb.europa.eu/
- EUROCONTROL (2020). Standard Inputs for Economic Analyses. Accessed at: https://www.eurocontrol.int/publication/eurocontrol-standard-inputs-economic-analyses
- ERICSSON (2021). Ericsson Mobility Report. Accessed at: https://www.ericsson.com/en/reports-and-papers/mobility-report/reports/november-2021
- IATA (2020). Industry Economic Performance Series. Accessed at: https://www.iata.org/en/publications/economics

"Aviation generates a similar contribution to global GDP with its allocated spectrum as the telecoms industry, and generates comparable revenues"

Aviation, therefore, generates a similar contribution to global GDP with its allocated spectrum as the telecoms industry, and generates comparable revenues. This means that both industries are operating at a similar level of economic spectrum efficiency, given their spectrum allocation.

However, this is achieved using fundamentally different market dynamics: there are a lot more smartphones on this world compared to CNS avionics on aircraft, and they are also a lot less costly. Taking into account the lifetime of devices, **the global mobile phone market is around 160 times larger[6] than the CNS avionics market in total sales volume, and subject to fundamentally different economies of scale.** While aviation's use of spectrum and economic value are both likely to remain stable, both **the use of spectrum and the economic value generated by the telecoms industry are expected to increase.**

Policymakers, therefore, need to tread carefully when deciding between competing spectrum demands. The quick-win of selling spectrum to mobile telecom could impact other spectrum users including aviation, which is why aviation needs to continue to explain its safety-critical requirements to the government representatives of State radio regulatory authorities who take such regulatory decisions. Specific attention is required for changes in adjacent spectrum bands since unfortunately it is not possible to put a "brick wall" between neighbouring spectrum users. However, evolution should still be possible without imposing undue business constraints on all spectrum users. **The 5G mid-band spectrum auction in the US yielded a record-breaking $82 billion in proceeds, providing a strong visualisation of the spectrum-investment readiness of mobile telecom.**

6 Using 7 Billion mobile devices at a cost of €200 replaced every 3 years vs. 1 Million CNS avionics devices at an average cost of €60'000 replaced every 21 years.

Is aviation doing enough to improve its use of radio spectrum compared to telecoms?

The availability of spectrum and high data rates are vital to consumer satisfaction with telecoms, and thus drive innovation in telecoms' use of spectrum.

Aviation does not have the same business drivers, however. The availability of spectrum for CNS avionics is equally vital, but for safety and airline operational purposes, and has no direct impact on passenger satisfaction. Aviation is a very mature industry compared to telecom, therefore CNS systems essential to airline operations are already on-board the aircraft.

Aviation also faces major hurdles to CNS innovation. Deploying new technology poses considerable difficulties, and there is only a very limited margin for investment in costly developments that will not drive profitability. While market competition works well in some parts of the aviation sector, with the industry pushing hard towards more efficient engines or lighter aircraft structures, this is not the case for CNS.

While a single mobile device can accommodate quite a variety of different communication standards in use around the world, introducing a new type of avionics and ground CNS infrastructure requires that manufacturers, airlines and Air Navigation Service Providers (ANSPs) all around the globe need to agree to acquire the same type of system on a voluntary basis. Given the maturity of the industry, such investments typically provide only a limited operational benefit. In conclusion, while the telecoms market drives positive technological development, the avionics market provides a significant barrier to this.

The need for global interoperability also stands in the way of introducing market forces as a way of accelerating innovation. While some States have considered introducing spectrum pricing for aviation-used spectrum to artificially create "spectrum market pressure", this approach does not work well for systems requiring global interoperability, which are subject to high development and safety certification costs. An

"Policymakers need to tread carefully when deciding between competing spectrum demands - selling spectrum to mobile telecom seems a "quick-win" but could impact negatively other spectrum users"

aircraft cannot decide to switch to a more spectrum-efficient communication system, because it still needs to allow pilots to speak to air traffic controllers using the system that they are using across different regions and geographies. CNS change only works, therefore, if almost everyone is implementing it.

However, **while it may be difficult to improve aviation's use of spectrum, aviation still should strive its utmost to do so.** Spectrum for CNS is essential for improvements in safety, cost-efficiency, capacity increase and reduction in environmental impact, but does not directly drive any of them. **Increasing spectrum efficiency should therefore be best understood as part of responsible risk management, as an activity to avoid dis-benefit, or avoiding operational limitations as a consequence of an evolving radio environment.**

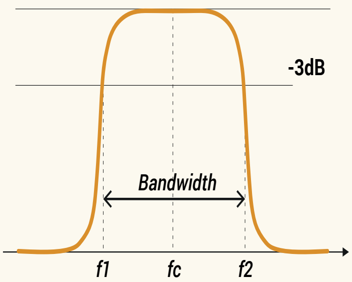
The risk of future unanticipated interference and its high potential cost should, therefore, incentivise aviation business leaders to dedicate more resources to ensure that aviation can continue to use its spectrum at a minimal cost. The need for focusing on spectrum more has also been put into sharp focus by the growing need to mitigate Radio Frequency Interference caused by State or proxy actors in conflict zones, as outlined in EUROCONTROL Think Paper #9.

The path to greater aviation spectrum efficiency

EUROCONTROL has identified three practical efforts which should be made and are feasible to make CNS systems more spectrum-efficient.

1. Maximise adjacent band filtering

Benchmark state-of-the-art capabilities and drive implementation in aviation to the greatest extent possible.



2. Maintain standards in line with parts obsolescence cycles

If equipment is in service for longer than a full aircraft generation (20-30 years), ensure that standards are updated to state-of-the-art RF performance in line with parts replacement-which the industry has to do anyway. Create incentives to facilitate updating certifications to better RF performance.

3. Don't wait forever to leapfrog to newer CNS technology (let alone then fail to do even that)!

Any conservative industry will, due to safety standards and certification, lag behind the state-of-the-art. But this should not lead to blocking innovation. Accept that new system implementation takes so long that systems will not be state-of-the-art once implemented.

1. **To do more to improve adjacent band filtering,** using all the available tricks in the physics manual to do so, especially in frequency bands where the boom in mobile technology makes this most relevant. Radio Frequency (RF) filters are important for transmitting and receiving signals, with the receiving side vital as it determines how vulnerable a system is to interference from other, adjacent band systems. **The better the filter, the easier it is to limit exposure to adjacent band energy** – even if there are limits to what can be achieved when a high-power terrestrial user (like telecoms in the US) is operating in the vicinity of a low-power user (like aviation RADALT, or satellite technology).

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To be effective, adjacent band filter design needs to **follow developments in other industries.** In the case of the RADALT debate, aviation has already missed the opportunity to adapt to evolving spectrum use in the frequency bands adjacent to RADALT. Growing demand from the telecoms sector was clear years ago; 3G and 4G were always going to develop towards 5G and beyond with ever higher frequency ranges to enable higher data rates. More effort should have been deployed much earlier to react to the evolution of usage of this region of spectrum.

2. To improve standards maintenance by allowing a lighter recertification process. CNS upgrades are closely linked to aircraft replacement cycles, which typically operate on a 20 to 30-year basis. Within such a timeframe, avionics manufacturers will need to deal with parts obsolescence, meaning that most avionics will have updated electronic components. Unfortunately, this normally does not lead to an update in standards, which would allow the device to be recertified against higher-performing RF requirements. Despite more modern and often better performing parts inside a box of avionics, certification linked to the initially written standards will be maintained, since recertification bears a significant engineering cost. Where newer parts with better RF performance have no impact on system performance, not triggering a full recertification process could incentivise innovation.

The prerequisite for that would be updated standards against which compliance can be evaluated. Once a given CNS system has been in operation for 20 or 30 years, all associated standards should be reviewed to see if various RF aspects could be updated. Changes in aeronautical bands (which happen infrequently) require updating, but sweeping changes in neighbouring bands – which aviation has no control over – should trigger fundamental review as they change the environment in which CNS systems operate in.

3. To prioritise the coordinated implementation of spectrum-efficient technologies, but also be ready to settle for less.

Replacing RADALT with a more spectrum-efficient technology runs into various problems. Lasers deliver very accurate readings for distance measurement, and could eliminate the need to use the C-band around 4 GHz – but only work well in clear visibility conditions, proving no help as a substitute for RADALT. And more advanced radar technologies with a smaller spectrum footprint do not exist outside classified military technology. There is no alternative technology to RADALT in a different frequency band.

Another system which could be evaluated is DME, or Distance Measuring Equipment, which like RADALT uses about 200 MHz of spectrum, split into a number of dedicated frequency channels that are already shared with a number of other aviation spectrum users. Similar to RADALT, DME also provides "just one number", which is the slant range distance between the aircraft and a station installed on the ground. As with GPS, an aircraft can determine its position by using several DME ranges. But while GPS, using just 20 MHz, is vastly more spectrum-efficient, problems with RF interference linked to the weak signal power of signals from satellites has confirmed that terrestrial alternates or back-ups to GPS will always be necessary to ensure safety.

Currently, DME is the best alternative to GPS, and due to high peak pulse power, it is very robust. But contrary to RADALT, a number of other technology options do exist to evolve towards greater spectrum efficiency. However, as this would only replace what can already be done, there is no operational benefit, which leads to the roadblocks already explained.

Different approaches are therefore required when it comes to CNS technology improvements. First off, existing approaches should be maximised as much as possible. One such option is to subdivide frequency channels. In the VHF band, navigation systems such as ILS or VOR started out using 100 kHz wide channels, and then moved to 50 kHz and later to 25 kHz channels. Similarly, voice communication between pilots and air traffic controllers has moved from 25 kHz to 8.33 kHz channels. The move towards 8.33 kHz COM channels was not the most spectrum efficient technology option available. But while transition was complex and challenging, it was still achieved, and spectrum efficiency was increased. Other technology options would have faced much greater transition obstacles. Another existing option to improve spectrum efficiency is the introduction of additional modulation to increase data rate, as was achieved with Secondary Surveillance Radar (SSR, and Mode S). Such improvements are not dramatic, but they are achievable

"Aviation should prioritise the coordinated implementation of spectrum-efficient technologies - but also be ready to settle for less if this aids wide-scale implementation"

and therefore a lot better than chasing after technology which will not be able to overcome transition and deployment obstacles.

Such "simple approaches" may mean having to accept converging on a less than perfect technology to achieve wide-scale implementation. This principle also holds true because of aviation's long transition timelines for introducing new technology: by the time a "new technology" in aviation is ready for deployment, it is often not so new anymore. Then, even if 10 years previously the international community had agreed to greenlight work on developing a new technology, doubts will arise as implementation draws closer, especially when a newer, even better technology appears to be on the horizon. This is what happened to MLS (Microwave Landing System) and what seems to be happening to AeroMACS, a data communication system for the airport environment. While hesitating to commit to the implementation of a new system when what looks like an even better system is on the horizon may seem logical, it tends to impede progress **and results in less spectrum efficient legacy system continuing in use for an even longer time.** Striving for the "art of the achievable" would help to ensure that aviation CNS systems make at least some progress in spectrum efficiency, even if it may not be as dramatic of a gain as some communities may wish for.

Spectrum-inefficiency could prove very costly in the long run

For justifying CNS system upgrades with limited operational benefit, it is therefore important to realize that **spectrum inefficiency could carry an alarming price tag in the long run.** Today's "old" CNS systems were designed with quite different operational needs and demand in mind. As a result, many **legacy systems are typically operating at full channel load, with little flexibility left in frequency bands to accommodate growth.**

This could have major consequences for aviation in the years ahead. **Frequency-congested systems could limit air traffic growth and efficiency** – with VHF COM channels used for pilot-to-controller voice communication being a case in point. These have been a contributing factor to growth limitation for over 10 years, and now increasingly need to share spectrum with VHF datalink. Each new air traffic sector created to meet rising capacity needs a new frequency, taking around 7 months to implement, and

often having a knock-on effect where quite a number of neighbouring sectors need to also change frequency in order to accommodate the new assignment. When assuming continued traffic growth, that all carries a price tag – in each case on average around 15,000 flights prevented from taking place, 2 million fewer passengers, €11 million less in revenue for ANSPs, and over €370 million in lost consumer benefits, based on EUROCONTROL data[7].

Efforts to move datalink to the L-Band spectrum are not a perfect solution, as such a datalink needs to share spectrum with DME channels, which are also near saturation. However, the longer this situation perpetuates, the more difficult will it be to accomodate any transition to such new systems. Furthermore, delays in introducing more modern and capable systems does have a tangible cost associated with it. In the case of VHF COM, it is directly linked to non-availability of spectrum.

All of this explains why moving forward with a "prioritised coordinated implementation of spectrum-efficient technology" is so difficult. Nonetheless, these obstacles need to be overcome. **This may require new approaches especially when it comes to financing equipment upgrades, by drawing a clear line between where the current market model is effective and where it is not, and by introducing the need for better spectrum efficiency as a major driver.**

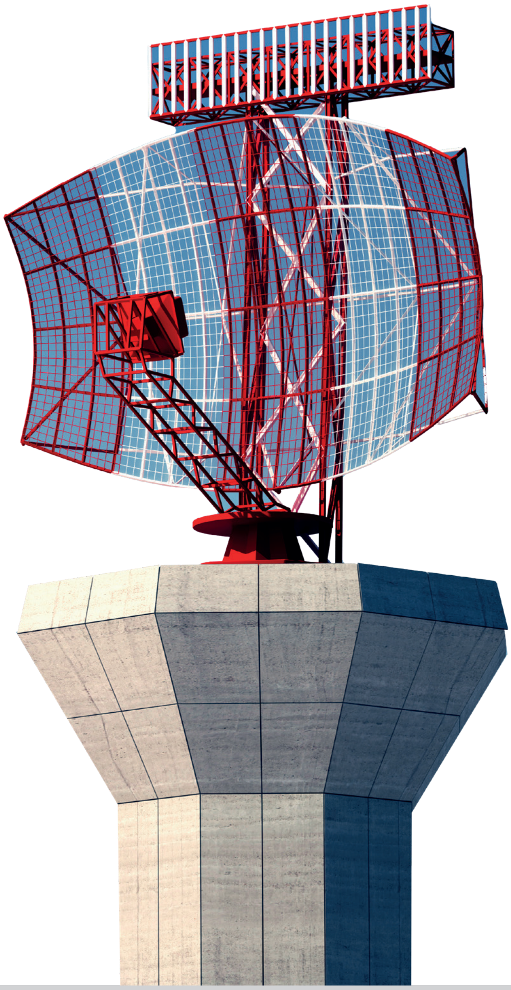
[7] Estimation based on Maastricht Upper Area Control Centre and EUROCONTROL (2019), Network Operations Plan 2019-2024. Accessed at: https://www.eurocontrol.int/publication/european-network-operations-plan-2019-2024

"Spectrum inefficiency could carry an alarming price tag in the long run: many legacy systems are typically operating at full channel load, running the risk that frequency-congested systems end up limiting air traffic growth"

Summary

Aviation has been using significant amounts of safety-protected spectrum for many years and essentially for free, while **other industries like telecoms are willing to pay huge sums to access spectrum, and are incentivised to exploit the finite spectrum allocated as efficiently as possible for commercial gain.** This puts aviation under increasing pressure to accommodate a rapidly-evolving RF environment in nearby frequency bands, to not stand in the way of other industries' growth, and improve how it uses its existing spectrum allocations.

Aviation needs to overcome the inherent limitations to deploying new CNS technology. Some simple changes are realistic and the minimum needed to comply with the ITU Radio Regulations, but **more fundamental improvements will require policy changes and incentives to enable technological progress.** This may in some cases have only limited operational benefit, but is vital if aviation is to maintain the right to use its spectrum at almost no cost.



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1. **Spectrum is a scarce resource that** aviation and telecommunications are competing for. **Policymakers need to balance conflicting demands of these two similarly-sized sectors** especially when auctioning high-value spectrum in or near frequency bands currently assigned to low power users like aviation.
2. While aviation has no difficulty to innovate in other areas, current business models inherently fail at creating incentives for improving aviation spectrum efficiency.
3. **Spectrum disruption could threaten aviation safety, and entail significant financial costs for airlines – a year of diversions triggered by 5G disruption to operations on low-visibility condition days could amount to €180M and impact 1.2 million passengers.** While 5G interference potential may be higher in the US mainly due to higher levels of radiated power, there is **a real risk that spectrum inefficiency will hold aviation back in coming years** as current systems increasingly struggle to meet evolving operational requirements.
4. While the telecoms industry pays huge sums for its use of spectrum compared to aviation and is a spectrum competitor, nevertheless **both industries are comparable in importance to global GDP (€3.6 trillion & €3.1 trillion, or 4.7% % 4.1% respectively), serving similar numbers of users (5.2 billion subscribers, 4.5 billion passengers).**
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6. EUROCONTROL has identified 3 strategies to improve spectrum use: **improving adjacent band filtering** as much as possible; **improving aviation equipment standards maintenance for legacy systems, and getting the balance right between coordinated deployments** of new CNS radio systems, including 'settling for less' if this aids global implementation.
7. **However, to effect real change, incentives may be required to coordinate deployment of CNS radio systems in a mature aviation business environment.** This would help convince all actors to equip with new technology, especially as the **cost of development and safety certification continues to provide a high barrier to innovation.**

In this document, "Europe" should be understood as the "EUROCONTROL Network Manager area", which encompasses our 41 Member States and 2 Comprehensive Assessment States (see our scope here).

Any queries on the data in this report should be sent to our Aviation Intelligence Unit at aviation.intelligence@eurocontrol.int.

EUROCONTROL Think Paper series

EUROCONTROL produces regular Think Papers aimed at decision-makers which are designed to inform, stimulate debate and present alternative approaches.

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