
DRAFT
GLOBAL CONCEPT
FOR
INTEGRATED
COMMUNICATIONS,
NAVIGATION,
SURVEILLANCE AND
SPECTRUM
Navigation
Communications
Surveillance
Spectrum

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Executive Summary

Modern-day aviation is not the same as a few years ago. Technological innovation and modernization are advancing at an ever-increasing pace. Major technological milestones often cannot be implemented, let alone in a harmonized manner, by ICAO Member States. To avoid unequal and incompatible implementation of new Communications, Navigation and Surveillance / Air Traffic Management (CNS/ATM) technologies, ICAO needs to continue improving the process of development/adoption of ICAO regulatory provisions and achieving consensus for timely and effective rollout.

In line with recommendations from the 13th Air Navigation Conference and recent Assembly Resolutions, ICAO has undertaken the integrated Communications, Navigation and Surveillance (CNS) and Spectrum (CNSS) project, focussing on a medium and long-term evolution of CNS systems and spectrum efficiency while improving global harmonization of the CNS infrastructure and identifying a new and streamlined framework for standardization of CNS systems and spectrum access. While remaining firmly focused on aviation safety and efficiency, this new framework would utilize input from industry in an effective yet fully validated manner, thus ensuring that the aviation sector remains a responsible user of the spectrum resource, while also delivering overall systems improvement.

Chapter 2 of this report indicates a draft high-level roadmap of CNSS evolution (which builds on several specialized roadmaps). Collectively, these outline the necessary strategic milestones and end goals in the medium (2040+) and long term (2050+). The CNS and avionics technology evolutional roadmaps include new concepts, such as flexible system design, that offer the opportunity to maximize the effectiveness with which aviation uses its allocated frequency spectrum. The result will assist: (a) early identification of spectrum-related issues and technology gaps; and (b) development of specific technical and performance specifications to support the implementation of future systems in a globally harmonized manner.

ICAO has prioritized the implementation of existing Standards over the development of new Standards. Performance-based Standards have been favoured over prescriptive Standards and detailed technical specifications. Faced with the rapid advancement of CNSS technology, the related ICAO CNSS standards framework needs to evolve. Otherwise one cannot ensure that SARPs, industry standards and detailed technical specifications will be developed in a harmonized manner and at the pace necessary to secure global interoperability and continued high safety levels. Achieving this will be a considerable challenge. However, the best approach needs to be defined in a timely manner, by ICAO, States and the aviation community as a whole, including new entrants. In order to identify the best methodology to balance “minimal essential CNSS SARPs” and “detailed technical specifications”, the ICNSS-TF has undertaken to scrutinize and develop potential new standardization frameworks to better support system development by industry; and to categorize required CNSS standards frameworks for new systems as well as any required validation activity of the resulting industry inputs within ICAO. This will be further discussed in Chapter 3 of this report.

While considerable progress has been made (in this report), the ultimate objective of this effort is to propose a set of recommendations for endorsement by a future Assembly. States, international organizations and industry stakeholders are encouraged to support ICAO in the continuation of this effort.

EDITORIAL NOTE:
EXECUTIVE SUMMARY WILL BE FURTHER REVISED, AS PROGRESS TO BE MADE BY ICNSS TF.

Glossary

ABBREVIATIONS

CC	Compliance Checklist
CNS	Communications, Navigation and Surveillance
CNSS	Communications, Navigation, Surveillance and Spectrum
EFOD	Electronic Filing of Differences
ICAO	International Civil Aviation Organization
ICNSS	Integrated Communications, Navigation, Surveillance and Spectrum
ITU	International Telecommunication Union
PANS	Procedures for Air Navigation Services
PQ	Protocol Questions
RCP	Required Communication Performance
RNP	Required Navigation Performance
RSP	Required Surveillance Performance.
SARPs	Standards and Recommended Practices
SOCC	Safety Oversight Compliance Checklist
USOAP	Universal Safety Oversight Audit Programme
WRC	World Radiocommunication conference

DEFINITIONS

Global technical Specifications. Detailed technical specifications to ensure interoperability at the technical level between airborne, ground and satellite-based installations, where performance-based SARPs are viewed to be insufficient.

Minimal essential SARPs. Concise SARPs (describing CNS systems and Spectrum access), using performance-based principles, i.e. specifying throughput and quality of service, should be developed whenever appropriate. These will still require some level of technical specifications, such as signal in space characteristics (as per Radio Regulatory requirements) and, other measures to protect the system, i.e. from interference.

Performance requirements**.** Minimum requirements needed for the application to function properly under nominal (no fault) conditions, generally quantitative in nature.

Performance-Based Approach.
A performance-based approach is a way of organizing the performance management process. It is based on the following three principles:

- Strong focus on desired/required results. Instead of prescribing solutions, desired/required performance is specified. The attention of management is shifted from a resource and solution-centric view (How will we do it?) towards a primary focus on desired/required performance results (What is the outcome we are expected to achieve?). This implies determining the current performance situation, what the most appropriate results should be, and clarifying who is accountable for achieving those results.

- Informed decision-making, driven by the desired/required results. This means working "backwards" from the "what"—the primary focus—to decisions about the "how". "Informed decision-making" requires that those making the decisions (decision-makers) develop a good understanding of the mechanisms which explain how drivers, constraints, shortcomings, options and opportunities influence (i.e. contribute to, or prevent) the achievement of the desired/required results. Only then can decisions — in terms of priorities, trade-offs, selection of solutions and resource allocation — be optimized to maximize the achievement of the desired/required (performance) results.

- Reliance on facts and data for decision-making. In the performance-based approach the desired/required results, as well as the drivers, constraints, shortcomings and options, are expressed in quantitative terms and in a qualitative way. The rationale for this is that "if you can't measure it, you can't manage it", i.e. unless you measure something, you don't know if it is getting better or worse. When facts and data are used, they should be relevant and reflect reality. This requires the adoption of a performance measurement culture. It also necessitates associated investments in data collection and management.

Note.- for more details, refer to Manual on Global Performance of the Air Navigation System (Doc 9883).

Required Communication Performance.[1] A set of requirements for air traffic services provision and associated ground equipment, aircraft capability, and operations needed to support performance-based communication.

Required Navigation Performance*.* A navigation specification based on area navigation that includes the requirement for performance monitoring and alerting.

Required Surveillance Performance.[2] A set of requirements for air traffic services provision and associated ground equipment, aircraft capability, and operations needed to support performance-based surveillance.

1) RCP requirements will need to be further improved to align with performance-based concept in CNS

2) RSP requirements will need to be further improved to align with performance-based concept in CNS

Safety of life. Article 40 of the ITU Constitution states that “International telecommunication services must give absolute priority to all telecommunications concerning safety of life at sea, on land, in the air or in outer space, as well as to epidemiological telecommunications of exceptional urgency of the World Health Organization”. In support of the safety aspects related to the use of radio frequency spectrum by aviation, Article 4.10 of the Radio Regulations states, “ITU Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference[3]; it is necessary therefore to take this factor into account in the assignment and use of frequencies.” In particular, compatibility of aeronautical safety services with co-band or adjacent band aeronautical non-safety services or non-aeronautical services must be considered with extreme care in order to preserve the integrity of the aeronautical safety services.

Signal-in-space characteristics. Basic radio frequency signal characteristics to be described in the minimal essential SARPs, such as amplitude, frequency, modulation, frequency tolerance, spectral mask, radiated power, minimum receiver sensitivity and selectivity, interference protection criteria etc.

Streamlined Standards and Recommended Practices**.** An optimized framework for the development of CNS standards and recommended practices (SARPs) and related provisions (TBD)

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3) harmful interference : Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations (CS).

Chapter 1 Introduction

1.1 Background

1.1.1 **Pace of innovation in aviation**

1.1.1.1 The communications, navigation and surveillance (CNS) systems used in aviation support safety critical functions and are therefore required to meet stringent operational requirements. Over the years these systems have evolved to meet industry needs and remains sufficient for most of aviation's current needs. The pace of that evolution has been determined by the need for additional airspace capacity, by the cost of retrofit including recertification, and the life cycle of aircraft. However, when compared to other industries, especially those that use radio frequency spectrum, CNS systems have generally evolved at a pace that lags available technology.

1.1.1.2 It is predicted that the current CNS systems will not be able to support the projected growth in aviation, with the introduction of new airspace users in the future (e.g., urban air mobility) only making the situation worse. This will require the industry to embrace new and more capable technology offering increasing performance, capacity and efficiency. If aviation can position itself to capitalize on current state-of-the-art of radiocommunications technologies being developed by other industries, that are more efficient in terms of spectrum use while taking advantage of reduced size weight and power of the new CNS equipment, then future demands for additional capabilities of that equipment may be met without needing additional spectrum access or with minimal requirement for additional spectrum access. This would lead to improved spectral efficiency as well as reduced environmental footprint and costs associated with size, weight and power.

1.1.1.3 To achieve this, ICAO and the whole aviation industry need to develop an action plan to identify a method by which new equipment, embracing the new technology, can be developed standardized and put into service in a shorter timeframe, while maintaining global harmonization and the principles behind minimum fit where possible. Considering the limited resources and expertise available to ICAO, improvements to the overall standards-making framework will be necessary. Noting Assembly Resolution A40-27 "*Innovation in aviation*", the Council has requested the Secretariat to assess the need and the resources required to evolve the processes of the Organization, including its methods of working with the aviation and aerospace industries in order to keep pace with innovations that may affect the sustainable development of civil aviation.

1.1.2 Spectrum challenges and their impact on long-term evolution of communications, navigation & surveillance

1.1.2.1 The availability of protected radio frequency spectrum is a critical prerequisite for the safe and efficient implementation of communications, navigation, and surveillance systems. Frequency spectrum is a finite and limited resource, managed internationally by the International Telecommunication Union (ITU) through the four-year process of the World Radiocommunication Conferences (WRC). As demand for radio spectrum from both aviation and non-aviation users continues to grow, aviation faces ever-increasing competition for the limited spectrum available, particularly from the mobile and broadband wireless services.

1.1.2.2 Aviation needs to continue to demonstrate that CNS systems are spectrally efficient. Otherwise, aviation will have to share its allocated spectrum with non-aeronautical users, which will result in reduced capacity and flexibility with which aviation can use its allocated spectrum resources. Were aviation to share access to frequency bands with other non-aviation users, then the planning rules and adherence to those rules would need to be sufficient to meet safety case requirements so that safety standards can be maintained. If the safety case requirements cannot be maintained when sharing spectrum, then the quality and availability of services will be compromised as a result of harmful interference In the worst case, aviation could lose access to frequency bands critical for the current and future provision of CNS, ultimately resulting in an overall reduction in aviation capacity.

1.1.2.3 Facing the problem statements highlighted above, the CNS community is confronted for the first time in the modern era by long-term challenges requiring a paradigm shift, from “segregation” to “integration while maintaining of safety”. This requires us to rethink the CNS concept. For example, the introduction of state-of-the-art technology could allow for the efficient and flexible use of the spectrum resource by eliminating boundaries between the traditionally separate communication (C), navigation (N) and surveillance (S) functions, for instance by making innovative use of precise timing.

1.1.2.4 The avionics industry is already looking into the development of distributed radio architectures on-board aircraft. As documented in this report, the challenges the aviation community faces has resulted in the development of a concept for the use of integrated CNS and spectrum where appropriate, to deliver multiple services, making use of common hardware platforms which function is software defined, enabling flexible use of spectrum.

1.1.3 ICAO actions relevant to CNS and Spectrum proposed by the 13th Air Navigation Conference

1.1.3.1 As aviation CNS systems evolve, the applicable industry standards necessary to ensure the interoperability of those systems have become increasingly complex. As a result, the development of ICAO Standards and Recommended Practices (SARPs) has similarly become increasingly complicated. In accordance with Assembly Resolution A39-22: Formulation and implementation of Standards and Recommended Practices (SARPs) and Procedures for Air Navigation Services (PANS) and notification of Differences, SARPs are often accompanied by notes which reference industry standards for more detailed information. Referencing applicable industry standards or detailed technical specifications prepared by other SMOs with manufacturers and other stakeholders, while useful, does not ensure sufficient performance and global interoperability, as the notes do not have the authority of SARPs.

1.1.3.2 Technology is advancing at a pace that exceeds the resources available to develop applicable aviation CNS standards within appropriate timeframe. Therefore, there is a need to streamline the standardization process within ICAO and industry, it is important that ICAO and its Member States take measures to foster CNS technology advancement such that aviation remains a responsible and sustainable user of the frequency spectrum and by doing so supports aviation’s case for access to sufficient, and suitably protected spectrum needed to meet future demand.

1.1.3.3 The Thirteenth Air Navigation Conference (AN-Conf/13, 2018) recommended that ICAO:

- *launch a multidisciplinary study to “evolve the required CNS and frequency spectrum access strategy and systems roadmap in the short, medium and long term, in a performance based and service-oriented manner, to ensure that CNS systems remain efficient users of the spectrum resource (Recommendation 2.2/1)*

- *review and enhance its standards-making processes in order to meet the requirements of the rapid pace of technological developments (Recommendation 5.5/3).*

1.1.3.4 The ICAO Assembly, during its 40th Session held in 2019, reaffirmed Recommendation 2.2/1, thus leading to the establishment of the Integrated CNS and Spectrum Task Force (ICNSS-TF) to address those difficult challenges in a proactive manner.

1.1.3.5 This intermediate draft global concept for Integrated CNS and Spectrum describes the progress of the work conducted by the task force thus far and includes two main conceptual deliverables: a roadmap of CNS and Spectrum evolution; and a new, streamlined framework for CNS standardization.

1.2 From Segregation to Integration of the Communications, Navigation and Surveillance

1.2.1 Integrated CNS is a concept whereby aviation communications (C), navigation (N) and surveillance (S) requirements are considered in their totality, rather than as an individual function or domain, thus enabling common resources, including spectrum, to be exploited for the benefit of aviation.

1.2.2 C, N, and S have been traditionally considered to be three separate and distinct domains/functions that have evolved in relative isolation from each other, leading at times to competing requirements for spectrum. The introduction of systems such as Global Navigation Satellite Systems (GNSS) provides advantages to each domain/function, however, common mode failures may be introduced that need to be properly managed. By considering CNS systems as a whole, such common mode failure points can be properly managed, and the spectrum requirements, a finite and limited resource, can be optimised.

1.2.3 Due to the high demand for radio spectrum from non-aviation users, aviation faces an ever-increasing competition for the limited resource. Facing such competition and observing the rapid technology advancements in other industries, the aviation industry has started to rethink the original CNS concept, resulting in a paradigm shift of CNS, from "segregation" to "integration while maintaining safety".

1.2.4 Three main design concepts for airborne CNS architecture can be considered:

a) federated - Individual CNS avionics functions are located within their own line replaceable units

b) integrated - Multiple CNS avionics functions are located within one integrated avionics line replaceable unit

c) distributed - Individual or multiple CNS avionics functions are distributed among multiple line replaceable units, using distributed sensors, centralized processing, and software applications

1.2.5 There is a trend away from federated avionics to more integrated and distributed architectures. See Figure 1-1. This trend and the resulting avionics implementations are beneficial in reducing the size, weight, power, and cost of CNS systems. Similar trends toward integration and networked distributed systems are also occurring in aviation, space, and ground infrastructure. The continuing evolution of ground, space and on board systems needs to be coordinated as necessary. Consideration must be given to the management of the total end-to-end system performance and safety during the transition from one design concept to another.

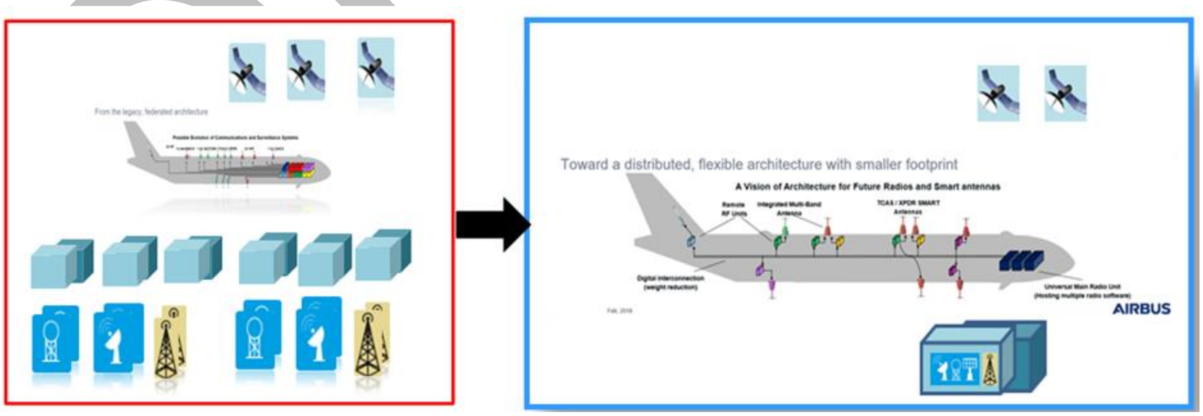


Figure 1-1 Toward a distributed, flexible architecture with smaller footprint

1.2.6 Applying the above approach where appropriate, in a harmonized manner globally, could deliver improved CNS facilities for all airspace users, improve spectrum efficiency, accommodate traffic growth and new entrants, and ensure safety. Such an approach will enable cross-domain/function identification of opportunities and delivery of a globally coordinated evolution of the CNS system that accommodates and mitigates potential common modes of failure. For example, GNSS is used for communications, navigation, and surveillance. However, to maximize the benefits that integrated CNS systems can offer, care must be taken in the overall design of the airspace management system, using mitigation techniques such as redundancy to ensure that the highest levels of service and safety is provided. Furthermore, CNS systems need to be developed with cyber-security considerations in mind. Chapter 2 describes integrated CNS and Spectrum in terms of future technology advancement.

1.2.7 As CNS systems have evolved and the use of digital technology and more complex waveforms have become more common, the technical standards describing those systems, including SARPs, have by necessity, become more complex in order to ensure global interoperability. By considering both air and ground CNS system as a whole, along with the development of technology agnostic requirements, convergence towards a globally harmonized concept of operations and supporting infrastructure becomes an achievable goal. With the new integrated CNS concept, the development of technical standards, from requirement to implementation, will require aviation stakeholders to redefine the existing current CNS development framework so that it can deliver integrated CNS systems in a timely manner. To this end, Chapter 3 of this report proposes a new framework for the global standardization of CNS systems.

1.2.8 In summary, as shown in Figure 1-2, to maximize benefits when introducing integrated CNS systems and services, a needs-driven and holistic approach must be taken. This will help ensure that both the concurrent development and deployment of airborne and ground CNS systems and associated networks will provide an early return on investment by providing gains in the required capability and performance and efficient spectrum utilization.

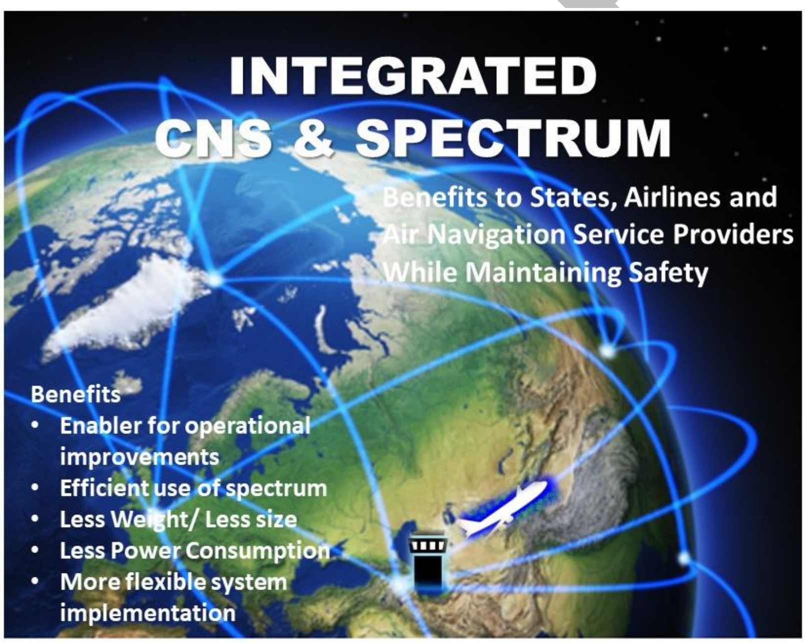


Figure 1-2 Integrated CNS and Spectrum

1.3 The Road Ahead – an approach to Integrated CNS and Spectrum

1.3.1 The Integrated CNS and Spectrum Task Force was established in 2020 and led by subject matter experts from a broad cross-section of the aviation industry. The two main tasks are as follows:

1) *Prepare CNS and Spectrum Roadmaps. The Roadmap Task will focus on drafting an initial CNS and spectrum roadmaps for the medium and longer term, leveraging recent advances in the state-of-the art of CNS technologies, to ensure that the aviation sector remains a responsible user of the spectrum resource while also focusing on safety, security, efficiency, and sustainability of global aviation.*

Roadmap task

Aviation CNS systems need to embrace emerging technologies for the purpose of safe, efficient, and sustainable aviation. Aviation will embrace new entrants, each placing a demand on CNS resources including radio frequency spectrum. Due to the high demand for radio spectrum from non-aviation users, aviation faces ever-increasing competition for this limited resource. Facing such competition and observing the rapid technology advancements of other sectors of industry, the aviation community has started to rethink the original CNS concept, resulting in a paradigm shift for CNSS, from “segregation” to “integration while at least maintaining the same level of safety”.

The 40th Assembly of ICAO has requested the development of roadmaps for CNS in the near, medium, and long terms. The proposed roadmaps in this report, will leverage recent advances in the state-of-the art of CNS technologies, to ensure that the aviation sector remains a responsible user of the spectrum resource while also focusing on safety, security, efficiency, and sustainability of global aviation.

2) *Propose a Standardization Framework for CNS Systems and Spectrum. This framework includes the definition of a new approach for the development of Standards and Recommended Practices (SARPs) and Detailed Technical Standards, by leveraging a more performance-based approach.*

CNSS standards task

There has been a consistent intent that the language of the SARPs must be clear, simple, and concise and that the content of the SARPs must be mature and stable. The SARPs must provide for requisite levels of safety, security, efficiency, sustainability, and interoperability. Although significant efforts have been made to move to performance based SARPs and rationalize the size of Annex 10, the lack of a well-established process has hampered its rationalization. Also, it is important to note that a study to identify the performance and technical specifications contained in Annex 10 and to suggest alternatives for separating performance specifications from technical specifications conducted by ICAO has identified several concerns and potential unintended consequences.

1.3.2 Before starting to the preparation of CNS and Spectrum Roadmaps” and any proposals for a standardization framework for CNS systems and spectrum, the ICNSS TF analyzed the current standardization framework and the possible need for organizational changes. The existing SARPs development process was analyzed including the role of performance-based standards, the role of ICAO Annex 10 and the overall goal of Integrated CNS and Spectrum interoperability. A proposed framework for streamlined CNS system standardization was developed as a result of this analysis (see Appendix A). A condensed version of this is given in the following table.

1) Streamlined SARPs

- *CNS SARPs, while having a minimal necessary number of provisions, should at least include signal in space characteristics, other measures to ensure interoperability and protect the system by defining a consistent standard at the beginning that can be used to ensure system performance. The provisions should also support the maintaining of performance at the required levels, as well as the requirements/specifications developed by ICAO as necessary to conform to radio regulatory requirements.*

- *Sufficient detail needs to be provided in the CNS SARPs and their related technical specifications, to ensure global interoperability and compliance with other regulatory and certification requirements. Purely performance-based SARPs may not always be sufficient and may not ensure interoperability.*

- *Performance-based Standards, in comparison with prescriptive standards, may be appropriate and contribute benefits (such as flexibility) when used to support operational and airspace requirements. However, the development and practicality of only focusing on performance-based metrics can result in an outcome that lacks essential details of how the relevant aviation systems function. Without core parameters being specified in SARPs, such as signal in space and other system factors, aviation will not fully understand how its systems actually function. Such details are essential for how aviation interfaces with external industries and national regulators. Therefore, a balance is needed of appropriate detail to define a suitable level of system operation while also maintaining a focus on performance metrics that assists States with implementation*

- *Globally recognized detailed technical specifications in standards publications similar to SARPs are necessary to maintain interoperability of complex communications, navigation and surveillance systems. Without these there is an increased risk, especially over time, that manufacturers will produce incompatible/non-interoperable equipment resulting in unpredictable service failure. There must be some mandatory mechanism to ensure the interoperability of future components and systems. One further concern is that performance-based standards tend to lack detailed requirements, hence they can be too flexible making them difficult to audit.*

2) Cooperation with several entities

- *The successful development of mature standards requires active involvement and coordination not only by ICAO, the Air Navigation Commission (ANC) and its Panels, but also with States, ANSPs, CNS service providers, Airspace Users, external SMOs, avionics and airframe manufacturers and integrators. In addition, ICAO and SMOs need to coordinate relevant activities in the development of Standards and technical specifications. Appropriate protection of CNS spectrum is achieved through the ITU radio regulatory framework and coordination with national radio regulators.*

- *With the potentially increasing role of other SMOs in the development of detailed technical specifications, it is becoming increasingly challenging for ICAO, including the ANC and its Panels, to provide the capacity and skill set to verify and/or validate the work of external bodies to the necessary level of assurance required for these external technical specifications to be referenced in SARPs.*

- *Industry will need to identify expected benefits of the proposed systems and standards through stakeholder engagement before full commitment of resources. Therefore, close coordination between ICAO and industry is essential.*

• *The purpose of [TBD] minimal essential SARPs as described above, and the detailed technical specifications to target global interoperability of equipment operating in accordance with those SARPs should be clearly defined before starting with the demarcation of these.* • *SARPs and technical specifications developed by ICAO need to be global and to cover both the infrastructure and the airborne segments. To prevent failure cases of implementation, ICAO should provide clearly written implementation guidance material. Furthermore, SARPs and technical specifications need to be verified and validated, to an acceptable and agreed standard to prevent poor/sub-standard implementation.*	

1.3.3 The result of this analysis is captured in two top-level recommendations. The gains to be made from these are shown in Figure 1-3. This will be discussed further in Chapter 3.

1) *Minimal essential SARPs for CNS systems that are performance-based and define the required signal-in-space characteristics*

2) *Global Technical Specifications (GTS) for CNS systems developed in coordination with SMOs*

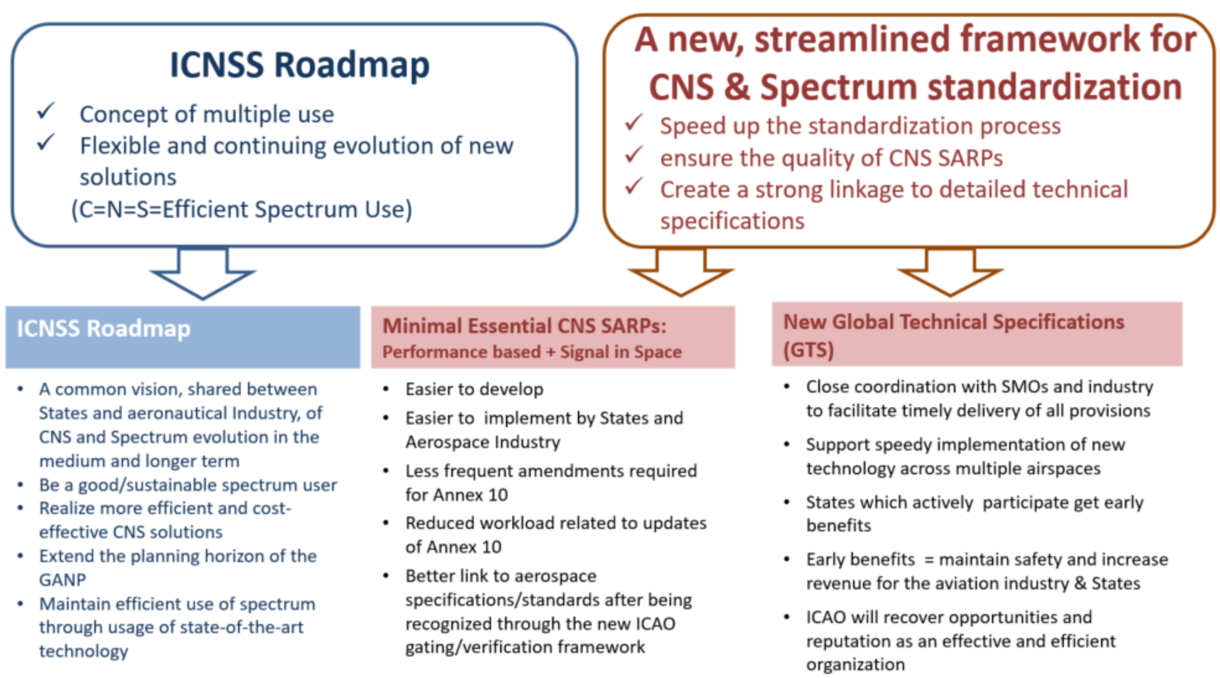


Figure 1-3 – The two recommendations and their benefits

Chapter 2 Integrated CNS and Spectrum Roadmaps

2.1 Development of roadmaps to address identified challenges

2.1.1 This chapter, while addressing multi-disciplinary issues, including efficient airspace and air traffic management, focusses on the provision of CNS in the context of overall improvements to the aeronautical services. The holistic approach employed takes a long term view from a systems improvement perspective and is consistent with and complementary to the Global Air Navigation Plan (GANP) which rather addresses the operational improvement perspective in a shorter timeframe. Building on this approach, this chapter introduces an overall roadmap of CNSS evolution as supported by several specialized roadmaps. The purpose of these roadmaps is to show how CNS systems can facilitate and support the improvements and initiatives in the Aviation System Block Upgrades (ASBUs) as described in the GANP. Additionally, other emerging initiatives are identified which, in the opinion of the ICNSS TF, could offer opportunities to further evolve the GANP providing increased operational, economic and environmental benefits. The roadmaps and the supporting explanatory text reference the GANP and ASBUs as appropriate whenever there is material in common. The below table demonstrates how the GANP and global concept for the Integrated CNS & Spectrum relate and complement each other.

	GANP	Global concept for Integrated CNS and spectrum
Main Focus	Operational improvements that are intended to provide increased capacity, efficiency, predictability, and flexibility that will allow the equitable accommodation of all airspace users.	Technological trends that can best help deliver the improvements foreseen in the GANP or could offer opportunities for further operational improvements.
Timeframe	Block 1 (by 2019) Block 2 (by 2025) Block 3 (by 2031) Block 4 (by 2037)[1]	Near-term: the present until 2030 Mid-term: 2030 – 2040 Long-term: 2040 – 2050

2.1.2 When new CNS systems are required, the roadmaps for the integrated CNS and spectrum global concept identify and aim to ensure delivery of operational benefits. Efforts need to be made to:

a. Ensure that those systems exploit the most appropriate new technological developments

b. Ensure that those systems take account of synergies with other CNS requirements

c. Achieve efficiencies in size, weight, and power (SWAP), particularly for avionics, without compromising required performance or safety (further discussed in Section 2.3)

d. identify, where appropriate, current systems and infrastructure that can and should be rationalized, supported when necessary by transition roadmaps (work in progress).

e. Use frequency spectrum in an efficient manner to the extent possible, including an evolutionary plan, providing for continuous improvement in spectrum efficiency.

2.1.3 The roadmaps also serve several purposes that go beyond the description of a path towards the implementation of the global concept for integrated CNS and spectrum. One of the primary purposes is to show the role that integrated CNS systems will have, both directly and indirectly, to meet a set of identified challenges that will confront civil aviation in the coming decades. Those specific challenges have been captured in a Strategic Roadmap (Figure 2-2). An explanation of the challenges and their derivation is given in the following paragraphs.

[1] ASBU elements in those blocks are/will be available for implementation by the time indicated above.

2.1.3.1 Challenge 1: Accommodate New Entrants and Manage Airspace Complexity.

2.1.3.1.1 New entrants are raised in the sixth edition of the GANP as one of the "*Challenges and Opportunities"* facing civil aviation. Within the GANP, the section on "*Roles and Responsibilities*" makes the point that new entrants may differ from legacy aviation in terms of their vehicles, CNS capabilities & requirements, airframe lifetime, airspace in which they operate, manner of operation, and pace at which they innovate. The application of existing aviation protocols is expected to constrain the ability to exploit innovations sought by new entrants to aviation and the airspace in which they intend to operate. To meet the timeline expectations of those new entrants, applicable standards, rules and procedures will need to be developed and implemented in a shorter timeframe. One of roles that the global concept for integrated CNS and spectrum needs to address is to analyze how to accommodate new entrants into the airspace and any potential new C, N, S functions and systems to do so. Such new entrants include:

a. RPASs[2]

b. Drones[3]

c. Urban mobility

d. Supersonic/hypersonic, high altitude and near-space vehicles

e. High altitude platforms

2.1.3.1.2 In the near-term, new entrants are typically accommodated in airspace segregated from other users, until common airspace requirements, intended to accommodate all users, can be identified and implemented in order to continue to ensure safety. Whilst segregation is required it is likely that the efficiency of that airspace will be reduced. For example, the use of temporary/permanent restrictions in airspace to accommodate the passage of RPAS or high altitude and near space vehicles will result in delays and/or re-routing of regular air traffic while the airspace segregation is in effect.

2.1.3.1.3 In the mid-term, technical, regulatory, and operational changes will be required to support better integration of new entrants, where necessary, into the existing airspace structure. This will be based on their performance, capability, the airspace they wish to access and the required level of safety. However, it may still be appropriate to accommodate certain classes of new entrants using legacy segregation techniques, provided that any potential decrease in the efficiency with which airspace is used and the impact on other airspace users can be justified. The focus in this phase is on accommodating new entrants, while reducing as much as possible their impact on other users.

2.1.3.1.4 In the long-term, it is envisaged that new airspace users, including those that may not have been identified yet, can be integrated into the airspace management system. The continued safety of airspace users will be ensured through well-defined and robust technical, regulatory, and operational standards, rules, and procedures that focus less on the type of user and more on the performance, capabilities, and required level of safety.

2.1.3.2 Challenge 2: Increasing Pressure on Aeronautical Spectrum

2.1.3.2.1 Aeronautical spectrum is expected to be subject to increasing pressures, both internally and externally, resulting from:

a. Expected growth in and the flexibility with which airspace is used;

b. expansion of operations into airspace not traditionally used by aviation (e.g. above 66,000 ft or below 1,000ft including urban areas);

c. growth in the connectivity requirement on current platforms;

d. growth in other radiocommunication related industry sectors seeking to expand their capacity and capabilities; and

e. spectral efficiency of aviation technology lagging that of technology employed by other industries.

[2] RPASs are vehicles able to operate in controlled and uncontrolled airspace beyond visual line-of-sight (BVLOS).
[3] Drones are vehicles for which traditional separation approach cannot necessarily be applied due to specific aerodynamics and flight technical characteristics (e.g. Vertical Take-Off and Landing - VTOL).

2.1.3.2.2 The current airspace management system is reaching capacity. To support the expected growth in air traffic, including that from new entrants, and the additional complexity that this growth is likely to bring for the foreseeable future, the use of airspace will have to become more flexible and efficient. Facilitating such improvements will require the provision of increased real-time knowledge of where an aircraft is and what its intentions are, which in turn will require improved CNS systems and the spectrum to support them.

2.1.3.2.3 New entrants are seeking access to extended areas of airspace which in the past have not been utilized. Achieving these changes in coverage requirements may be accommodated by the modification of some existing CNS systems, however it is likely that use of new systems capable of providing more capacity and coverage will be required, especially in urban and oceanic areas. This will often require access to additional spectrum.

2.1.3.2.4 In order to reduce maintenance costs and improve regularity of flight, aircraft are being fitted with additional sensors to provide real-time aircraft health data which in turn requires additional connectivity with the ground and spectrum to support that connectivity. Additionally, passengers are demanding better in-flight connectivity which also adds to the ground connectivity required, further increasing the demand for spectrum.

2.1.3.2.5 The increased demand for spectrum from all radiocommunication related industries has prompted national spectrum regulators to reassess current spectrum usage and having to make difficult choices between various industries competing for spectrum resources. Such a process often puts aviation at a disadvantage, as many of the competing industries are more agile in their ability to develop and field new technologies, leaving aviation with technologies that appear a generation or more behind and apparently unnecessary duplication of systems. This also creates the perception that aviation's usage of spectrum is not as efficient as that of competing industries, and results in a disadvantage when decisions are made by national radio spectrum regulators. Furthermore, if such decisions result in a change of how aviation uses its spectrum, such a change will likely include mandatory retrofit of avionics and changes to the infrastructure, requiring lengthy implementation timescales.

2.1.3.2.6 The above issues have been recognised by ICAO, as stated in Appendix 4 of the fifth edition of the GANP, "*Frequency spectrum availability has always been critical for aviation and is expected to become even more critical with the implementation of new technologies*". It goes on to say that **"***In addition to the five Technology Roadmaps … a global aviation spectrum strategy for the near, medium- and long-term must support implementation of the GANP"*. ICAO maintains and supports such a strategy primarily through the Frequency Spectrum Management Panel (FSMP) of the Air Navigation Commission (ANC) and other groups. The global concept for integrated CNS and spectrum will contribute to the maintenance and protection of adequate spectrum required for CNS systems in the mid to long-term.

2.1.3.2.7 In the near term, aviation must first identify how it currently uses spectrum, how spectrally efficient that usage is and what spare capacity may be available for the implementation of new systems to accommodate growth including the expansion of operations into airspaces not traditionally used. Aviation must consider spectrum as a fundamental requirement in the development of future CNS systems. This will provide a foundation for the efficiency and resilience of CNS systems, enable more use of commercial services that are not necessarily within traditional aeronautical spectrum, while also supporting aviation in the protection of its current spectrum resources needed to support existing systems.

2.1.3.2.8 In the mid-term, long term goals should be identified, the process of optimising the use of spectrum allocated to aviation started and, transition arrangements to new systems, where required, including integrated CNS systems to meet the long-term goals created. This will result in gains for capacity and efficiency for new and existing airspace users as they evolve over time.

2.1.3.2.9 Once the transition has started, aviation can begin to fully benefit from scalable and resilient CNS functions as part of its long-term goal. While not all existing CNS systems will need to transition, many of those systems transitioning will be sufficiently far enough through the process that larger system-wide benefits can be realized, in terms of capacity and efficiency, increased redundancy and resiliency through spectral diversity.

2.1.3.3 Challenge 3: The need to minimise the impact on the environment while accommodating growth[4]

2.1.3.3.1 Environmental protection with the aim of minimising the adverse environmental effects of civil aviation activities is one of ICAO's strategic objectives. This is reflected in the GANP at the Strategic Level[5] under *"Vision, Roles and Responsibilities and Ambitions"*. The global concept for integrated CNS and spectrum is expected to make a contribution towards this ICAO strategic objective by offering additional CNS functionality that can provide opportunities to further optimise flight routing and automation, reducing fuel consumption and noise levels.

[4] https://www.icao.int/about-icao/Council/Pages/Strategic-Objectives.aspx
[5] https://www4.icao.int/ganpportal/GanpDocument#/lessons/LSC4_YUBsGUdxV51fUzTENIJeptJrmH7?_k=bubf1s

2.1.3.3.2 On board integration, including new concepts in distributed architectures, enabled by the introduction of new technological advances in electronic components and capabilities, is expected to reduce the size, weight, and power of CNS systems. This is further expected to reduce costs, fuel consumption, and associated carbon emissions. Further gains should be achieved through the expected simplification and reduction in size of cable installations as well as through the reduction in the number of antennae required and associated drag.

2.1.3.3.3 Ground systems are also expected to leverage emerging technologies to create efficiencies such as improved weather models and weather forecasting which is expected to further enable optimisation of aircraft routing helping to deliver ANSP environmental objectives.

2.1.3.4 Challenge 4: Growing Demand for Access to Airspace

2.1.3.4.1 The GANP provides the following forecast as to the growth in demand for access to airspace: "*Air traffic, with its movement of passengers and goods around the world, is expected to double within the next 15 years. At the same time, new demands on the aviation system, emerging technologies, innovative ways of doing business and the shifting human role are bringing not only challenges but also opportunities that call for an urgent transformation of the global air navigation system*".

2.1.3.4.2 The challenge will be how to accommodate the expected increase in demand for access to airspace resulting from growth in existing traffic and the introduction & integration of new entrants into the airspace whilst, maintaining required safety levels. This will require careful consideration as to the CNS systems needed, taking into account synergies between requirements, where appropriate, and the spectrum required to support those systems. The global concept for integrated CNS and spectrum is expected to provide a mechanism by which, the expected growth can be supported by facilitating the timely introduction of new CNS technologies, as necessary.

2.1.3.4.3 In the near-term, growth can be supported by developing CNS solutions supporting automation, trajectory coordination and capacity management. In the mid-term, those CNS solutions will be implemented while also expanding those to integrate new entrants. In the long-term, innovative technologies/procedures will be required to induce further transformation and efficiency gains of the global air navigation system, supporting further aviation growth.

2.1.3.5 **Challenge 5: Institutional Challenges**

2.1.3.5.1 In addition to the above four practical challenges, two other challenges have been identified as fundamentally related to current institutional structure of the global aviation industry and regulatory framework. These challenges are 1) Slow adoption of new techniques/technology across the globe and 2) Regulatory framework needs to accommodate the accelerating pace of innovation. While these institutional challenges are a natural consequence of aviation being a global and safety-oriented industry, it is now necessary to address these institutional challenges promptly and effectively so that the aviation industry can benefit from the technological evolution and innovation made by non-aviation industries, and can keep pace with its own rapidly changing operational issues.

2.1.3.5.2 Institutional Challenge 5.1: Slow adoption of new techniques/technology across the globe

2.1.3.5.2.1 As mentioned in the Chapter 1, the life cycle of aeronautical CNS systems and equipment is much longer than that of other, non-aviation, systems using similar electronic/communication/computing technologies. Global standardization, certification and safety approvals for aviation safety systems and procedures often take time and thus result in a high investment cost. Adoption and deployment of new techniques/technology within aviation requires alignment and coordination efforts by various stakeholders, including at the very minimum: regulators, air navigation service provides and airspace users. Moreover, due to the global nature of their operations and aircraft capability, airlines need globally harmonised and performance based CNS systems, in the air and on the ground. While global harmonisation also benefits other aviation sectors, reaching global agreements and deployment decisions does often take substantial time.

2.1.3.5.2.2 These factors combined have resulted in aeronautical CNS systems not being developed to benefit from the latest technologies or new solutions being innovated as quickly as within other industries. On the other hand, for example within other sectors, such as the telecoms sector, technologies and resultant innovations are being developed and implemented at a rapid pace. Consequently, aviation is increasingly being left behind those other sectors in terms of adoption of new technologies. The main hindrances to adopting new technologies and deploying those technologies globally are, among others, the following:

a. Rigid regulatory framework (High cost, slow speed)

b. Lack of a streamlined process for safety certifications and operational approval

c. Many CNS systems cannot achieve a return on investment within the timeframes required by airspace users.

d. Diverse operational needs result in uneven global deployment/implementation leading to a non-harmonised CNS system globally.

e. The aviation market is relatively small compared to the general consumer markets and the telecommunications industry as a whole. This means that development costs of CNS systems and equipment are amortized over fewer units resulting in comparatively high unit cost and longer return on investment period. This often hampers incentives for such investment.

2.1.3.5.3 Institutional Challenge 5.2: Regulatory framework needs to accommodate the accelerating pace of innovation

2.1.3.5.3.1 The second institutional challenge is the regulatory framework to support the accelerating pace of innovation. While this challenge can be considered as a subset of the hindrances identified within the Challenge 5-1, it is specifically highlighted in this report due to the critical role ICAO can play in addressing the challenge.

2.1.3.5.3.2 To ensure the overall safety of the airspace management system, CNS systems are implemented and overseen through an extremely thorough regulatory framework. This in turn, may often have resulted in the systems leveraging older technologies. It needs to be highlighted that the current regulatory framework contributes to the level of integrity and reliability required for and achieved by the aeronautical CNS systems, providing for a level of safety which is much higher than that of other comparable systems outside of aviation. However, the current framework faces difficulties in adapting to accelerating pace of technological development and innovation, particularly noting the growth of new airspace users and the increasingly competitive environment for the frequency spectrum resource, an environment which encourages and often demands faster adoption of newer, more spectrum-efficient technologies. As a consequence the aviation regulatory framework needs to evolve while ensuring that the high level of integrity and reliability of aeronautical CNS systems is maintained, to ensure continued safe and efficient aviation. This evolution of the regulatory framework may include introduction of new equipment/aircraft certification paradigms and more timely and robust approval processes for new service provisions. The enhanced regulatory framework should, among other:

a. Be accessible to all airspace users for uniform evolution of global technology;

b. be globally/regionally harmonized & synchronized with suitable monitoring and oversight;

c. encourage innovation while being scalable where possible;

d. support timely global dissemination and uniform implementation;

e. ensure that there is a plan for a smooth transition;

f. better define and strengthen the relationship between ICAO and other standards making organisations; and

g. streamline the end-to-end approval and certification process

2.1.3.5.3 The transformation of the regulatory framework will take a certain amount of time. Considerable work is necessary for the CNS system to continue to be sustainable within the quickly evolving environment. Chapter 3, Streamlined SARPs, discusses options proposed for a framework to resolve these challenges.

2.1.3.5.4 In summary, a robust institutional and regulatory structure, along with a globally harmonized and recognized process, are of paramount importance in ensuring that the aviation industry can effectively and promptly utilize new technologies, and thus be able to support upcoming and future airspace and air traffic management needs. Aviation must take ownership of these institutional challenges as soon as possible and, through a holistic approach, ICAO needs to lead the way in this harmonisation to effectively deliver the global concept for integrated CNS and spectrum, which will be fit for purpose, address the needs of all users, be cost effective and maintain or improve safety. An enhancement of the current regulatory framework and structure will be necessary. This will include streamlining of and improvements to the ICAO standards making process, as well as better definition of the relationship/collaboration between ICAO and other standards making organisations. Systems/service/aircraft certification and the approval process will also need to be streamlined.

2.2 How to interpret the roadmaps

2.2.1 The suite of roadmaps are a response to the resolution by the 40th Assembly of ICAO, held in Montréal 24 September to 4 October 2019, that ICAO should launch a multidisciplinary study to "evolve the required CNS and spectrum access strategy and systems roadmap in the short, medium and long term, in a performance based and service-oriented manner, to ensure that CNS systems remain efficient users of the spectrum resource." Hence the suite of roadmaps covers the following timeframes:

a. Near-term: the present until 2030

b. Mid-term: 2030 – 2040

c. Long-term: 2040 - 2050[6]

2.2.2 The roadmap suite follows a hierarchy starting with high-level Strategic, integrated CNS and spectrum trendlines followed by a series of detailed roadmaps.

2.2.3 **High Level Roadmaps**

2.2.3.1 These are intended to provide a high-level overview of the rationale behind the global concept for integrated CNS and spectrum and then the direct benefit of their activities. They are as follows:

a. **Strategic Roadmap** – a high level roadmap showing the specific challenges described in section 2.1.3 and progress made towards their resolution through the timeframes given above.

b. **Trendline towards Spectral efficiency –** a roadmap indicating specific trends and phases in the management, maintenance and defence of aeronautical spectrum while i) exploiting this spectrum in an increasingly efficient manner and ii) enabling ICNSS where appropriate.

c. **Trendline towards the global concept for Integrated CNS and spectrum –** A roadmap showing how emerging trends in CNS systems and practices will directly address the above challenges. This roadmap is made up of two charts, one showing how ICNSS will address the challenges and another showing the prerequisites needed to make the global concept for integrated CNS and spectrum a success.

2.2.4 **Detailed Roadmaps**

2.2.4.1 The detailed roadmaps show how the global concept for integrated CNS and spectrum contributes to the resolution of the challenges via a set of initiatives referred to as "Threads", many of which are identified in the GANP.

a. **Detailed Conceptual Roadmaps** - These roadmaps show how ICNSS will indirectly contribute to the resolution of the challenges via the various threads. The "threads" are as follows:

Thread 1- Airspace Integration (incl. UTM/ATM)

Thread 2- Formation Flight

Thread 3- TBO and 4D Trajectories/Cooperative Trajectories

Thread 4- Flexible Allocation of Capacity

Thread 5- New Entrants

Thread 6- Automation (incl. single pilot ops and AI/Machine Learning)

b. **Technology Roadmaps –** roadmaps with specific information on integrated CNS technologies developed and their application to the resolution of specific operational and existential problems. These will be updated as specific technologies are developed. The global concept for Integrated CNS and spectrum aims at being technology agnostic to the extent possible. The technology roadmaps are industry-driven, while ICAO's role

[6] These are different to those of the GANP and cover a longer timeframe. All ASBU elements in Block 1 were available for implementation by 2019. Similarly All ASBU elements in Block 2 and Block 3 will be available for implementation by 2025 and by 2031 respectively.

is to provide guidance to the industry to avoid unequal and incompatible implementation of CNS technologies between the different ICAO regions. (Editorial note: work in progress.)

2.2.5 **Charts containing Trendlines and Roadmaps**

2.2.5.1 Figure 2-1 below illustrates the relationship between the various charts containing, trendlines and roadmaps described in the preceding Section.

- The technology roadmaps will be drafted once candidate technologies or families of technologies have been identified. These will be a living document subject to regular yet infrequent updates.
- The institutional framework is a pre-requisite in order to achieve the full benefit of the global concept for integrated CNS and spectrum.
- There is a synergy between the efforts to improve spectral efficiency and the implementation of the global concept for integrated CNS and spectrum.
- Although the trendline towards integrated CNS and the trendline towards Spectrum Efficiency will generate indirect benefits, they will also indirectly help solving other initiatives (via the various threads).

Note.- The strategic roadmap, not included in Figure 2-1, is an overarching high-level roadmap which describes the challenges and methods to solve them in the near-, mid- and long-term.

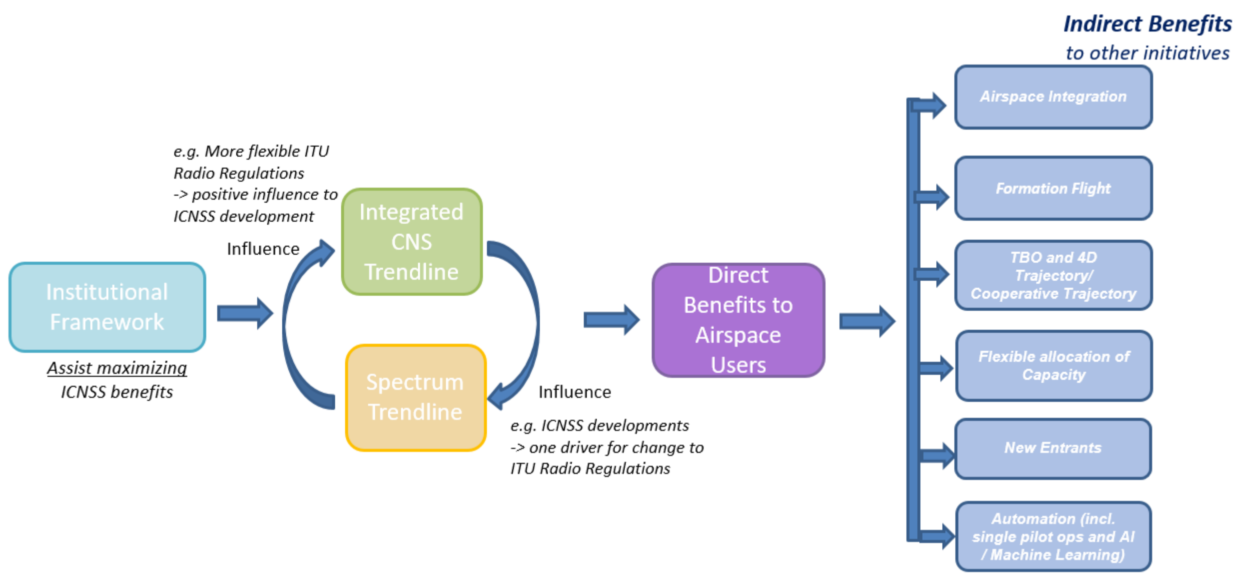


Figure 2-1 Schematic showing the relationship between charts (technology roadmaps not included)

2.2.5.2 The following chart shows the interaction between the identified challenges, and other emerging initiatives (also known as threads). Interaction between challenges and trendlines (integrated CNS and Spectrum) is also shown. A strong or direct dependency is illustrated in red, a mild or indirect dependency is indicated in yellow.

2.2.5.3 An increase in interdependency between challenges, specific threads and trendlines will increase the complexity of required solutions. A solution focusing on one specific thread may however potentially provide effective solutions to other challenges as well. For example, while three specific challenges have been identified to strongly influence the trendline towards spectral efficiency, solving one of those challenges may be sufficient to alleviate many of issues or pressures itemized by the other identified challenges.

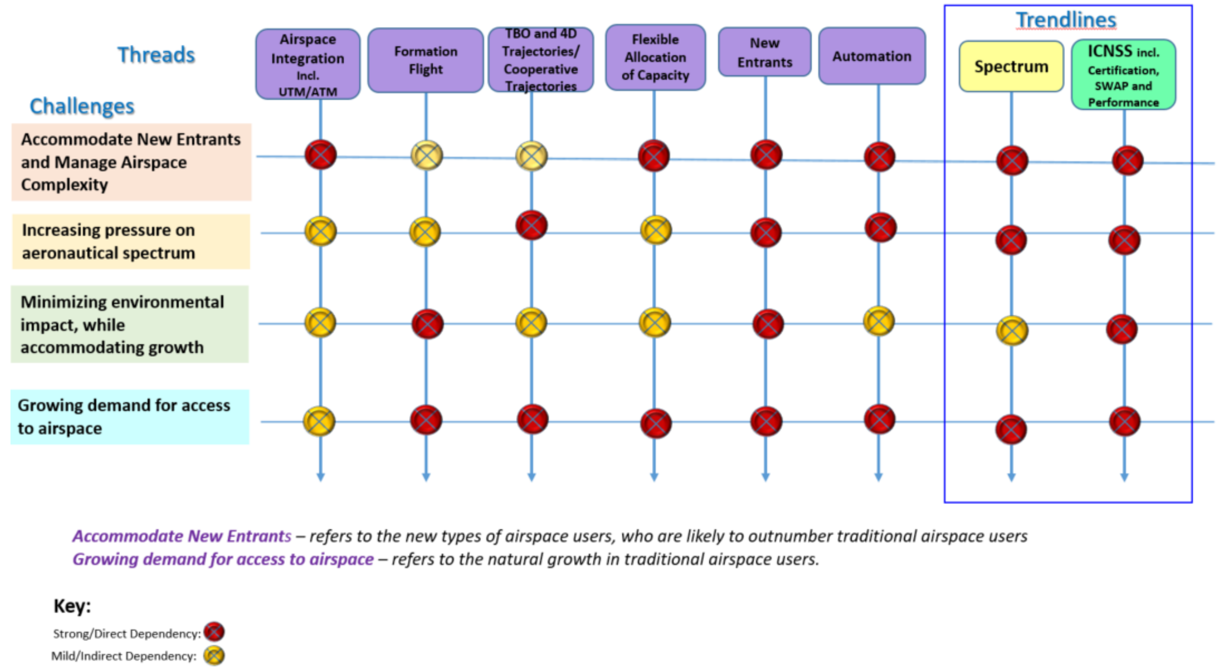


Figure 2-2- Interaction between integrated CNS systems and threads/trendlines

2.3 Roadmaps/Explanatory text

2.3.1 Strategic Roadmap

2.3.1.1 Following is a high-level roadmap showing the identified specific challenges and the progress towards their resolution through the timeframes shown.

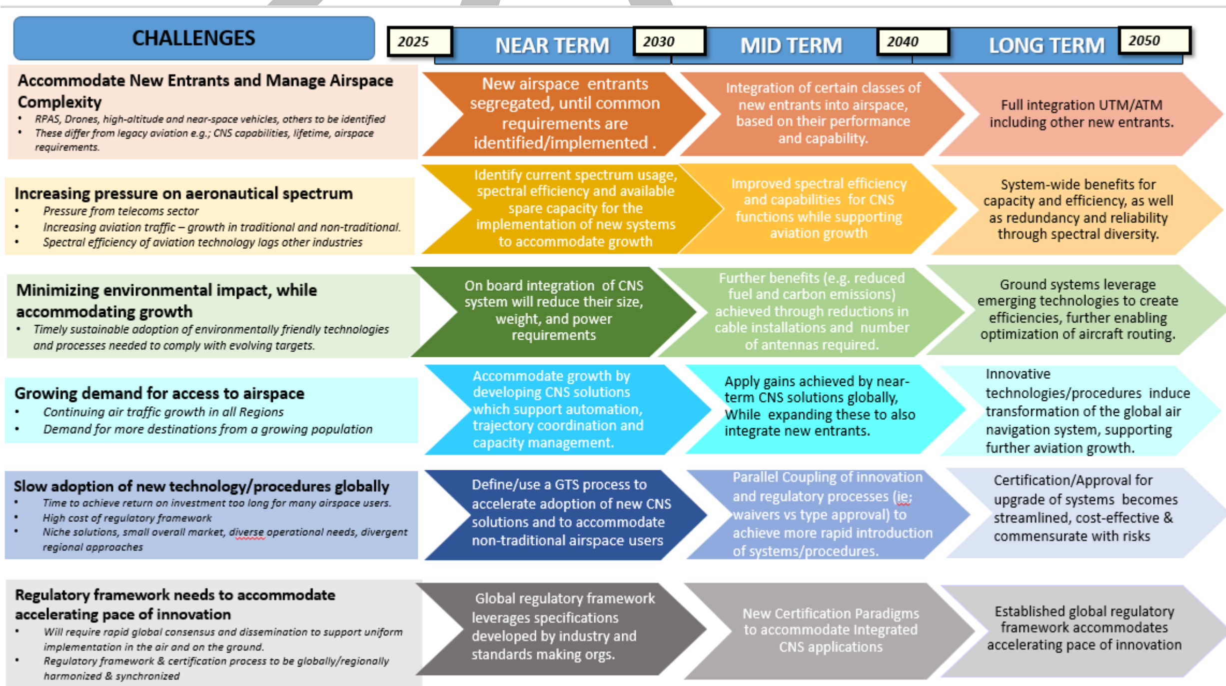
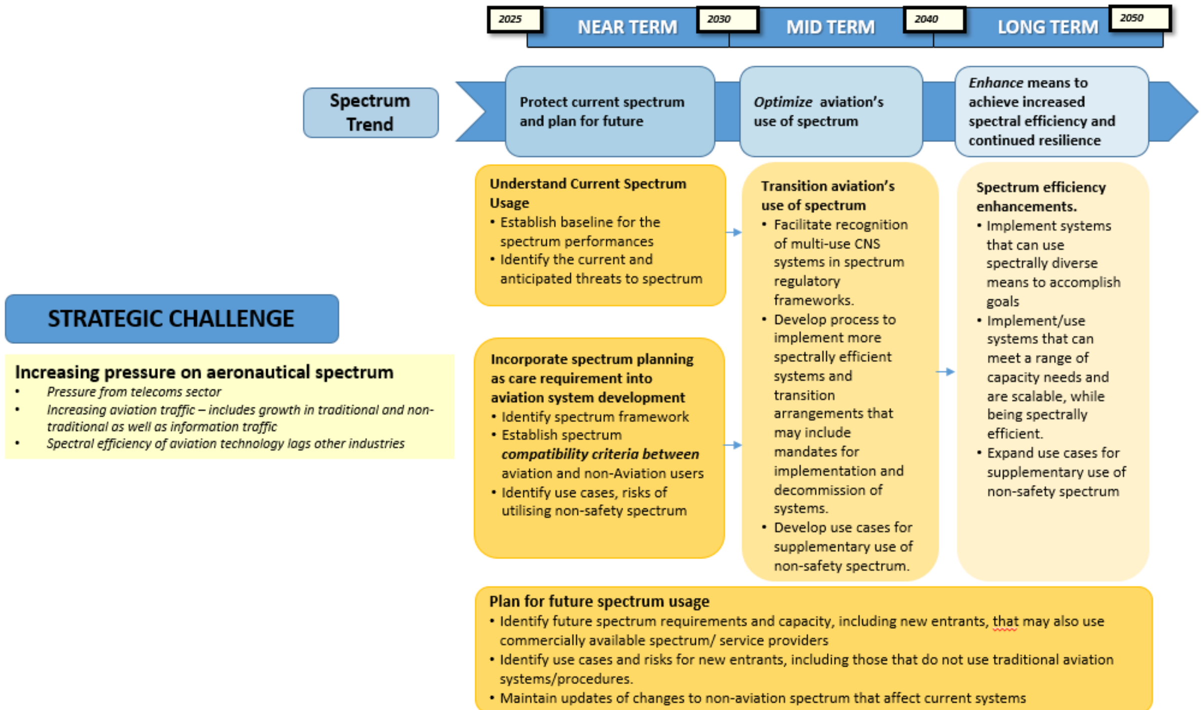


Figure 2-3 Strategic Roadmap

2.3.2 Trendlines

2.3.2.1 **Trendline towards Spectral efficiency**

This roadmap describes how specific trends and phases in the management, maintenance and defence of the aeronautical spectrum will not only enable ICNSS but do so in an increasingly spectrally efficient manner.



Note.- although figure 2-2 indicates a strong dependency between the trendline towards spectral efficiency and three specific challenges (accommodating new entrants, the growing demand for access to airspace and increasing pressure on the aeronautical spectrum), in order to avoid complexity, figure 2-4 focuses only on the strongest of those three dependencies.

Figure 2-4 - Trendline towards Spectrum Efficiency

2.3.2.1.1 **Near Term: Protect current spectrum and plan for future.**

1) Description

Moving aviation on to a planned path towards greater spectrum efficiency will require three fundamental areas:

a. **Understanding the current usage and threats to aviation spectrum**.

The global nature of aviation across many classes of airspaces and users, creates a multitude of different systems and requirements. Aviation must expend resources to fully audit what and how current CNS systems are used and identify any shortcomings that may pose a weakness in the defence of aviation spectrum. While a significant task, especially for legacy systems, this should be prioritized by concurrently assessing what possible threats may result from changes to spectrum use and therefore where effort is needed most. Lastly, this work must also include an appropriate framework to prioritize and guide RF studies between the systems of aviation and other industries to bridge the gap between the significant differences in assurance and operational requirements that often exist.

b. **Incorporate spectrum as a core requirement into new CNS system development**.

By incorporating a framework for spectrum use into the development of new CNS systems and making it a core requirement, aviation will have a forward-facing process providing the aviation community with confidence that systems remain robust and resilient in the face of spectrum challenges. This process must also take into account how non-safety spectrum used by commercial services may also be incorporated into CNS system development and certification.

c. **Initiate a process to plan and roadmap future spectrum usage**.

Given the long duration of both CNS systems development and the potential changes in spectrum available to support their development, aviation must plan its future spectrum requirements carefully. A roadmap that takes account of current ABSU requirements including uses cases and risks and then translates these into the spectrum domain can inform aviation and international regulators of future requirements. Such work should take account of technology trends including changes to non-aviation spectrum uses that can affect current and future aviation systems.

2.3.2.1.2 **Mid Term: Optimize aviation's use of spectrum.**

1) Description

Once the foundation components are established, aviation can transition into an optimization phase for spectrum usage. Given airframe lifecycles, this will not result in rapid change but introduce a gradual process leveraging the current state-of-the-art of the technology as they enter the start of their respective development cycle. This will include the increased use of multi-use systems. For example, communications systems may also support navigation and/or surveillance. In this regard, a clear explanation of spectrum needs must be considered and incorporated into the regulatory framework. Such needs include the families of frequencies (L band, C band) and emission and spectral limits. Hence, for future transition to integrated CNS services, candidate bands will need to be identified and a transition plan will need to be developed. Spectrum requirements based on a better understanding of the needs of these future CNS systems will further inform the spectrum roadmap.

Supplementary use of non-safety spectrum for specific use cases should be expected at this stage, adding momentum to the need for a framework or the use of "non-safety of life" spectrum. The certification impact resulting from the use of this spectrum and the subsequent changes to systems/processes will need to be examined.

The framework can now be further advanced to consider Spectrum resiliency, and how systems can achieve inherent redundancy (mesh networks etc.) and robustness, using spectrally diverse means to accomplish goals and meet performance requirements. This would be incorporated into the development process to implement more spectrally efficient systems along with the transition arrangements that may include mandates for implementation and the decommissioning of systems.

2.3.2.1.3 **Long Term: Implementation of means to achieve increased spectral efficiency and continued resilience.**

1) Description

With a mature framework and the first transitionary processes reaching completion, aviation can begin to benefit from systems that can use spectrally diverse means to accomplish its goals. These will include both:

a. Spectrum resiliency: Implementation of systems that can use spectrally diverse means to accomplish goals and meet performance requirements.

b. Implementation of and use of systems that can meet a range of capacity needs and are scalable while being spectrally efficient.

While not all systems will have achieved this, the systemic benefits from those that have will already become clear for aviation and should further reinforce changes in other systems. This state should also expand the use cases for supplementary use of non-safety spectrum.

2.3.2.2 Trendline towards Integrated CNS Systems

This trendline shows how emerging trends in integrated CNS systems and practices will help address the above challenges. This trendline is made up of two charts, one showing how integrated CNS systems will help address the challenges and another showing the prerequisites needed to make integrated CNS systems a success. The reader should note that these "prerequisites" relate to two areas (i) the institutional issues referred to above and ii) the evolution called for in the spectrum conceptual roadmap.

The key challenges facing this trendline are accommodating the new entrants while pressure increases on the airspace (increasing access to the airspace without sacrificing efficient operations), spectrum (the increasing use of radio equipment and frequencies supporting that equipment) and the environment (minimizing the impact of aviation on the environment through reductions in equipment Size Weight and Power and increasing the efficiency of operations).

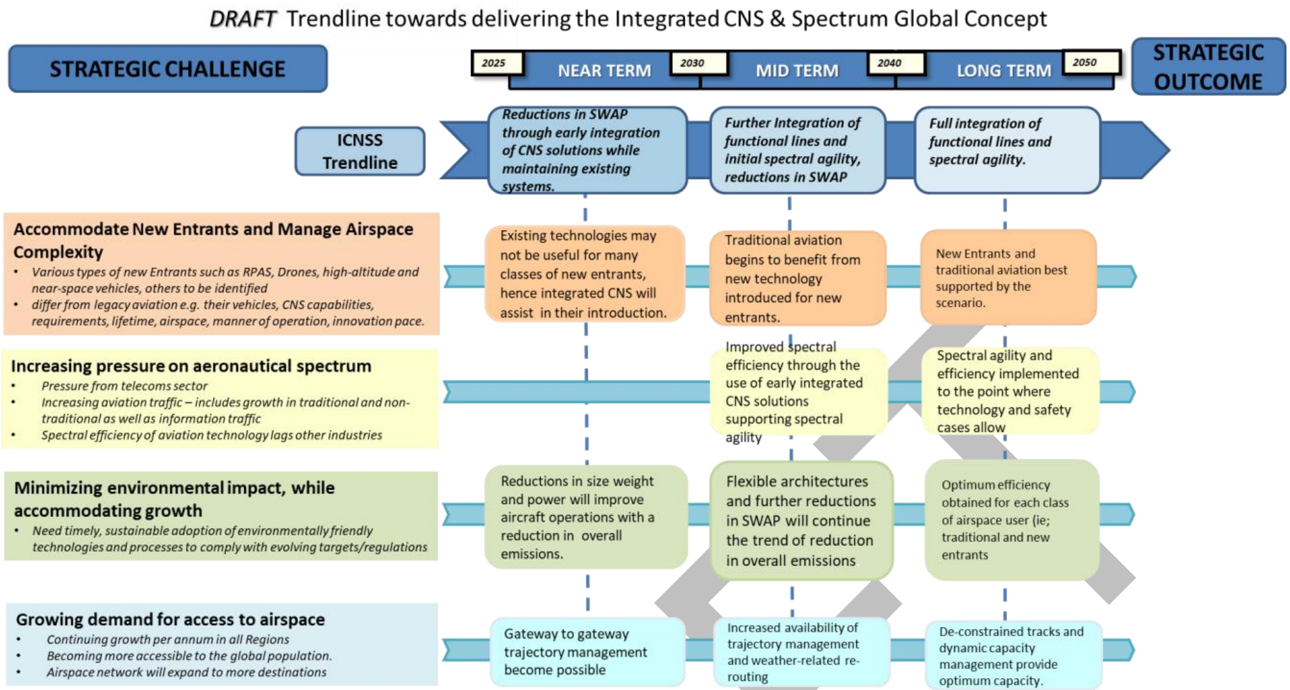


Figure 2-5- Trendline towards Integrated CNS (Integrated CNS Addressing the Challenges)

2.3.2.2.1 Near Term: Initiate integration of CNS technologies while maintaining existing systems.

1) Description

The main initiative for airborne CNS radio equipment will be the use of advanced equipment design architectures, yielding reduced size, weight, and power (SWAP). Different airspace users may require significantly different architectures and a challenge will be to ensure that safety cases can be satisfied.

a. These developments may be based on miniaturization of hardware and improved interfaces/connections (such as Ethernet and Optical fiber), use of software-defined CNS functions housed in integrated modular avionics or remote units, advanced antennas, while limiting the impact on certification[7].

b. The first practical step will be to initiate the integration of new CNS technologies, while maintaining existing systems. Maintaining backward compatibility between new and old systems leads to a reduction in efficiencies relative to what having a new homogenous architecture would provide. In other words, a mixture of equipment will improve efficiency but only incrementally because less efficient operations still need to be supported. All airspace users can operate integrated CNS avionics but need to ensure interoperability with existing equipage.

c. This will generally mean accommodating the existing functions through innovative hardware (e.g. combination of C, N or S functions in the same equipment) and possibly implementation of new software.

d. New equipment must be backwards compatible with the current ATM infrastructure; however, that new equipment is also expected to exploit any new integrated CNS technologies.

- ANSPs will begin trials of new integrated CNS systems, but all requirements for legacy functions will remain in place

- At this early stage, integrated CNS systems are encouraged to, but not required to, be capable of simultaneous support of CNS applications

- ATM will continue to be the focus of the automation developments between ANSPs

[7] Federal Aviation Regulations, Part 25 – Transport Category Aircraft.

- Existing systems will continue to operate under existing safety risk management whilst integrated CNS systems may have to operate on an experimental or trial basis.
- Need for CNS performance to be established based on use cases in ICAO SARPs.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- Existing technologies are unlikely to be practical for some types of new entrants.
- New entrants will either be segregated from or must make use of the existing functions and features of the current CNS architecture.
- As new entrants expand the capabilities of their equipment, the existing CNS infrastructure available today may not be able to fully support their operational needs
- To accommodate the needs of new entrants and provide compatibility with existing airspace usage changes to the CNS infrastructure are necessary
- Modern integrated CNS systems that can flexibly accommodate new airborne features brought by new entrants will assist in their introduction.

b. Minimizing the impact on the environment while accommodating growth:

- New types of equipment that provide more features will be developed to rapidly support new entrants
- Decreasing the SWAP for the new equipment will allow more efficient operations of all airspace users
- Reductions in SWAP will reduce the fuel burnt per passenger mile and hence overall emissions.

c. Growing demand for access to airspace

- Improved CNS solutions accompanied by automation make gateway-to- gateway trajectory management feasible.

2.3.2.2.2 Mid Term: Further Integration of functional lines.

1) Description

- Integration of functional lines, ie; a surveillance cabinet supporting DME, TCAS, ADS-B and similar for communication and navigation.
    - Ability to support GNSS and Satcom in same box is a likely first candidate.
    - Telecommunications services such as commercial mobile and satellite systems that have not traditionally supported safety of life services, operating in appropriately allocated frequency bands could be used, if the use case and applicable availability, continuity and integrity as well as certification requirements are verified through safety assessment.
- Implementation of new CNS systems should offer the opportunity to provide operational benefits in certain airspace but will require the coordinated implementation of associated CNS infrastructure and airspace management procedures.
- There will be a need to ensure continued interoperability with existing infrastructure and aircraft equipage where applicable.
- Airborne systems become more automated and begin to take additional roles in the development of trajectories and airspace management.
- ATM is transitioning to the integrated CNS infrastructure.

- Transition to integrated performance-based standards to enable the integration of functional lines and full ICAO safety risk management activity for operation using integrated CNS infrastructure.
- Integration of operations proceeds based on safety risk continuum. Backwards compatibility requires higher margins for safety assurance.
- Certification aspect for integrated functionality need to be carefully considered such as potential common mode failure points regarding technical and spectrum (RF interference) aspects
- New Certification Paradigms needed to support the following.
  - adaptive/agile avionics
  - airborne decision support tools
  - other automated systems
- SARPS or equivalent to be raised or developed which define the applicable high-level performance and clearly stipulate relevant “generic aspects” as described in 2.3.2.2.1 above.

2) Support for Challenges:

a. Accommodate new entrants and manage airspace complexity:

- Existing aviation users will begin to identify and adopt efficiencies and improvements to their operations that new entrant technology can bring
- This will drive an expansion of even more new entrant capabilities from traditional sources, possibly using existing technologies
- Existing aviation infrastructure for CNS may not be scalable to accommodate many types of new entrants. This may result in the need to increase the use of systems operating in non-safety spectrum.

b. Increasing pressure on aeronautical spectrum

- Initial attempts at spectral agility for multi-use CNS systems provide greater spectral efficiency.

c. Minimizing the impact on the environment while accommodating growth:

- As operational efficiencies are gained using new equipment and flexible architectures or the introduction of new functionality, the incentive to reduce SWAP will further increase gains
- Further reductions in SWAP and decommissioning of more legacy avionics will further reduce the fuel burnt per passenger mile and hence overall emissions.

d. Growing demand for access to airspace.

- Further exploitation of the capabilities of the CNS solutions and accompanying automation extend the availability of trajectory management and weather-related rerouting.

2.3.2.2.3 Long Term: Full integration of functional lines

1) Description

- Integrated and performance-based CNS systems to support the integration of ATM/UTM/Space planes.
- Integrated CNS operations are routine; Safety Risk Management also allows non-integrated CNS by exception.
- Fully integrated CNS infrastructure that can adapt to all users.
- ANSPs will be operating infrastructure based on new integrated CNS systems.

- Integrated CNS systems will typically be capable of simultaneous function of two or more CNS applications.

- Flight information originates and is immediately processed in the integrated CNS infrastructure and its airborne components. Information about a flight is carried by the aircraft and relayed to the integrated CNS infrastructure - thus needing the maintenance of a single source of trusted data that is uniquely identifiable with a single aircraft.

- As systems becomes obsolete, they will be decommissioned in a planned manner.

2) Support for Challenges:

a. Accommodate new entrants and manage airspace complexity:

- Integrated CNS systems flexibility quickly accommodates all forms of aviation without requiring segregation or long transition periods

- Scalable technologies and open architectures allow for continual “plug-and-play” software/hardware improvements implemented with minimal downtime without requiring large changes in integrated CNS equipment

- The increasing number of new entrants encourages and accelerates the innovation cycle allowing efficiencies to be quickly realised by the system

b. Increasing pressure on aeronautical spectrum

- Spectral agility and efficiency improvements have been implemented to the point that available technology allows, further gains could negatively impact safety cases.

c. Minimizing the impact on the environment while accommodating growth:

- Higher performance CNS functionality will enable operational efficiencies such as optimal routing, minimum disruption resulting in less fuel and less carbon in the atmosphere

- Efficiencies introduced by the rapidly accelerating innovation cycle include reductions in SWAP that drive down the impact on the environment by all classes of airspace user.

d. Growing demand for access to airspace:

- Adoption of advanced CNS systems and the application of complementary automation by the majority of airspace users lead to de-constrained tracks and dynamic capacity management providing optimum capacity.

2.3.2.2.4 Timeline and prerequisites to progress the Integrated CNS and Spectrum

2.3.2.2.4.1 Figure 2-6 indicates the required prerequisites to progress the Integrated CNS and Spectrum concept.

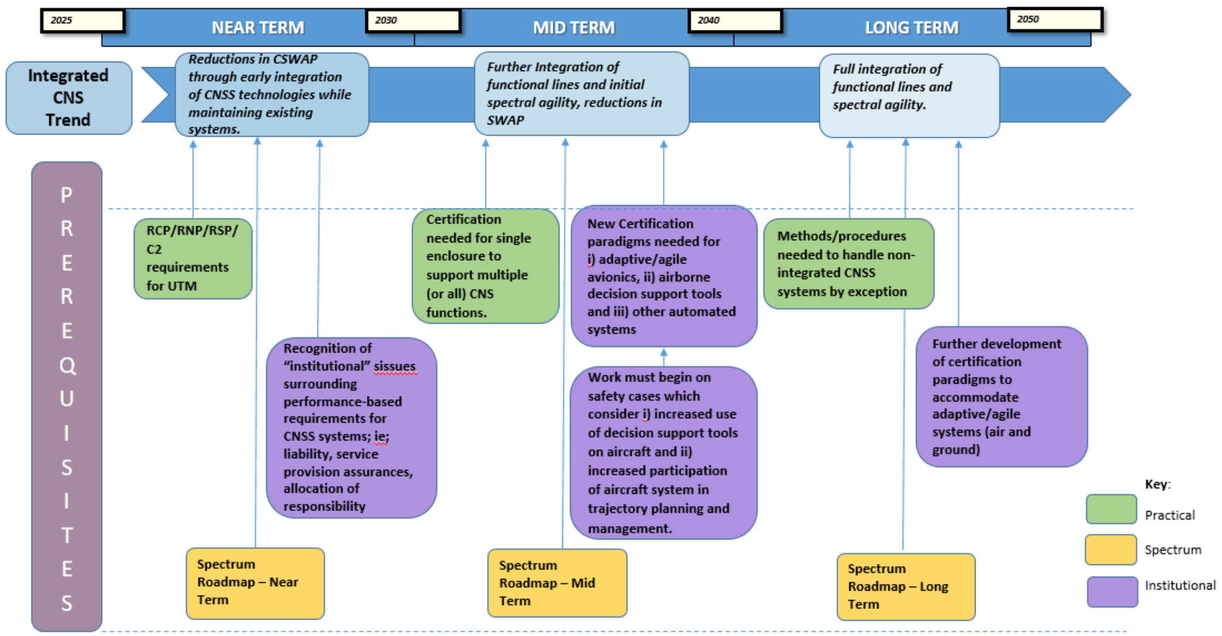


Figure 2-6 – Prerequisites for Integrated CNS and Spectrum to succeed

2.3.3 Detailed Conceptual Roadmaps

2.3.3.1 **Thread 1 – Airspace Integration *(relates to ASBU threads, FFICE, ACDM, FTRO, CSEP and NOPS[8])***

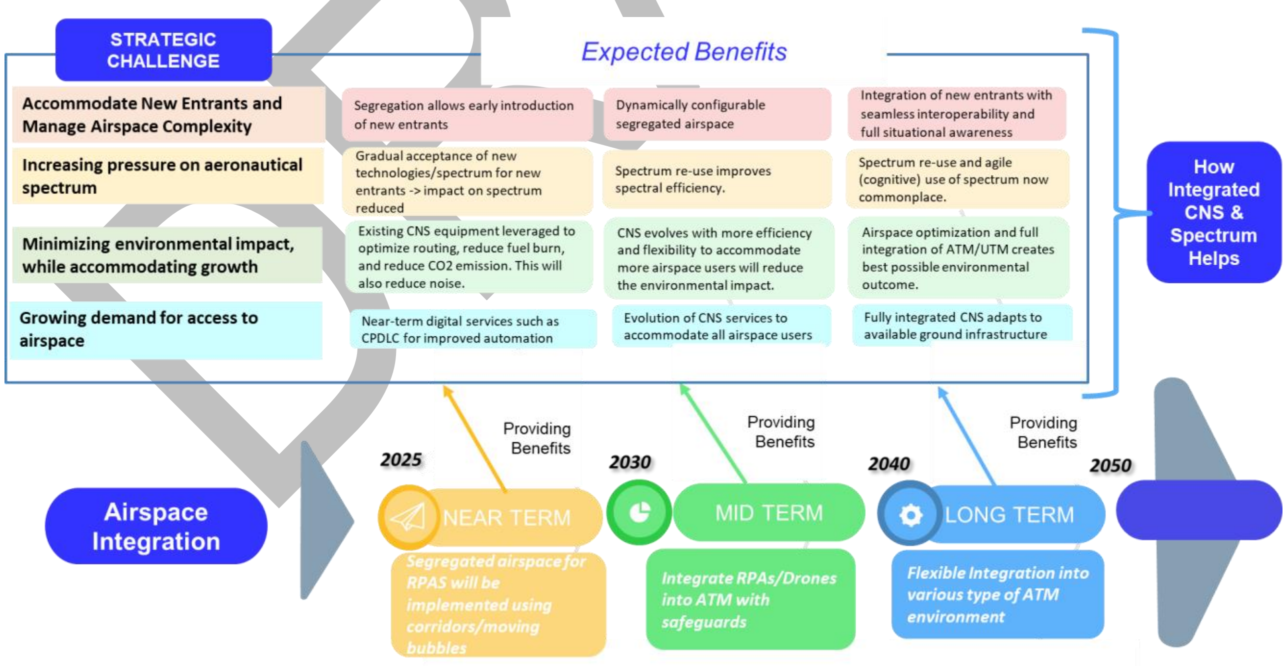


Figure 2-7- Detailed Conceptual Roadmap (Thread 1- Airspace Integration)

[8] XX: FFICE, XX: ACDM, XX: FTRO, XX: CSEP and XX: NOPS

2.3.3.1.1 **Near Term: Prepare for integration with traditional CNS Equipage and segregated airspace (case by case)**

1) Description

- In the near-term, efforts to provide integrated airspace will focus on the integration of RPAS (as opposed to drones and other new entrants). In this case users will require the use of traditional CNS systems for air traffic services while operating in controlled airspace. Additionally, the RPAS may use Ground-Ground communication as a means to support ATS exchanges with the airspace manager while operating in controlled airspace. Drones and other new entrants may use other, non-aviation CNS systems, such as commercial cellular networks when operating in uncontrolled airspace.

- Segregated airspace (for RPAS) will be implemented through the use of airspace corridors/moving bubbles, which has already been done on a trial basis. The intent is to see broader implementation of these by 2025 while ensuring minimal workload impact on air traffic controllers.

- New entrants (including RPAS) may be segregated to allow for metered operations.

- One significant challenge is the provision of common performance requirements that ensure consistent services regardless of technology used.

2) How Integrated CNS helps:

   a. New entrants will embrace new technologies, through timely airspace integration will be expedited.

3) Support for Challenges:

   a. Accommodate new entrants and manage airspace complexity:

      - Use segregated airspace, as necessary due to the different operating characteristics of new entrants.

   b. Increasing pressure on Aviation Spectrum:

      - Gradual acceptance of new technologies/spectrum for new entrants -> impact on spectrum reduce

   c. Minimizing the impact on the environment while accommodating growth:

      - CNS equipment will optimize routing, reduce fuel burn, and reduce CO_2 emission. This will also reduce noise.

   d. Growing demand for access to airspace:

      - Near-term digital services such as CPDLC for improved automation

2.3.3.1.2 **Mid Term: Integrate RPAS/drones into ATM environment with safeguards**

1) Description

- This will see the safer integration of RPAS and drones into the ATC environment with safeguards, with an increase in the use of non-segregated airspace for new entrants; however, ATM still provided in segregated airspace, due to their need for (real time) negotiated trajectories.

2) Support for Challenges:

   a. Accommodate new entrants and manage airspace complexity:

      - Gradual integration will commence.

      - Advanced integrated CNS systems capabilities will enable 4D/TBO and eventually formation flights, which will lead to dynamic airspace operational capability. Once new entrants are fully integrated into the airspace, further optimization will be possible through dynamic capacity management at a macro level covering air spaces across national, continental, and oceanic boundaries.

b. Increasing Pressure on Aeronautical Spectrum

- Use of new technologies allows reuse of spectrum. Spectrum once used for navigation could also be used for communication, or communication spectrum could also be used for the determination of position. This also implies that (hardware) systems can be adapted to perform multiple roles, ie: primary communication, secondary or back-up navigation.

c. Minimizing the impact on the environment while accommodating growth:

- Integration will assist with more efficient operations, however safeguards may limit the overall benefit. Accommodation of technology disruptors such as RPAS and drones into a classic ATC environment will be challenging. Well considered safeguards will be required when forming the basis for a flexible airspace integration framework.

d. Growing demand for access to airspace:

- In this case, novel or new technologies generally used by the new entrants will also find application among the traditional airspace users who will in turn reap benefits. Once a critical mass of users possesses similar capability, then things such as access to dynamically configurable airspace become possible.

2.3.3.1.3 **Long Term: Flexible Integration into various types of ATM environment**

1) Description

- This will see full UTM operations in the ATC environment. Methods will be required to maximise airspace capacity and to provide common airspace situational awareness.

- The goal is to achieve a unified airspace, enabling all users (RPAS, balloons, others) to gain access to airspace on a cooperative basis, optimizing airspace efficiency and minimising the CNS equipage

- This will also include the full integration of systems performing high-altitude operations.

2) Support for Challenges:

a. Accommodate new entrants and manage airspace complexity:

- Full integration achieved

b. Increasing Pressure on Aeronautical Spectrum

- Spectrum re-use becomes commonplace and more sophisticated through the use of agile or cognitive techniques. This will allow on-board systems to operate in different frequency bands (and using different waveforms/coding) dependent on the capabilities of the local ground facilities.

c. Minimizing the impact on the environment while accommodating growth:

- Airspace optimisation and full ATM/UTM integration leads to best possible environmental outcome.

d. Growing demand for access to airspace:

- Fully integrated CNS adapts to available ground infrastructure. For aircraft with advanced avionics that may be a dynamic process, for other avionics this may need to be configured on a flight-by-flight basis.

2.3.3.2 Thread 2 – Formation Flight *(relates to ASBU threads ACDM, FTRO, CSEP, NOPS and TBO)*

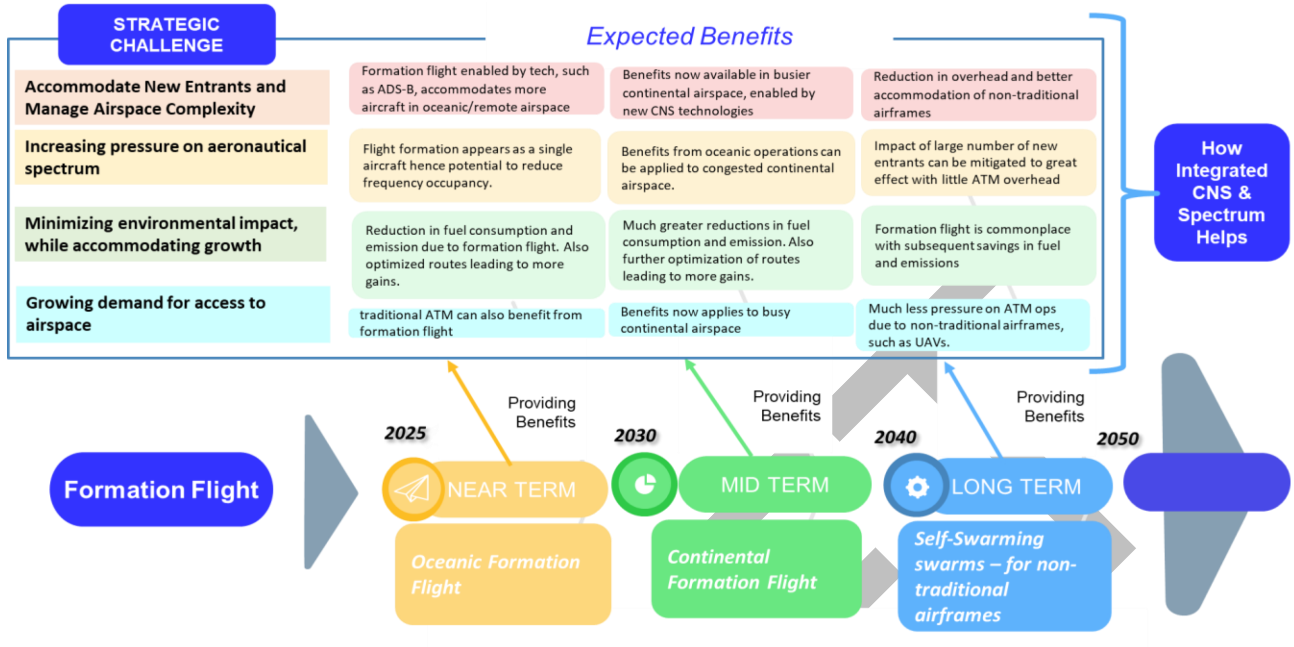


Figure 2-8 - Detailed Conceptual Roadmap (Thread 2- Formation Flight)

2.3.3.2.1 **Near Term: Introduce formation flight function - oceanic (station keeping, cooperative trajectories, and air-to-air communication)**

1) Description

- The objective of this thread is to introduce efficient oceanic and remote operations. A key component of this will be air-air communications, which for example could be supported by ADS-B. However effective communication requires communication among aircraft, most likely via voice. Procedures for formation flight would also be needed.
- As the participating aircraft could be operated by different airspace users, new methods would be needed to support cooperative trajectories.
- This approach to flight would result in worthwhile fuel savings with the commensurate reduction in emissions and so limits the impact on the environment of civil aviation operations. Introduction of this concept in the large trans- North Atlantic and trans-Pacific oceanic flows in a first step, will be easy for the near term, due to mono-directional tracks in these areas.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- New entrants flying in formation will not require large separations.

b. Increasing pressure on aeronautical spectrum:

Opportunity for flight formation to appear as a single aircraft thus reducing frequency occupancy with Ground ATC, however this will depend on the need for internal coordination within the aircraft formation. Provisions must be made for an aircraft experiencing an emergency to communicate directly with ATC.

c. Minimizing the impact on the environment:

- Extensive flight testing with long-haul aircraft has been conducted by industry bodies and research institutes to check the theory. In some cases, instantaneous fuel reductions were observed to be over 10% for the follower. The potential of Wake Energy Retrieval (WER) for reducing fuel consumption and hence carbon emission, is therefore well established.

- Whilst the principles of WER apply to any aircraft, the main benefits apply to flights made by widebody aircraft, and specifically on sectors longer than 2000NM. Traffic flows between global regions therefore are of primary interest.

d. Demand for Access to Airspace to Support Growth:

- Formation flying leads to other improvements including efficient flight procedures and optimized routing.

2.3.3.2.2 **Mid Term: Introduce formation flight - Continental**

1) Description

- The objective of this thread is to introduce efficient oceanic and remote operations in continental areas where mono-directional RVSM is performed. Deployment of WER operations is expected to be in low-density and predominantly continental long-haul flows such as those in continental North America, and between Asia and Europe. A number of shorter-range continental flows also offer high potential.

- This comes with greater challenges and therefore will demand more from on-board systems and spectrum availability particularly in continental areas. For example, future ADS-B-like functions, which will need to support additional parameters such as aircraft state and intent. The need for communication between Aircraft would also require careful consideration as to its spectral implications.

- To maximize the environmental benefit from this thread, it will be necessary to optimize departure and arrival procedures and to consider the interface between oceanic and continental airspace.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- Benefits from near term now available in busier continental airspace.

- Formation flights would allow the accommodation of (large numbers of) new entrants with less impact on the airspace capacity.
- The density of traffic in continental airspace raises the complexity of introducing WER operations. High density continental RVSM flows where lateral and longitudinal separations are much lower, present a higher level of complexity

b. Increasing pressure on aeronautical spectrum:

- Any benefit obtained in the near term (oceanic airspace) can be applied to continental airspace, noting that communication between aircraft in formation would also require additional spectrum resources.

c. Minimizing the impact on the environment:

- Any benefit obtained in the near term (oceanic airspace) can be applied to continental airspace. Additional to this will be the Introduction of arrival and departure procedures with minimal environmental impact and initial self-separation

d. Demand for Access to Airspace to Support Growth:

- Formation flying leads to other improvements including efficient flight procedures and optimized routing. The benefits previously obtained in oceanic airspace are now also applicable to continental and perhaps higher density airspace for new entrants.

2.3.3.2.3 **Long Term: Self-forming swarms (formation flights) for optimization and efficiency - RPA forming such swarms.**

1) Description

- This will largely be limited to RPAs *(Drones, VTOL)* having the manoeuvrability for such operations.
- Spontaneous swarms may also occur with manned aircraft but only under certain conditions.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity :

- Greatly reduced overhead in managing non-traditional airframes as multiple aircraft can be treated as a single flight.

b. Increasing pressure on aeronautical spectrum:

- The use of self-forming swarms by new entrants will help mitigate the additional pressure on the aeronautical spectrum presented by only needing C2 and/or ATC links with the lead aircraft. Thus mitigating the effects of new entrants.

c. Minimizing the impact on the environment:

- Formations/swarms could result in concentrated noise and visual footprints, which could be more acceptable to the general public. Such improvements become commonplace.

d. Demand for Access to Airspace to Support Growth:

- Greatly reduced overhead in managing non-traditional airframes as multiple aircraft can be treated as a single flight.

2.3.3.3 **Thread 3 TBO and 4D Trajectories/Cooperative Trajectories *(relates to ASBU threads CSEP, TBO)***

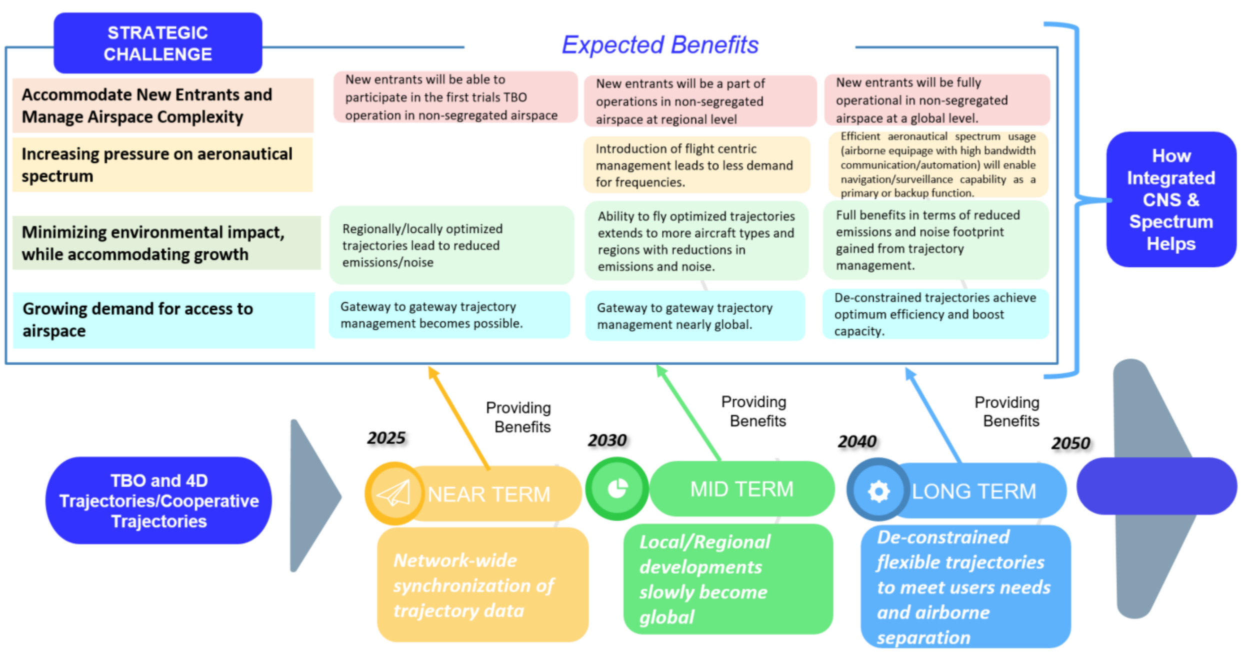


Figure 2-9- Detailed Conceptual Roadmap (Thread 3 – 4D Trajectory/TBO)

2.3.3.3.1 **Near Term: Network-wide synchronization of trajectory data**

1) Description

- In certain regions, the 4D-TBO function is being gradually brought into service across several countries for the ground part. This will involve the development of regional shared trajectory data platforms.
- Networked ground-to-ground demonstrations/trials between 2 or more ANSPs to validate “free route airspace concepts" already started and planned to continue in the near term.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- New entrants will be able to participate in the first trials of TBO operation in non-segregated airspace.

b. Minimizing environmental impact, while accommodating growth:

- Regionally/locally optimized trajectories lead to reduced emissions/noise.

c. Growing Demand for Access to Airspace:

- Gateway to gateway trajectory management becomes possible.

2.3.3.3.2 **Mid Term: Local/regional developments slowly become global**

1) Description

- 4D-TBO function will be operational at a regional level and utilized for each stage of flight.
- Global interoperability framework will be setup to ensure onboard equipment compatibility.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- New entrants will be a part of operations in non-segregated airspace at regional level.

b. Increasing pressure on aeronautical spectrum:

- Minimizing environmental impact, while accommodating growth:
- Ability to fly optimized trajectories extends to more aircraft types and regions with reductions in emissions and noise.
- Growing demand for access to airspace
- Gateway to gateway trajectory management nearly global.

2.3.3.3.3 **Long Term: De-constrained, flexible trajectories to meet users' needs and airborne separation**

1) Description

- This will be achieved with automation allowing seamless flow management and trajectory coordination without (or minimal involvement of) a human in the loop.

2) Support for Challenges

a. Accommodate New Entrants and Manage Airspace Complexity:

- New entrants will be fully operational in non-segregated airspace at a global level.
- Impact of large number of new entrants can be mitigated to great effect with little ATM overhead.

b. Increasing pressure on aeronautical spectrum:

- Efficient aeronautical spectrum usage due to airborne equipage by default with high bandwidth communication and automation capability accommodated within existing aeronautical spectrum.
- Integration of redundant or back-up CNS functions within data communications, i.e., by providing support to navigation and surveillance functions. Examples: using datalink for surveillance data (ADS-B messages, DAP, etc) or using datalink to provide a ranging function to support performance-based navigation.

c. Minimizing environmental impact, while accommodating growth:

- Full benefits in terms of reduced emissions and noise footprint gained from trajectory management.

d. Growing Demand for Access to Airspace:

- De-constrained trajectories achieve optimum efficiency and boost the airspace capacity.

2.3.3.4 Thread 4 – Flexible Allocation of Capacity

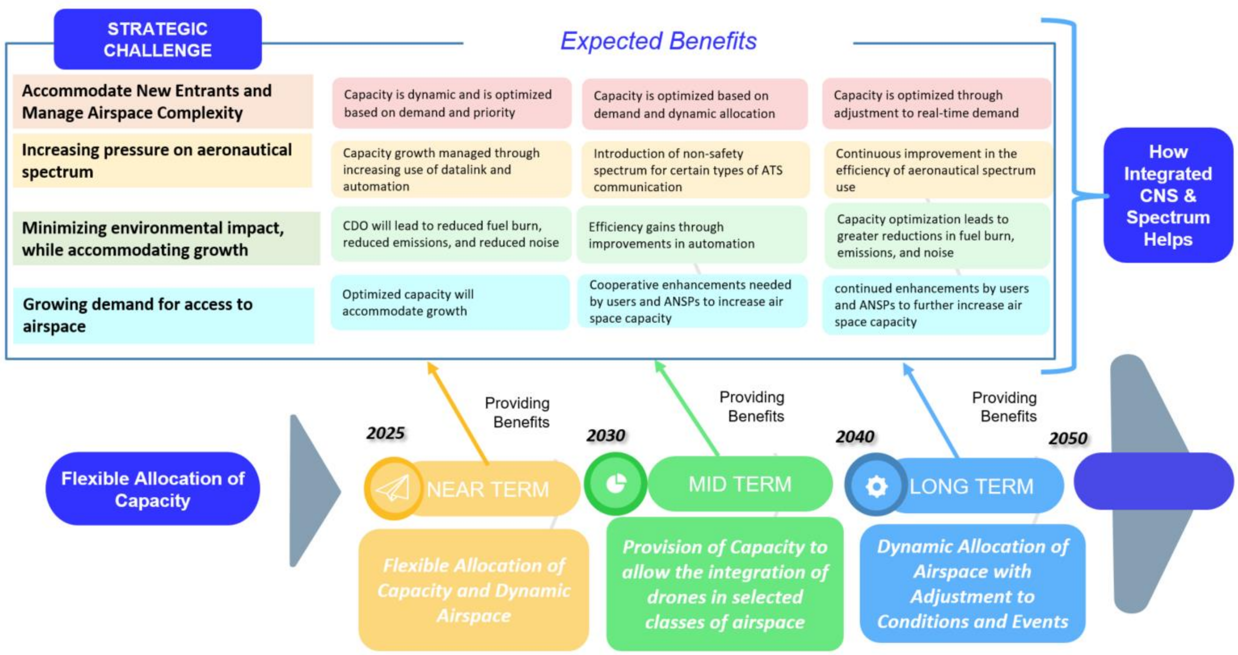


Figure 2-10- Detailed Conceptual Roadmap (Thread 4 – Flexible Allocation of Capacity (new figure to be provided)

2.3.3.4.1 Near Term: Flexible Allocation of Capacity and Dynamic Airspace

1) Description

- This will be the initial phase of the implementation of capacity on demand and the attendant dynamic configuration of airspace. The basic components of this will be as follows:
  - Dynamic airspace management and airspace configurations (DAC)
  - Continuous Descent Operations (CDO)
  - Dynamic extended TMA (including the procedures and systems to enable Continuous Climb Operations (CCO)).

- Demonstration of RPAS accommodation in Controlled Airspace (Classes C to A).
- Introduction of Flow-Centric Approach (Including the Full reconciliation of ATFM measures with other measures such as Advisories and Multiple Constraints.
- Introduction of Digital Integrated Network management and ATC Planning (INAP)
- Integrated weather alerts and predictions will be available to automated systems.

- Transition will be managed using the principle of best equipped/best served in segregated airspace.

2) Support for Challenges:

a. Accommodate new entrants and manage airspace complexity

- Capacity is dynamic and is optimized based on demand and priority.

b. Increasing pressure on aeronautical spectrum:

- Airspace capacity growth managed through increasing use of datalink between Aircraft and ATM system, which enables a higher level of automation
- Airspace capacity provides justification for aeronautical spectrum allocation by accommodating increasing spectrum demand within existing allocations by means of a stringent requirements definition for new allocations and optimizing channels reuse for existing ones.

c. Minimizing environmental impact, while accommodating growth:

- CDO will lead to reduced fuel burn, reduced emissions, and reduced noise.

d. Growing Demand for Access to Airspace:

- Optimized capacity will accommodate growth.

2.3.3.4.2 **Mid Term: Provision of Capacity to allow the integration of drones in selected classes of airspace VFR and IFR.**

1) Description

- This will include the partial automation of weather-related re-routing and trajectory management.
  - Regular use of Continuous Climb Operations (CCO)
  - ANSPs to provide dynamic use of restricted airspace and military airspace
  - For appropriately equipped aircraft, airspace management is automated with priority access for specific types of aircraft in a given airspace
  - Reduction in separation standards through improved navigation, surveillance, and situational awareness
  - Wake vortex awareness, broadcast, and management
  - Broad use of Flow-Centric Approach (Including the Full reconciliation of ATFM measures with other measures such as Advisories and Multiple Constraints
  - Broad use of Digital Integrated Network management and ATC Planning (INAP)
  - Integrated weather alerts and predictions will be available to automated systems.

2) Support for Challenges:

a. Accommodate new entrants and manage airspace complexity:

- Capacity is optimized based on demand and dynamic allocation

b. Increasing pressure on aeronautical spectrum:

- Capacity growth provides justification for aeronautical spectrum allocation
- Most AOC communication on non-safety spectrum
- Introduction of non-safety spectrum for certain types aeronautical applications
- Flexible use of spectrum across C,N,S functions

c. Minimizing environmental impact, while accommodating growth :

- Efficiency gains through improvements in automation
- Use of community noise management systems

d. Growing Demand for Access to Airspace:

- Cooperative enhancements needed by users and ANSPs to increase air space capacity

2.3.3.4.3 **Long Term: Dynamic Allocation of Airspace with Adjustment to Conditions and Events**

1) Description

- Free route - user preferred routing, considering:
  - Different users with different needs requiring an equitable and fair allocation of resources.
  - Near real-time dynamic allocation and real-time accommodation
  - Dynamic adjustments to changes in airspace conditions (weather, VIP transit, commercial events, etc.)
  - Ability to see and understand impact of system-wide and individual preferences, constraints & resource levels calling for optimization at local, regional, and global levels.
  - As requirements will vary from user to user and subsystem to subsystem – near real time, multivariate optimization will be needed to provide seamless (de-constrained) flexible trajectories to meet users' needs/conditions
- Automation will need to accommodate weather and priority operations, all manner of airspace events including VIP flights, special events, military operations, and individual mission objectives
- Such accommodation will require system to user Interaction, offering optimized choices/alternatives to individual users based on user criteria and real-time system constraints.
- Safeguards will be required to identify and safely mitigate the impact of non-conforming airborne platforms.

2) Support for Challenges:

a. Accommodate New Entrants and manage airspace complexity:

- Capacity is optimized through adjustment to real-time demand while considering individual preferences.

b. Increasing pressure on aeronautical spectrum:

- Capacity growth provides justification for additional aeronautical spectrum allocation
- Some further services are likely to be moved to non-aeronautical spectrum
- Continuous improvement in the efficiency of aeronautical spectrum use

c. Minimizing environmental impact, while accommodating growth:

- Capacity optimization leads to greater reductions in fuel burn, emissions, and noise.

d. Growing Demand for Access to Airspace:

- continued enhancements by users and ANSPs to further increase air space capacity

2.3.3.5 Thread 5 – New Entrants

One of the challenges accommodating new entrants will be the need to accommodate their different operating constraints, (ie: UAS/drones, vs RPAS vs HPAS) which will also depend on their given operating environment, ie; local/regional/global.

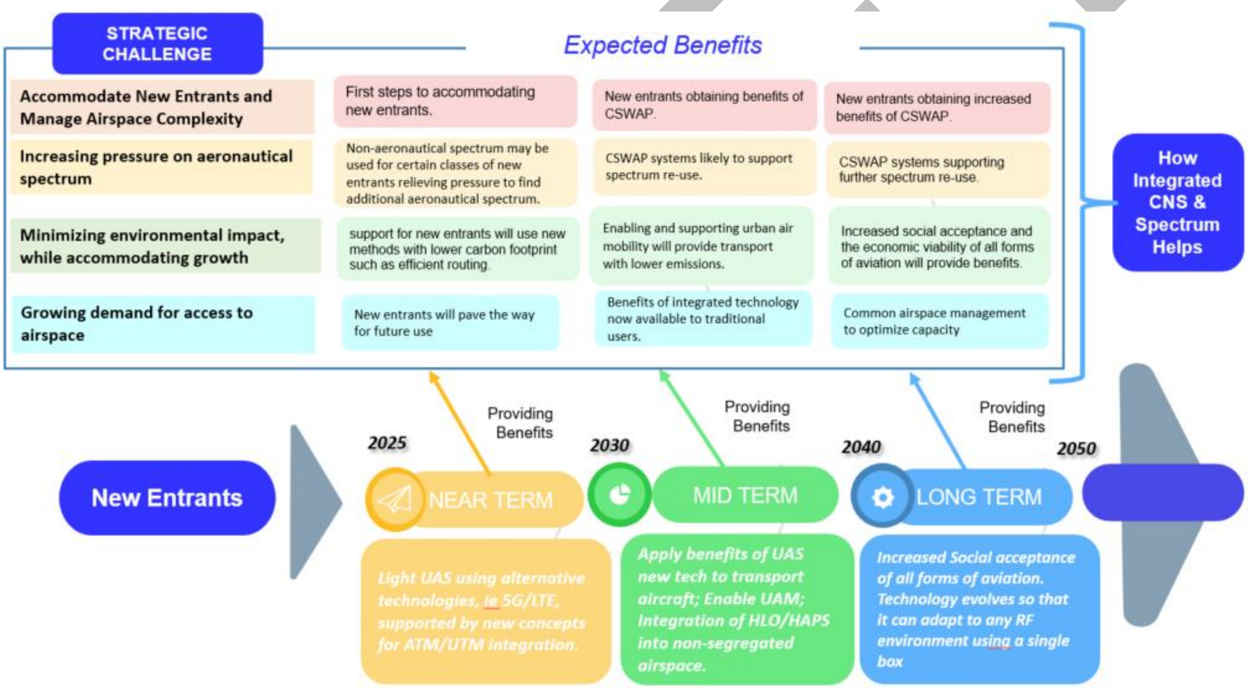


Figure 2-11- Detailed Conceptual Roadmap (Thread 5 – New Entrants)

2.3.3.5.1 **Near Term: Light UAS possibly using alternative technologies, ie 5G/LTE, C-band, supported by new concepts for ATM/UTM integration including UAM, HAPS, etc[9].**

1) Description

- Light UAS will not only use conventional CNS systems but could also use technologies such as LTE/5G or C band for the C2 link and detect and avoid. May use GNSS but with Augmentation or some alternate means of providing positioning, navigation and timing (APNT).
- There will be few overlaps in the CNS systems used either on the ground or on-board or in terms of spectrum.

[9] This includes Regional Air Mobility (RAM), Advanced Air Mobility (AAM), Direct Air Mobility (DAM) and Mobility as a Service (MaaS).

- The scope is very broad and will include near-space, sub-orbital vehicles and High Altitude Platforms (HAPS)

- Providing new entrants with efficient routing will be a priority that will require the development, validation and deployment of basic UTM and urban air mobility services across various regions. Later integration of these services with (traditional ATM) will be an objective.

- Air-air communication will be a key enabler for ATM/UTM.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- First steps to accommodating new entrants.

b. Increasing pressure on aeronautical spectrum:

- Non-aeronautical spectrum may be used for certain new entrants relieving pressure to find additional aeronautical spectrum.

c. Minimizing environmental impact, while accommodating growth:

- Support for new entrants will use new methods with lower carbon footprint through means such as efficient routing.

2.3.3.5.2 **Mid Term: Apply benefits of UAS new tech (SWAP) to transport aircraft; Enable UAM; Integration of HLO/HAPS into non-segregated airspace.**

1) Description

- At this point the newly developed technologies for UASs (improving SWAP) will have matured and achieved some level of economies of scale. Hence, they can be applied to traditional ATM airborne and ground-based systems.

- The first attempts will be made to achieve the seamless integration of new entrants into ATM airspace.
  - Requiring support for UAM.

- Super-high-altitude operating aerial vehicles. High Level Operations (HLO) for super-high- altitude operating aerial vehicles are expected to begin their transition from segregated to non-segregated airspace with appropriate regulations (with EASA/FAA involvement), clearly defined technological capabilities and suitable performance for such air platforms well-established.
  - This will also see the network integration of Higher Airspace Operations (HAO) (FL500 and above) (refer to Upper Class E Traffic Management (ETM))[10].

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- New entrants obtaining benefits of SWAP.

b. Increasing pressure on aeronautical spectrum:

[10] Upper Class E Traffic Management (ETM). Upper Class E airspace operations refer to those that take place over 60,000 feet above mean sea level (MSL) in the National Airspace System (NAS). Operations in upper Class E airspace have historically been limited due to the challenges faced by conventional fixed wing aircraft in reduced atmospheric density. However, recent advances in power and propulsion technology, aircraft structures, flight automation, and aerodynamics have increased the number of vehicles that can now operate in the low atmospheric density airspace that is characteristic of upper Class E. This means that sophisticated high altitude, long endurance (HALE) vehicles, unmanned free balloons, airships, and supersonic/hypersonic aircraft can now efficiently and economically satisfy research objectives, demands for broad coverage services (i.e., earth sensing, telecommunications), and supersonic passenger flight.

- Systems with benefit of SWAP and likely to support greater spectrum re-use.

c. Minimizing environmental impact, while accommodating growth:

- Enabling and supporting urban air mobility will provide transport with lower emissions.

d. Growing Demand for Access to Airspace:

- Benefits of new technology now available to traditional aviation.

2.3.3.5.3 **Long Term: Increased Social acceptance of all forms of aviation. Technology evolves so that it can adapt to any required CNS functions using a single box.**

1) Description

- Should they prove to be a commercial success and meet aviation requirements including compliance with the relevant safety case, for instance, advantage is likely to be taken of the new massive LEO constellations. This will also apply to HAPS networks and other terrestrial means.

- Increased social acceptance of all forms of aviation will be a success criteria.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- New entrants obtaining increased benefits of SWAP.

b. Increasing pressure on aeronautical spectrum:

- SWAP systems supporting further spectrum re-use.

c. Minimizing environmental impact, while accommodating growth:

- Increased social acceptance and the economic viability of all forms of aviation will provide benefits.

2.3.3.6 Thread 6 – Automation (including AI/Machine Learning)

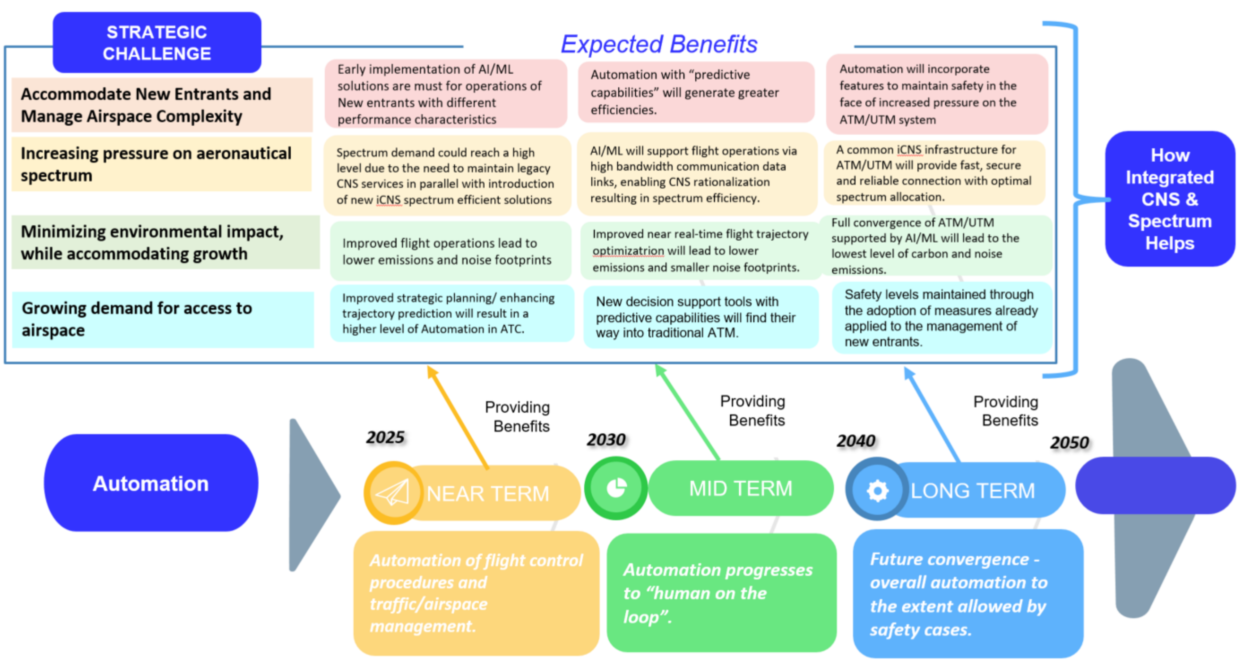


Figure 2-12- Detailed Conceptual Roadmap (Thread 6 – Automation)

2.3.3.6.1 **Near Term: Automation of flight control procedures and traffic/airspace management.**

1) Description

- Extensive operational evaluations will be needed before the introduction of new airborne vehicles. A benefit of this will be that it will facilitate transition from "human-to-human" to "machine-to-machine" and/or other partially automated airspace usage modes as these will most likely be the “test case” for the new techniques.

- The use of automation tools will increase the use of automated action in systems such as ACAS, DAA, and automation in CDM. Automation in pre-flight planning will make it possible to accommodate the new entrants, who quite often will be the “test cases”.

- Global, regional and national regulatory process need to accommodate AI/ML solutions

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- Early implementation of AI/ML solutions for operations of New entrants with different performance characteristics, especially for performing fast, better optimized and unscheduled trajectories.

b. Increasing pressure on aeronautical spectrum:

- Spectrum demand could reach a peak level due to the need to maintain legacy CNS systems in parallel with introduction of new Integrated CNS spectrum efficient technological solutions.

c. Minimizing environmental impact, while accommodating growth:

- Improved flight operations based on strategic planning lead to lower emissions and smaller noise footprints.

d. Growing Demand for Access to Airspace:

- Improved strategic planning and enhancing trajectory prediction. As a result a higher level of Automation in ATC will be reached.

2.3.3.6.2 **Mid Term: Automation progresses to “human on the loop”.**

1) Description

- The first steps will see the trial/test use of integrated airspace to accommodate mixed use of "human-to-human", "machine-to-machine" and/or other partially automated airspace usage modes.

- There will be new and adapted rules and procedures tailored according to CNS capabilities.

- UTM will have a greater use of automation.

- Automation to support flexible flight will move to “human on the loop”.

- New paradigms will be required to support changes such as:

    - The increased reliance on decision support tools with increased predictive capabilities (in the event of failure – who will be at fault, “the man or the machine”.

    - Use of information from remote sources.

    - Arbitration between rogue pilot and/or rogue ground control systems.

- Technological enablers that can best help to deliver the improvements foreseen in the GANP or could offer opportunities for further operational improvements.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- Automation with “predictive capabilities” will generate greater efficiencies.

b. Increasing pressure on aeronautical spectrum:

- AI and ML will support flight operations via high bandwidth communication data links and enable CNS infrastructure rationalisation, improving spectral efficiency.

c. Minimizing environmental impact, while accommodating growth:

- Improved near real-time flight trajectory optimization will lead to lower emissions and smaller noise footprints.

d. Growing Demand for Access to Airspace :

- Many of the efficiencies obtained through the use of new decision support tools with predictive capabilities will find their way into traditional ATM including improved airborne capabilities.

2.3.3.6.3 **Long Term: Future Convergence - overall automation to the extent allowed by safety cases.**

1) Description

- Operational use of integrated airspace to accommodate mixed use of "human-to-human", "machine-to-machine" and/or other partially automated usage modes.
- Automation will increase to the extent allowed by safety cases with the aim of achieving Increased, reliable, safe automation at every aspect of the flying experience starting from planning to arrival at destination.
    - Anticipated development in automation includes AI and deep learning
- The role of automation will ultimately be to fulfil the human intent and to this end, the human must have the ability to override the automation.
- In addition to the above, automation will be developed according to the following design principles:
    - It must be auditable and should have self- (independent) checks with performance indicators
    - Resiliency is to be “inbuilt” to the greatest extent possible as systems must gracefully degrade or recover to provide the desired capabilities
    - Predictability of the impact and consequence of system (mal) function in the near future will be required at the micro and macro levels.

2) Support for Challenges:

a. Accommodate New Entrants and Manage Airspace Complexity:

- Automation will incorporate many features to maintain safety in the face of increased pressure on the ATM/UTM system, such as inbuilt resiliency and independent self-checks

b. Increasing pressure on aeronautical spectrum:

- A common Integrated CNS infrastructure for ATM/UTM will provide fast, secure and reliable connection which should lead to near optimal spectrum utilisation.

c. Minimizing environmental impact, while accommodating growth:

- Full convergence of ATM and UTM supported by AI and ML will lead to the lowest level of carbon and noise emissions.

d. Growing Demand for Access to Airspace:

- ATM will demand that safety levels are maintained, hence this will lead to the adoption of measures already applied to the management of new entrants.
- AI and ML will enable a fully dynamic airspace configuration and allow a dynamic spacing separation.

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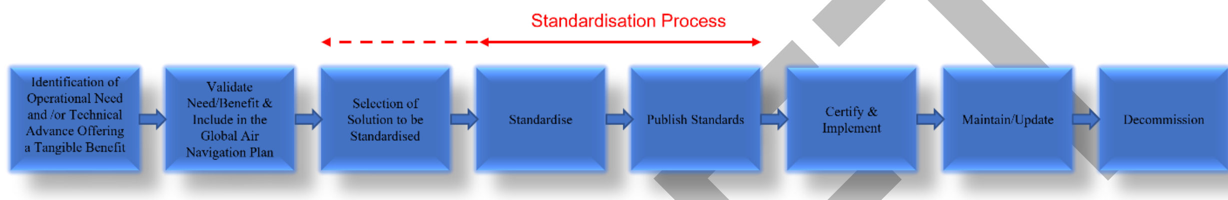
Chapter 3 Streamlined System Standardisation

(Editor's note: This chapter is in an early stage of development.)

3.1 The necessity

3.1.1 To have a process that can take an idea from inception, through standardisation and implementation to decommissioning in line with the principles behind minimum global harmonized systems and no country left behind, that is aligned with modern system development timescales.

3.1.2 The establishment of ICAO Standards and Recommended Practices (SARPs) and associated documentation such as Minimum Aviation System Performance Standards (MASPS) / Minimum Operational Performance Standards (MOPS) are only part of that process as indicated in the simplified design process shown below.



3.1.3 It should be noted that if the overall process is to be optimised, then other areas such as when an operational need or technical advance that offers tangible benefits is identified or when systems are no longer required should also be reviewed.

3.2 The Issues

3.2.1 Introduction

3.2.1.1 The SARPs process, including the production of associated documentation, in the past served ICAO and aviation however the increasing pace of technological change, competition between systems, variations in implementation, the increased pressure on spectrum and the cost of the regulatory framework has meant that the process is now out of step with modern system development timescales. Therefore, the process needs to be streamlined. Additionally, SARPs only address systems where inter-operability is required and do not address self-contained systems such radio altimeters, primary surveillance radar or airborne weather radar and since there is no other global regulatory authority that define standards these systems are open to wide variation in their specification although ICAO is looked to provide advice on their technical parameters.

3.2.2 Technological change

3.2.2.1 When SARPs were first developed in the 1950's aeronautical Communication/Navigation/Surveillance (CNS) systems were analogue, the design for which were relatively simple and the amount of SARPs material required to ensure inter-operability in Annex 10 was manageable. However, with the introduction of digital technology from 1995 that uses data, employing advanced modulation scheme and signal processing has necessitated an explosion in the detailed and therefore pages in SARPs to ensure interoperability. For example, analogue VHF communication systems take up 11 pages in Annex 10 whilst VHF Data Link (VDL) systems require 30 pages in Annex 10 a manual for each of the 3 VDL modes.

3.2.2.2 Clear, simple and concise language, as called for by various past Assembly resolutions is inconsistent with the detail necessary to define these systems to be interoperable and implemented so that deviation from the standards is not possible. The issue is only going to get worse as the speed of technological change increases, including the introduction of integrated CNS systems, which are expected to require even more complex standards, generating new challenges for the standards making process, implementers and ultimately the State regulators.

3.2.2.3 With the introduction of new concepts such as unmanned aircraft, including remotely piloted aircraft and drones, has significantly increased the number of aircraft seeking access to airspace, the complexity of operations and inevitably the technological challenge. These new entrants to the market are used to the modern pace of change and are not necessarily expecting airframe lifecycles that are expected from current airframes and are therefore prepared to update technology on a far more frequent basis.

3.2.2.4 Additional a mechanism needs to be found by which equipment that has reached the end of its useful life can be decommissioned globally and its functionality can be replaced which is simpler and less costly to the industry. Without such a mechanism the number of systems fitted to an aircraft will continue to increase (current in excess of 33 antennae for C/N/S) at significant cost to the industry.

3.2.3 Competition between systems providing similar functions & variation in implementation

3.2.3.1 Through a lack of clear direction and decision making within ICAO and its panels and as a result of vested interests there have been cases where systems have been SARP'd because of regional differences in perceived requirements and/or competition between similar systems where the proponents of one system won't allow the other system to progress unless their system does as well. Such an approach has provided a toolbox of solutions from which States/regions can select but at a cost of moving away from the principles behind global harmonisation and minimum fit as aircraft flying between regions have had to equip with all systems. This has significantly delayed the SARP's process, increased the cost, delayed implementation, and lead to increasing regional differences in implementation.

3.2.3.2 This situation has not been helped by user groups such as the airlines, general aviation or the military becoming more cost conscious and demanding evidence that changes, including upgrades, to equipment are required and will provide a long-term benefit. Where a sector such as general aviation cannot see a benefit to themselves then they have increasingly sought clear justification as to why they need to make the change and sought cross-subsidisation to offset the cost then discussions of which have delayed further implementation

3.2.4 Pressure on spectrum

3.2.4.1 When ICAO was first formed the applications to which spectrum could be applied that we see today had not been envisaged and hence it was not a constraining factor on system design. Aviation being one of the first industries to realise its potential were able to gain access to sufficient globally harmonised, exclusive spectrum allocations to meet both its current requirements and assumed future requirements. Over the years aviation as been able to expand its spectrum access as necessary and largely has not had that access threatened by other industries due to the safety of life nature of its operations and hence aviation has become used to a relatively comfortable position with respect to spectrum usage where thoughts of spectrum efficiency have not necessarily been high on the design priority.

3.2.4.2 However, in the last 30 years, as spectrum has become a scarce and valuable resource, so radio regulators have started to challenge aviation about its spectrum needs and the efficiency with which it uses that spectrum. This has resulted in aviation being forced to take account of a more challenging spectral environment and consider the possibility of sharing existing spectrum not only with new aeronautical systems but also non-aeronautical systems that do not have the same safety-of-life mentality. As a result, the SARPs process has become more complex as one of the prerequisites for adoption is that any new system introduced into a frequency band used by an existing system is that compatibility between the two systems is proven.

3.2.4.3 Additionally concerns about the pressure on spectrum has meant that aviation has sought changes to the radio regulations to accommodate new concepts before those concepts have been proven to work or offer a benefit to aviation. This has had a detrimental impact on aviation's reputation n the radio regulatory framework for not implementing systems for which radio regulatory changes have been approved.

3.2.5 Regulatory framework

3.2.5.1 The regulatory framework, including certification, has hardly changed since its inception, and the associated timescales and cost at the time may well have been appropriate. However, advances in technology that have speeded up communication and experience with certification process would suggest that the standards approval process and certification can be streamlined, and timelines shortened, and costs reduced whilst maintaining the integrity of the process.

3.3 Required Solution

3.3.1 The issues identified in the equipment standardisation process indicate that not only are there issues that need addressing with the standardisation process but also in the whole design process from inception to decommissioning that if addressed could assist to minimise the time from inception of a system to its decommissioning. The scope of this document is the standardisation process, but consideration should be given to how other processes within the overall process could be streamlined and how interfaces with other parts of the process optimised. For instance, the standardisation process should only address a single solution to any approved requirement.

3.3.2 The standardisation process should either be presented with either a system to be standardised or a technical requirement for which a technical solution needs to be identified. Where a technical solution needs to be identified then prior to any standardisation work the solution needs to be identified and approved so that in either situation the standardisation process is only addressing one technical solution. In both cases the design will need to be mature enough that it can be standardised, have demonstrated that it is compatible with systems operating or intended to operate within or adjacent to the selected frequency band and be cost effective.

3.3.3 Having identified the technical solution to be standardised the process should then identify any changes to the radio regulation that may be required and establish Global Technical Specifications (GTS) that all legitimate aeronautical stakeholders have had a chance to contribute to, comment on and approve at the relevant level.

3.3.4 GTS are intended to provide a clear aeronautical regulatory framework that will ensure global inter-operability/harmonisation and through which technical specifications can be defined at the appropriate level(s) and made globally enforceable. For States they can be referenced in national regulation and by demonstrating compliance will support the States safety case. However, the main aim of the technical specifications against which radiocommunication equipment manufacturers can design products and airframe manufacturers/air navigation service providers can purchase equipment.

3.3.5 Accepting the principle of GTS as a concept is simple however, it does raise several practical problems that need to be addressed:

- Scope of the systems to be considered
- Whether a hierarchical framework is required and if so, how do the levels inter-relate
- The level of detail required in each
- Who is responsible for developing what?
- What is the approval process?

3.3.6 Scope of the systems to be considered

3.3.6.1 SARPs addressed systems, both airborne and ground, where inter-operability between different pieces of equipment is required at a level of detail sufficient to ensure that interoperability. MOPS and MASPS on the other hand have focused on the detail specification of airborne equipment. This has left national or regional organisations to develop standards for ground-based equipment where there is no need for inter-operability or no suitable standards exist in ICAO/EUROCAE/RTCA.

3.4 Potential Options for Implementation

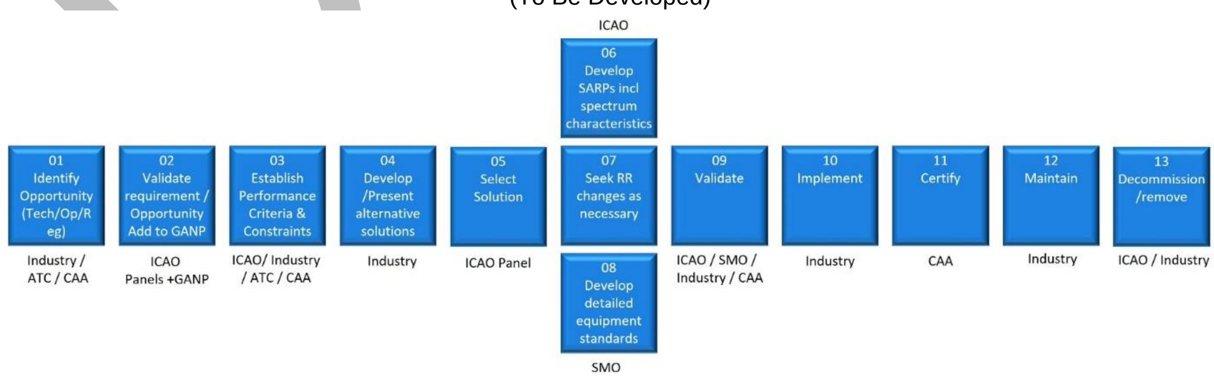
(To Be Developed)

3.5 Proposed Method to be Implemented

(To Be Developed)

3.6 The Solution and how to implement it

(To Be Developed)



Chapter 4 Conclusions/Way Ahead

(To Be Developed)

Appendix A Framework Analysis

The following sections provide the findings of that analysis.

A. 1 Analysis 1: Existing SARPs and supporting ICAO provisions relevant ICAO document framework

A.1.1 The establishment and maintenance of international Standards and Recommended Practices (SARPs), as well as Procedures for Air Navigation Services (PANS), are fundamental tenets of the Convention on International Civil Aviation (Chicago Convention) and a core aspect of ICAO's mission and role. SARPs and PANS are critical to ICAO Member States and other stakeholders, given that they provide the fundamental basis for harmonized global aviation safety and efficiency in the air and on the ground, the worldwide standardization of functional and performance requirements of air navigation facilities and services, and the orderly development of air transport. Today, ICAO manages SARPS with over 12,000 provisions across the 19 Annexes and six PANS to the Convention, as well as regional supplementary procedures, technical manuals, air navigation plans and circulars many of which are constantly evolving in concert with latest developments and innovations. This process is outlined in several documents published by ICAO. The following table summarizes the process and references the appropriate documents where applicable (refer also to the figure for hierarchy of the ICAO technical documents).

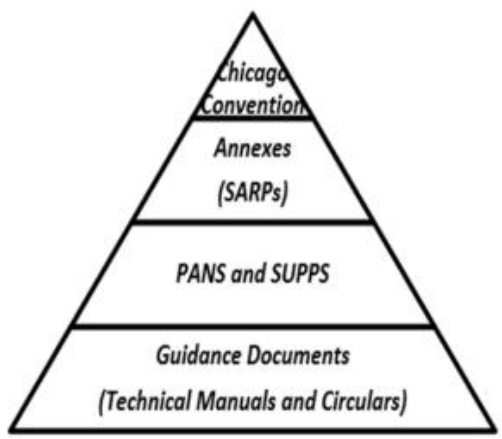


Figure A-1 Hierarchy of regulatory status of ICAO technical document

Table A-1 ICAO technical documents	
SARPs	SARPs are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation as well as of environmental protection.

PANS	PANS are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as SARPs, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome. PANS do not have the same status as the Standards and Recommended Practices. While the latter are adopted by Council in pursuance of Article 37 of the Convention on International Civil Aviation, subject to the full procedure of Article 90, the PANS are approved by the Council and recommended to Contracting States for worldwide application.
SUPPS	Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain procedures apply to overlapping regions or are common to two or more regions.
Technical Manuals	Technical Manuals provide guidance and information in amplification of the SARPs and PANS, the implementation of which they are designed to facilitate.
Air Navigation Plans	Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared under the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.
Circulars	ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

A.2 Analysis 2: History of the initiative towards Performance-Based Standards

A.2.1 In the field of air navigation, performance requirements have long been an important aspect with an ever increasing emphasis being placed on this. During the past 20 years this issue has been debated intensely within ICAO. The outcome has been a shift in the focus of its resources, to prioritize assistance in the implementation of existing standards rather than development of new standards, and to develop performance-based standards rather than detailed technical specifications.

A.2.2 ICAO's increased focus on performance-based standards is clearly illustrated in the outcomes of several ICAO fora, including the ICAO Council. Several relevant Assembly resolutions also indicate this outcome. The following table summarize relevant discussions and assembly resolutions.

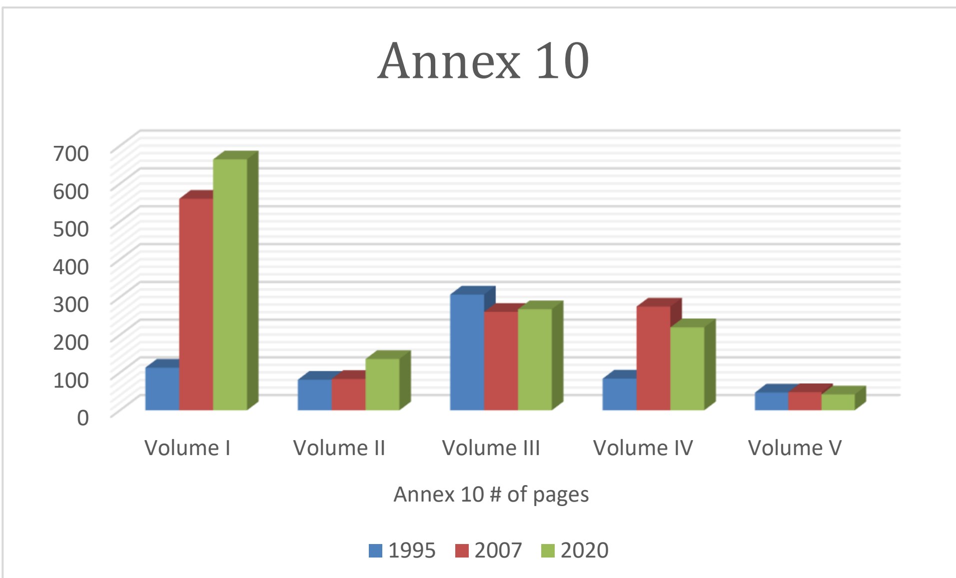
Year	Table A-2 Discussions and assembly resolutions related to the initiative towards performance-based standards
2001	The 33rd Session of the Assembly resolved that Standards and Recommended Practices (SARPs) should, inter alia, specify performance requirements (Resolution A33-14, Appendix A, operative clause 3)
2004	The 35th Session of the Assembly reaffirmed and strengthened this policy in Resolution A35-14 (Appendix A, operative clause 3).
	In addition, resolution A35-15 urged that necessary steps be taken to ensure that the future global ATM system is performance-based and that the performance objectives and targets for the future system be developed in a timely manner.
2006	At the Directors General of Civil Aviation Conference on a Global Strategy for Aviation Safety (DGCA/06), among the outcomes of the conference, there was Recommendation 3/1 d) 3), which called for ICAO to "develop criteria for determining which Standards are of critical importance for ensuring global safety and for which notifying differences would be acceptable only exceptionally and which Standards are of a detailed technical nature and should be changed into Recommended Practices or removed from ICAO Annexes and turned into guidance material". This

	recommendation was made due to 1) low implementation/compliance rate to Annexes recognized by audit outcome and 2) difficulty to understand and comply with detailed requirements for many States developed and adopted by ICAO. On 15 June 2006, the Council agreed with this recommendation and directed the Air Navigation Commission to study means of implementation.
2007	Responding to Council's directive, the Commission studied the subject and presented its recommendations to Council on 20 June 2007, having concluded that identifying a set of safety critical Standards for which notifying differences would be acceptable only exceptionally could be misleading and counter-productive. However, the Commission identified measures that could be taken to meet the intent of the DGCA/06 recommendation through establishment of multi-disciplinary working group; the following problem statement was presented at the council in September 2007 and at the 36th session of the Assembly in 2007. *Problem statement presented at the 36th session of the Assembly in 2007* *Universal Safety Oversight Audit Programme (USOAP) audits have confirmed a significant level of non-compliance with Standards and Recommended Practices (SARPs). Most of the 11 000 SARPs contained in the ICAO Annexes are prescriptive in nature and provide little flexibility with respect to their application. The remaining SARPs, generally the most recent ones, are performance-based. Every SARP has an impact on the safety, security, regularity and/or efficiency of international air navigation. However, the absence of an explicit hierarchy between the various safety Standards adds to the difficulties of prioritization and implementation, especially for States with limited resources. In addition, the Convention makes it possible for States to deviate from Standards provided that they file differences to ICAO, potentially undermining global safety, harmonization and the principle of mutual recognition.*
	At the 36th Session of the Assembly in 2007, further relevant discussions took place. In particular, the following summary of discussion by the Technical Commission should be noted. Also, after the discussion on this matter, the 36th session of the Assembly agreed to amend Clauses 3 and 4 of Appendix A to Resolution A35-14. *Summary of discussion at the 36th Session of the Assembly* *With respect to the proposed amendments to Resolving Clauses 3 and 4 of Appendix A to Resolution A35-14, several concerns were expressed by a Contracting State relating to the removal of the text "any technical specification necessary to achieve these requirements shall be appendices to Annexes"; to the placement of supporting technical specifications in separate documents; and to the legal validity of the procedure whereby Council would have to approve material developed by other standards-making organizations as meeting ICAO requirements. The Commission was reassured by the Secretary that the intention was to strengthen the recent urging by the Council for SARPs to be performance based and less technically oriented; and, in light of budgetary cuts which would take effect from the beginning of the next triennium, to avoid duplication of effort and to determine how ICAO and technical standards-making organizations could best support each other's work.*
2005-2007	When the Council discussed the reports on adoptions of Amendments to Annex 10 and performance-based standards, a number of issues related to Annex 10 were discussed. Salient points from those discussions are as follows,
	The Council emphasized the need to implement Assembly Resolution A35-14, Appendix A, Operative Clause 3, which specified that SARPs shall consist of broad, mature and stable provisions and that any related detailed technical specifications shall be placed in separate documents.
	Despite Assembly Resolution A35-14, Appendix A, Annex 10 was increasing in size; The Council should invite the ANC to set out a plan to rationalize Annex 10, perhaps by separating the optional (opt-in) Standards from the mandatory ones and incorporating them in a technical manual. The Council should clearly indicate that Annex 10 could not continue in its current form and leave it to the Secretariat and the ANC to determine the best way of rationalizing it.
	The President of the ANC noted that the Commission was fully aware that there was future work to be done regarding the restructuring of the Annexes. It had to consider what was practical versus what was possible, taking into account legal advice. Underscoring that the ANC was moving towards performance-based Standards, it was indicated that some 300 pages had been removed from Annex 10 in 2007. The President of the ANC assured Representatives that the Commission would be working with them and the Secretariat in carrying out that difficult task.

2007-2010	The ANC and the Secretariat attempted to progress the rationalization of Annex 10, using the guidance of Assembly Resolution A36-13 as basis. A significant aspect of this work was an effort to fully interpret and implement clause 4 of A36-13, describing the use of a verification and validation process when accommodating the work of other standards making organizations (SMOs) in ICAO SARPs and associated guidance material. However, the lack of a well-established framework and processes has hampered its rationalization. In this context, reference is made to Table 1, which indicates the transition of a number of pages from Annex 10 into guidance material. As Table 1 illustrates, as a result Volumes III, IV and V were slightly reduced, while Volumes I and II continued to increase in size.
2010	There was little discussion on this subject at the 37th session of the Assembly, in 2010. Some modifications were made to A36-13, the resulting modified resolution being A37-15. However, no changes of substance were made to A37- 15 Appendix A clauses 3 and 4.
2013	The 38th session of the Assembly made a complete overhaul to the structure of A37-15, which now became A38-11. However it is important to note that no significant changes were made to the contents of A37-15 clauses 3 and 4.
2016	The 39th session of the Assembly (2016) saw little discussion on the subject, but some changes were made to other clauses, this resulting in the new resolution A39-22.

Note- Resolution A33-14, A35-15 and A39-22 are included in Appendix B of this document. A35-15 and A39-22 are still in force as of 40th session of the Assembly in 2019.

Table A-3 Number of pages included in Annex 10



A.2.3 **Observations drawn from Analysis 2**

1) During the past 20 years, ICAO has shifted its focus from detailed technical SARPs to performance-based SARPs. This is relevant for all areas of SARPs.

2) The Council has had extensive discussions on the difficult task to "develop criteria for determining which Standards are of critical importance for ensuring global safety and for which notifying differences would be acceptable only exceptionally and which Standards are of a detailed technical nature and should be changed into Recommended Practices or removed from ICAO Annexes and turned into guidance material".

3) Although significant efforts were made to reduce the page count of Annex 10 in 2007 by hundreds of pages, subsequent Assembly and Council sessions keep asking for further rationalization of SARPs, especially related to the detailed technical provisions contained in Annex 10.

4) A broad definition of performance based SARPs and their supporting technical provisions has been agreed at recent Assemblies, as illustrated in A36-13 (current A39-22). However, the lack of a well-established process has hampered its rationalization.

A.3 Analysis 3: Study undertaken by SAE International in 2012 to identify the performance and technical specifications contained in Annex 10

A.3.1 As referred to in section A.2, during the past 20 years, ICAO has made an effort to shift to performance-based SARPs and by so doing, to rationalize Annex 10. To assist with those efforts, in 2012 ICAO contracted SAE, to undertake a study to identify the performance and technical specifications contained in Annex 10 and to suggest alternatives for separating performance specifications from technical specifications.

A.3.2 A key conclusion from the SAE study was as follows.

1) Some of the material in the five Volumes may be retained as ICAO Annex 10 material, but a significant amount of information may be amalgamated into existing ICAO Manuals, or may be deferred to other organizations that provide similar material that may, in fact, be references that are presently in the Annex.

2) Recommendations are offered on the options that may be appropriate for the technical specifications, such as:

   a) Publish technical specifications as guidance material in ICAO Manuals;

   b) Incorporate content into globally accepted industry standards;

   c) Publish as ICAO Technical Instructions;

   d) A hybrid of two or more of the above options.

A.3.3 Before reaching the conclusion of the SAE study given above, the SAE study took account of several important factors, which from the ICNSS TF's perspective should be taken into account for considering the CNSS standards task.

1) **ICAO Universal Safety Oversight Audit Programme(USOAP) and associated Protocol Questions (PQ) on Annex 10 topics**

- The USOAP assesses and verifies States' capabilities in performing safety oversight of its aviation system. This includes the assessment of compliance with Articles 37 and 38 of the Chicago Convention on filing of differences to ICAO standards. As part of the USOAP States should complete and maintain up-to date its Safety Oversight Compliance Checklist (SOCC). The SOCC, which was developed to examine the standards in Annex 10, included more than 700 pages of material. It is a reflection of the size and complexity of Annex 10. A correctly completed SOCC offered benefits both to ICAO and to States using a single vehicle for documenting the status of their implementations of Aeronautical Telecommunications services.

  Note –After 2013, in line with the relevant assembly resolution in force (originally A38-11 and A39-22), instead of SOCC, a State is to regularly review and complete its Compliance Checklist/Electronic Filing of Differences (CC/EFOD). The CC includes more than 5368 pages related to Annex 10. The EFOD differs from the CC in that it is an electronic means for States to notify ICAO of their differences.

- It was questioned, however, whether the magnitude of the SOCC that was directly proportional to the complexity of Annex 10 caused a burden to States' administrative resources. In particular, for States that do not have State-operated air navigation service delivery but rely on others, it may be difficult to meet the requirement to complete the SOCC.

  Note.- The statement above indicates issues studied in 2012 regarding the SOCC, especially in relation to Annex 10. It is important to note that current practice is different, as ICAO has since transitioned to use CC/EFOD instead of SOCC.

- USOAP activities include interviews between auditors and State representatives to verify the application of the critical elements of the State safety oversight system. During such interviews the auditor assesses the status by use of protocol questions (PQ) which are designed as a means to sample States implementation of the eight critical elements of the safety oversight system. Most of the PQs relating to Annex 10 are contained in the PQ checklist for Air Navigation Services (ANS). Unlike the comprehensive SOCC for Annex 10, there were four PQs at that time referred to compliance with the requirements of Annex 10. It is important to note that this protocol was not developed for an in-depth examination of systems, equipment and software for compliance with the full suite of Annex 10 requirements, but rather to assess the oversight capabilities of the State by means of sampling.

  Note.- The statement above indicates issues studied in 2012, regarding the number of PQs related to Annex 10. It is important to note that several updates have since been made to the PQs and the current practice may be different from the statement above.

2) **State regulations**

An examination of several States' regulations which demonstrated compliance with Article 37 was conducted as part of the Study. These States incorporate the requirements of Annex 10, in part or in whole, by reference in their domestic regulations. Most also include their own specific technical requirements that may characterize the local operational environment. In 2012, the most concise and dependent on Annex 10 was Canada's CAR-802.

The absence of Annex 10 standards would cause gaps in or complete loss of domestic regulatory standards. The point of discussion here may be to what minimum level of detail and complexity should be in the Annex, considering the practical application of its contents for regulatory and auditing purposes.

3) **Equipment Acquisition and Service Provision**

It is not possible to construct equipment or write computer code based solely on Annex 10, nor would it be possible to use the Annex on its own as an operations manual. States may rely on Annex 10 to furnish some specifications for the acquisition of systems and services. Manufacturers and service providers make use of their own interpretations of many technical requirements and on the design and implementation standards of other bodies to design, manufacture, and operate aeronautical telecommunications equipment and systems. No single document can be used in isolation.

To enable an air navigation service, States and service providers must take into consideration standards and requirements for health and safety, environmental protection, radio frequency emissions, electrical equipment, building codes, and so on. Air navigation service performance requirements are influenced by national policies, international treaties and agreements, and the needs of customers including air carriers and aerodrome operators. The complete details of services and equipment are found in a range of technical documentation, including Annex 10.

4) **Protection of Aeronautical Telecommunications Spectrum**

The International Radio Regulations include provisions for aeronautical telecommunications services. The use of radio frequency emissions by systems and services that are elements of Annex 10 is governed firstly by the International Radio Regulations, then by State radio regulations, then by the provisions of Annex 10 via the Convention on International Civil Aviation and corresponding State aviation regulations in accordance with Article 37 and Annex 10.

Realizing that the radio frequency spectrum is a resource with many suitors, the protection of aeronautical spectrum allocations is a primary consideration. Frequency planning and utilization standards are contained in Annex 10 and should be used by all Contracting States. However, transmitter & receiver spectral masks, on which frequency protection is based, are not consistently defined within Annex 10 for all safety of life system. Retention of spectrum related provisions and their extension to include spectral masks in Annex 10 is considered to be essential.

In deference to the hierarchy of regulations - International Radio Regulations, State radio regulations, State aviation regulations – States must have available the tools to protect aviation spectrum including Annex 10 and the corresponding guidance contained in the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation* Including statement of approved ICAO Policies (Doc 9718).

A.3.4 **Potential unintended consequences of the reorganization identified in the SAE Study**

A.3.4.1 In addition to the points raised in section A.3.3, the SAE study also identified a number of potential unintended results which may be caused by a reorganization of the material in Annex 10. It may be the intent to focus the SARPs on the most stable, concise, and essential system-level descriptions of aeronautical telecommunications, but the extraction of large amounts of information may cause concerns in several areas. Some potential issues are described in the following table.

Table A-4 Potential issues

Governance.	The definition of governance as the act of establishing a law, rule, standard or principle is particularly applicable to the present study. It is the nature of Annex 10 to ensure that the technical material is so comprehensive as to enable a particular implementation or technology while prohibiting others that would not meet the international requirements. The Convention on International Civil Aviation, whereby States have “agreed on certain principles and arrangements”, provides direction in Article 28, Air navigation facilities and standard systems. States undertake to “Adopt and put into operation the appropriate standard systems of communications procedure, codes, markings, signals, lighting and other operational practices and rules which may be recommended or established from time to time, pursuant to this Convention.” Article 37, Adoption of international standards and procedures, provides direction on the application of SARPs to ensure a uniform set of regulations, standards and procedures. This approach has laid the foundation for international standards that may exist as rules of a State, incorporated by reference in domestic law, or that may be incorporated in a larger body of domestic rulemaking, all associated with the State’s commitment and obligations under the Convention, and subject to verification under the ICAO Universal Safety Oversight Audit Programme. This chain of governance derives some strength from the comprehensive nature of Annex 10. To reduce or eliminate technical details may give rise to more subjective interpretation and varying implementations, and greater difficulty to measure system performance and compliance with the spirit of the Convention.
International utilization	The availability of one document containing international standards, which constitute the rule of law through the ICAO Convention and form a regulatory framework for aviation ensures the harmonized CNS systems. That is, while a number of manufacturers provide equipment for both the ground-based and airborne components that make up the aeronautical telecommunications system, all implementations would be designed, fabricated and operated to comply with the SARPs. Global full implementation of a particular standard may not be required by a Region or a State, one example being the operational use of 8.33 kHz channel spacing for VHF communications, although such channel spacing is specified in SARPs. Comprehensive SARPs will provide all States and industry with transparency. The international operation of commercial aircraft will remain a driving market force with respect to the application of the SARPs. Operators are accustomed to the requirements for carriage of certified equipment and expect to receive a consistent, minimum level of air traffic services. A set of standards that is not applicable in all contracting States and that does not impose a singular

	implementation may give rise to other solutions. It may be argued that other technologies are more readily available at a much lower cost than SARPs compliant and State certified equipment. Domestic or regional implementations of non-standard equipment and systems would not meet the operational needs of the international fleet.
Use of other standards.	This SAE study has identified a number of standards, from other bodies, that are closely associated with the SARPs. These standards support the SARPs and in many cases were developed in parallel with the drafting of the SARPs, by the same groups of technical experts. There is, however, a somewhat narrow focus when considering the following. The major aircraft manufacturers, the major avionics and ground system manufacturers, the largest air carriers, and the hosts of most of the other standards are concentrated in Europe and North America. A reorganization of Annex 10 to defer the international requirements to organizations that are not fully recognized as international standards bodies at a global level may be perceived to promote some Regions or States over others. Also, given that these organisations do not have the same governance arrangements this would remove control of potentially key parameter away from ICAO and leave them in the hands of national/regional bodies that could result in clashes in requirements. This could threaten efforts to achieve globally harmonized standards. Nevertheless, it is recognized that the relevant standards making organizations (SMO's) are proactively working to ensure their processes are as open and transparent as possible and globally inclusive. However, action being taken to improve co-ordination between ICAO and the SMO's will minimize the risk of variances between relevant documentation.
Gaps in State regulations.	This SAE study has pointed out that some States rely to a great extent on the SARPs to be elements of their domestic regulatory regimes. Annex 10 may be considered as a foundation, a base of minimum requirements and specifications, upon which States build their sets of rules. To minimize or eliminate parts of that base would cause gaps in the foundation and a weakening of the regulatory regime. State administration requirements in the absence of SARPs. States and regional entities would be required to put into place more comprehensive rules to replace the SARPs. The task to prepare, refine, consult and implement such material would be extensive, both in the time required and the financial costs to undertake and could lead to conflicting requirements between States. In the end, to accommodate the international fleet, a multitude of standards (to be developed by States and regional entities) would be required to replace the single document of ICAO SARPs that is presently available.
Future-proofing.	To future proof, to anticipate future technological developments, to minimize negative consequences, and to seize opportunities, is a desirable approach. Based on the historical advancements in aviation, it is reasonable to anticipate a future scenario in two ways. Firstly, new implementations of existing technologies may appear, such as a transition from “ground-based” to “space-based” CNS service provision from one side and full transition from “analogue” to “digital” from another side. Secondly, new technologies may appear, such as optical communications to supplement or replace traditional technologies. It may be observed that a reality in the development and adoption of SARPs is the non-technical, perhaps “political” nature of the discussions. That is, whether an operational need has been identified that requires supporting technology, or technology has been developed that requires an application, there may be underlying strategic factors that influence the development of the material. Commercial or State interests may influence decisions along the pathway from concept to design, from validation to implementation. Nonetheless, the collaborative nature of SARPs development does result, in most cases, in agreement. Considering these points, the expectation that more material will be proposed for Annex 10 as time advances, and the traditional process of SARPs development with its detailed specifications and consensus approach, it may be preferable to “stay the course.” Noting that as older systems are phased out those SARPs will be

	removed.
Practical effects.	For ICAO to propose a significant restructuring of Annex 10, in deference to its member States, some level of consultation and coordination would be in order. To follow the traditional route, proposals to amend Annex 10 would be tasked to the various ANC Panels of Experts. The ensuing debates would, no doubt, be extensive. Based on past experience, a major restructuring of Annex 10 in this way could take five or more years. For States and regional organizations, and other standards bodies, a significant review of their standards, guidance material, certification and approval methods would be required. The time and costs required for such an exercise cannot be predicted, but would, intuitively, be significant.

A.4 **Analysis 4: The issue of Interoperability**

A.4.1 Throughout this document the discussion on the high-level SARPS has revolved around the need for SARPS that satisfy the requirements of Assembly Resolution A35-14 and those Assembly Resolutions succeeding it, to; consist of broad, mature and stable provisions specifying system-level, functional and performance requirements. These statements have also been accompanied by others asserting the need for SARPS to maintain “Interoperability”. The need for interoperability is not however universal. In some cases where interoperability (between service providers) was not an essential requirement, progress has been relatively prompt, as in the case of PBN. The need for interoperability has in other cases sometimes presented an obstacle, as has occurred with Data Link. The ICNSS TF recognized the need for clarifying the meaning of “interoperability”. This section will explore the subject of interoperability and the reasons why and when it would be required.

A.4.2 **Areas of Differentiation:**

A.4.2.1 For the purposes of this section, interoperability will be considered as the property of CNS systems that allows an aircraft to operate globally using the same systems, processes and procedures. This will not however cover those parts of applications which are operationally driven, such as message sets, etc.

A.4.2.2 The need for interoperability is brought about by the fact that for a given service there may be different solutions that may be used however they may not be interoperable. This document has identified three areas of differentiation where the need for interoperability may arise. These are shown below with some simple, yet typical examples. Readers will note that the same circumstances could be the result of multiple areas of differentiation.

A.4.2.3 It is also important to note that the concept of integrateability is introduced. This is the process where two non-interoperable services can be integrated to appear as once service. This is usually done via some external specialized processing or a third-party service provider.

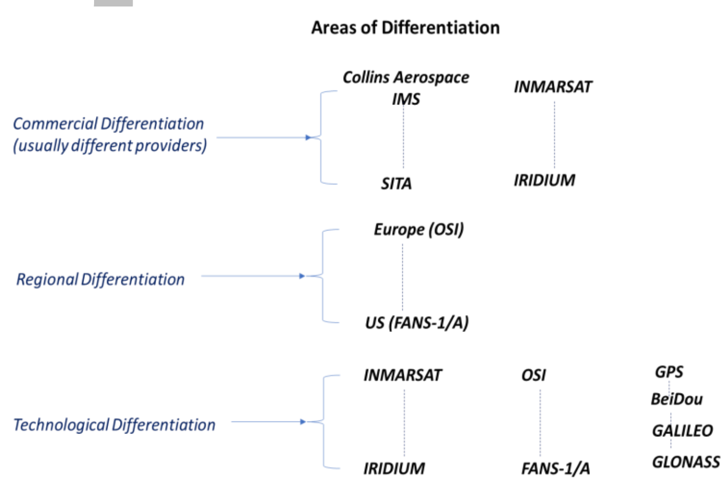


Figure A-2 Areas of Differentiation

Table A-5 Descriptions of the areas of differentiation	
Technical Differentiation	This is the most straightforward case and occurs when different technologies are used to provide, what is operationally, the same or similar service however these technologies are not compatible nor interoperable. This can be resolved through the use of gateways which are generally used as a temporary solution or the use of third-party service providers who can act as service integrators. An example of the latter is the use of Communication Service Providers who can provide access to the Iridium and INMARSAT services via a single connection.
Commercial/ Operational Differentiation	Commercial differentiation can result in a user being denied access to given service, unless they have a contract or agreement with the provider. Commercial barriers can be resolved by applying institutional measures such as regulations that prevent the blocking of safety-related traffic. Operational differentiation, on the other hand, occurs when a user requires configuration or qualification by the provider in order to obtain access to the service.
Regional Differentiation	This form of differentiation usually occurs when different solutions are used to provide a given service in different regions. It can also be the result of commercial differentiation but in a form that (for example) foreign carriers find hard to accept. Although regional differentiation is really a manifestation of technical or at times commercial differentiation, it is mentioned here as it is a term commonly used to describe the lack of interoperability between regions.

A.4.3 Decision Table:

A.4.3.1 Given below is a generic table showing how a determination can be made as to whether performance-based SARPs alone are adequate or whether they need to be supported by provisions ensuring interoperability. To achieve this, basic questions are asked to determine whether examples of the above forms of differentiation exist.

A.4.3.2 This table supports the introduction of a new CNS technology or service. This was chosen as it reflects the reality that the aviation community will be facing, as we already have a fully functioning CNS/ATM system however it is constantly being augmented and expanded. The choices in the table relate to a new system or service, not the extension or of an existing service which may or may not be governed by a mandate.

A.4.3.3 As the table is generic by nature, it will be more helpful to review the areas of differentiation using a number of representative scenarios. The chosen scenarios are as follows:

Table A-6 Scenarios selected for the analysis
Scenario 1 – Independent (Beacon-like) service This scenario involves a beacon-like service being provided directly to an airspace user, where the same signals are transmitted to all users. This is considered an independent[1] service as end-users must process this signal to derive information such as distance or position. The ideal example of this is GNSS, where a constellation of satellites transmits signals which are received by an airspace user who can derive useful information from them. In reality, a substantial organisation is needed to operate and support the satellite constellation but this does not directly interact with the user. Similar examples are navigation beacons and visual aids. Another distinguishing feature is that the number or type of users does not usually directly affect the service.

[1] DO-242A: Minimum Aviation System Performance Standards (MASPS) for ADS-B

Scenario 2 – Service provides a *Direct Connection between Two Parties*

In this scenario, the facilities of one or both of two parties are used to provide a direct connection between the parties. An ideal example of this is standard VHF radio service used to provide a connection between pilots and air traffic controllers. Other examples include cooperative dependent surveillance systems such as SSR and ADS-B. In practice the provision of the service may be contracted out to a service provider however the choice of service, the geographic reach and the quality of service are dictated by the contracting party.

Scenario 3 – Service provides a *Connection between Two Parties via a Third Party*

This scenario is somewhat opportunistic as it involves the use of an existing service offered by a third-party which can solve all or part of an operational need. In such cases, the geographic reach, the choice of technology and quality of service is dictated by the service provider. In certain cases the contracting party can dictate changes to any of those parameter sets however the general performance envelope is unlikely to change.

Table A-7 Whether performance-based SARPs alone are adequate or whether they need to be supported by provisions ensuring interoperability.

			DIFFERENTIATION	
		Technical	Commercial/Operational	Regional
Independent Service	Global	N/A – however performance-based standards should be adequate.	Possible, hence provisions in the form of SARPS needed to ensure the carriage of safety-related traffic	Unlikely however provisions in the form of SARPS needed to ensure the carriage of safety-related traffic
	Local	Standards needed to ensure interoperability and performance.	Possible, hence provisions in the form of SARPS needed to ensure the carriage of safety-related traffic	Unlikely however provisions in the form of SARPS needed to ensure the carriage of safety-related traffic
Direct Connection between Two Parties	Global	Unlikely scenario	Unlikely scenario	Unlikely scenario
	Local	Standards needed to ensure interoperability and performance.	Possible, hence provisions in the form of SARPS needed to ensure the carriage of safety-related traffic	Standards needed to ensure interoperability and performance.
Connection between Two Parties via a Third-Party	Global	The use of a service integrator. Technical standards needed to ensure the consistent function and performance of the service “bundle” Sub-allocation of performance standards at each stage of the system chain to ensure consistency of performance and between contractual agreements.	Possible, hence provisions in the form of SARPS needed to ensure the carriage of safety-related traffic	Technical standards to ensure the consistent function and performance of the service “bundle” Sub-allocation of performance standards at each stage of the system chain to ensure consistency of performance and between contractual agreements.

	Local	The use of a service integrator and the ground infrastructure necessary to ensure non-discriminatory access to all safety services. These will require technical standards for the service "bundle". Sub-allocation of performance requirements at each stage in the system chain to ensure consistency of performance and between contractual agreements.	Possible, hence provisions in the form of SARPS needed to ensure the carriage of safety-related traffic	The use of a service integrator and the ground infrastructure necessary to ensure non-discriminatory access to all safety services. These will require technical standards for the service "bundle". Sub-allocation of performance requirements at each stage in the system chain to ensure consistency of performance and between contractual agreements.

A.4.4 Analysis using the Table

A.4.4.1 Before beginning the analysis let's examine the peculiarities of each scenario above, especially in the light of the various areas of differentiation.

Table A-8 Explanation of Scenario 1 – Independent (Beacon-like) Services.

Some independent services can be considered global or near-global, such as the GNSS Services; GPS, GLONASS, GALILEO and BeiDou. Although the various GNSS services are not strictly-speaking interoperable[2], the fact that they are independent and global, does away with the need for ICAO provisions on interoperability, hence performance-based standards may be adequate. In such cases Regional differentiation is unlikely to occur.

Other independent services can be considered local, such as navigation beacons and aids or visual aids. In such cases regional differentiation is possible as happened with MLS deployment in certain countries in the past.

The next thing to consider is commercial/operational[3] differentiation. Can the service be blocked to those not paying a fee or signing a contract? This could be possible with any independent service but has not yet occurred[4]. Nonetheless commercial/operational differentiation is a possibility.

In summary, independent services which are global are unlikely to have problems due to technical or regional differentiation however there are two possible negative outcomes:

a) Commercial differentiation could be applied (with the possibility of this being regionally applied). For safety-critical communications, this would need to be dealt with through provisions in the form of SARPS, guaranteeing non-discriminatory access for safety-related traffic/signals.
b) Lower equipage rates may limit utility however this is generally a local concern. In such cases new procedures based on the capability may only be implemented once equipage reaches a critical mass or they may be applied on best-equipped/best served basis providing an incentive for equipage.

Independent services which are local in nature, are quite likely to require standards to ensure interoperability (according to the definition used in paragraph 1.3.7.2.1 above). This is because technical and by extension regional differentiation could occur if States and/or Regions select different systems for their infrastructure. For independent systems, the use of a service integrator is not an option, hence aircraft would need to carry multiple systems in order to operate globally. This is clearly an unfavourable outcome in the near to midterm; however in the longer term, it is hoped that software-defined, "agile" systems could overcome this problem.

[2] Multi-mode avionics (with an operating mode for each service) could achieve interoperability.
[3] Commercial differentiation would not apply to services provided by States – as with the GNSS Services today.
[4] Blocking could be achieved by encoding, as was done with high precision GPS in the past.

Both global and local independent services will be prone to the problems described in points (a) and (b) above.

Table A-9 Explanation of Scenario 2 - Direct Connection between Two Parties
Technical differentiation can certainly exist in some cases. There are different versions of ADS-B which have been mandated in certain regions leading to regional differentiation. Similarly whitelists have been applied to the use of VDL Mode-2 in Europe, to block aircraft not meeting the required levels of performance. As direct services are generally provided by an ANSP or a contractor to an ANSP, global services are unlikely and hence it would be unusual for commercial differentiation to occur.
In summary, Technical differentiation (leading to regional differentiation) could be a problem for international aviation, therefore standards would be needed to ensure backward compatibility of new or updated systems. These provisions would cover such things as the characteristics or signals in space and any external interfaces. Commercial differentiation would be unlikely as the ANSP (or an entity contracted by the ANSP) would be the provider of the ground infrastructure concerned and would likely act in the interests of safety.

Table A-10 Explanation of Scenario – Connection between Two Parties via a Third Party.
There is potential for technical differentiation at all points in the equipment chain, avionics, ground infrastructure and interface to the ground (ATSU) systems. As with other scenarios this could lead to regional differentiation. The first example to be dealt with would be the case of Iridium and INMARSAT who are satellite service providers, offering a global and near-global service respectively. These are soon to be joined by the operators of LEO systems. In each case these services use very different technology, which in turn requires different avionics. Nonetheless, the situation with this scenario is similar to that of independent global services. That is, they may be technically different but can co-exist however in this case a service integrator is needed. To avoid the need for ANSP to make different contractual, technical and operational arrangements in order to accommodate the choices (as opposed to needs) of all airspace users, this responsibility is passed on to a service integrator. Today this role is performed by the Communications Service Providers, who can provide an ANSP access to a number of services via a single connection (and service contract). Should the use of dissimilar technologies be discouraged or even prevented through the adoption of a single technical standard? In this case no, as the use of dissimilar technology can provide system robustness and fill service gaps. This occurs today as some aircraft carry both Mobile satellite and HF voice and data or in some cases, both INMARSAT and Iridium satellite avionics. What is therefore needed is a set of technical standards and provisions that dictate how the service "bundle" shall function and perform in order to meet the overarching operational requirements. Broad technical standards will also be necessary to prevent a proliferation of technology choices and ensuring consistency of service. Performance standards will also be necessary at all stages in the system chain, in order for systems at each stage in the chain consistently. Commercial differentiation between service providers must also be limited to prevent the blocking of any safety-related exchanges. As with the other scenarios, provisions in the form of SARPS will be required for this. Regional differentiation for global services was discussed above under technical differentiation. For local services, the situation regarding technical differentiation is somewhat different. Although the use of a service integrator would also be necessary for local terrestrial services. Provisions must be in place to ensure this, or else certain airspace users may be denied access to (safety-related) services or be forced to carry and use different equipment depending on the FIR that they are operating in. This in turn leads to two possible sub-scenarios:

a) Institutional and technical standards to ensure that where a dissimilar (and non-interoperable) technology is used for terrestrial facilities, a service integrator and any necessary ground infrastructure is available.

b) The adoption of a single (or reduced set of) global technical standard(s) to provide the required service.

In summary: Global services providing connection between two parties via a third party will require the use of a service integrator if technical differentiation has been allowed to occur. The resulting "service bundle", will need to be governed by technical standards and provisions to ensure consistency of function and performance. Performance requirements will require sub-allocations at each stage in the system chain.

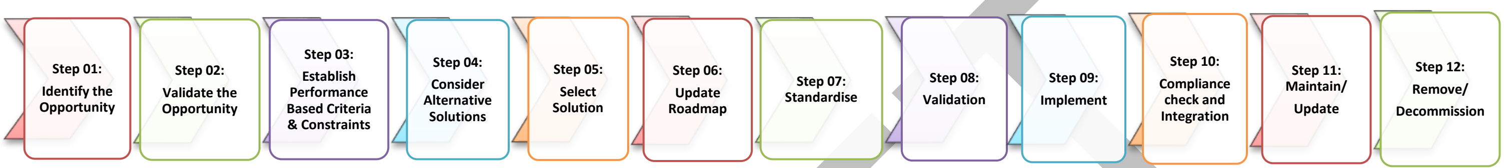
For local services, technical and hence regional differentiation if allowed, will require a service integrator and the necessary ground infrastructure to ensure non-discriminatory access to all safety services. These too, will require technical standards for the service bundle and the sub-allocation of performance requirements at each stage in the system chain.

For all services provided via a third-party commercial differentiation will require high-level provisions in the form of SARPS to prevent the blocking of any safety-related traffic.

Appendix B
Design Process from Inception to Implementation

1) Rationale and need for the process.
2) May include section on prescriptive vs performance-based standards
3) How and when to apply the process.

B.1 THE ENTIRE PROCESS DESCRIBED IN THIS APPENDIX



B.1.1 Successful selection, adoption and implementation of any integrated CNSS technology is highly dependent upon comprehensive evaluations, careful validation and robust deployment planning. The success of these activities entails clear and common understanding of operational expectations, technical possibilities as well as willingness and readiness of aviation stakeholders to invest in and adopt such technologies.

B.1.2 In this Appendix, a 12 step methodical approach is provided to describe the Design Process from the inception phase to the implementation phase. This Appendix also provides discussion related to each of those 12 steps, all of which together constitute a high-level guidance throughout the "life-cycle" design process. The 12 steps are as follows:

- Step 01: Identify the Opportunity
- Step 02: Validate the Opportunity
- Step 03: Establish Performance Based Criteria and Constraints
- Step 04: Consider Alternative Solutions
- Step 05: Select Solution
- Step 06: Update Roadmap
- Step 07: Standardise
- Step 08: Validation
- Step 09: Implementation
- Step 10: Compliance Check and Integration
- Step 11: Maintain and Update
- Step 12: Remove/Decommission

B.1.3 Throughout these steps, robust engagement of all stakeholders is necessary. Managing the "life-cycle" design process requires a thorough and continuing commitment by all stakeholders.

B.2 STEP 1: Identify the Opportunity

B.2.1 During the initial part of **Step 1: Identify the Opportunity**, broad discussions among aviation stakeholders, (i.e., the airspace providers (states), regulators (CAAs), services providers (ANSPs), and operators (both civil and military) are important to collectively identify the need, the opportunity, and timing for, *inter alia*:

- New operational concept (e.g. drones, high altitude platforms, space planes etc)
- Capacity Improvement (refer to B.2.3)
- Operational efficiency

- Maintain/Improve Safety (e.g., ICAO GADSS)
- Technology advances (adoption available technology)
- Business and operational needs
- Establish new capability (future enablers)
- Societal needs (Sustainability, environmental considerations)

B.2.2 In these discussions, existing and foreseen issues related to safety, efficiency and capacity constraints within the airspace of interest should be reviewed and assessed to determine if these issues can be mitigated or improved by the availability of a new CNSS technology or service. Moreover, a common understanding on current and foreseeable air traffic types and volumes and the interactions thereof should be established and documented.

B.2.3 Following the broad discussions, however, it is necessary to "narrow down the search" and to identify and document a specific set of goals for operational improvement/enablers. The identification outcomes may be in the form of one or both of the below:

- A documented set of related, concise and measurable operational improvement targets; or
- a well-defined concept of operations for a new operational enabler.

B.2.4 During this identification, an effective consultation process among stakeholders including, at the minimum, a selective group of regulators, equipment and aircraft manufacturers, air navigation service providers and airspace users are necessary in this Step. Direct input and participation from air traffic controllers, pilots and engineers can also be very beneficial. Findings and issues acquired during this identification should be well documented.

B.3 STEP 2: Validate the Opportunity

B.3.1 Following Step 1, once the opportunity for a specific set of operational improvements/enablers is identified, it is crucial that the identified opportunity is carefully validated. This validation is required to "gain necessary buy-ins" and to increase the confidence from all aviation stakeholders. This confidence is the cornerstone for long-term commitment and continuing engagement. Noting that aircraft and CNS/ATM infrastructures are costly investments with long life cycles and a long timeframe required for return-of-investment, it is clear that a long-term commitment from all stakeholders is necessary.
Similar to Step 1, an effective engagement process among stakeholders including, at the minimum, a group of regulators, equipment and aircraft manufacturers, air navigation service providers and airspace users are necessary for this Step. Direct input and participation by air traffic controllers, pilots and engineers can also be very helpful. It is also beneficial that, where possible, the validation activity be conducted using opinions and inputs from stakeholders who are independent from the initial stakeholder group consulted during Step 1. The result of the validation should be well documented.

Possible Benefits: In this Step 2, it is helpful to capture, validate and document if the identified opportunity can offer significant benefits to one or more stakeholder groups and/or can provide more than one specific benefit including, *inter alia*,

- Operational benefits (ground and air)
- Cost savings (as identified by each aviation stakeholder)
- Possible removal and decommissioning of existing equipment and infrastructures and reuse/reconfiguration of spectrum
- Increased capacity
- Allow access to airspace for new users

Potential Cost and Schedule: As in all proper business decisions, all possible required costs and schedules should be identified, categorized and documented. Cost items and schedules which require consideration during this Step include:

- costs of equipment/systems development, manufacturing and certification;
- cost and schedule for airframe technology insertion;

- o equipage and operational approval cost to aircraft operators; and
- o cost for infrastructure deployment and maintenance

B.3.2 **Risk Evaluations:** In addition to validating potential benefits and costs, it is also essential that risk evaluations are taken place during this Step 2. These risk evaluations should address, at the minimum, uncertain aspects related to operations, engineering, finance and regulations. Regarding the regulatory risks, it is also necessary to establish a good understanding of current and foreseeable regulatory environment and potential resource constraints which may occur during the life cycle. The outcomes of the risk evaluations should be documented.

B.3.3 **Alignment to ICAO Visions and Roadmaps**: In ensuring their longer-term relevancy, the identified operational improvements/enablers and their potential technical solutions once validated should be aligned with long-term visions and, thus, can be integrated onto the global ICNSS roadmap. Short-term solutions, which do not support the GANP, long term vision or align with the overall roadmap, should be discouraged.

B.3.4 **Involving Stakeholders**: Validation of the CNS opportunity is essential to direct investment choices in the right direction. The magnitude and duration of future investments of any particular technology needs to be directed in a cost-effective manner. Trial programs and incentives involving air and ground stakeholders (e.g., private-public partnership) are recommended in Step 2. Both government and aviation stakeholders, particularly the airline community, need to agree on the scope of the validation effort.

B.4 STEP 3: Establish Performance Based Criteria & Constraints

B.4.1 Performance-based criteria are predicated to the intended application of the proposed solution which subsequently requires a clear concept of operations and a supporting safety case. In addition to existing applicable ICAO Annexes and PANS, the outcomes from Step 1 - the documented set of measurable operational improvement targets or the well-defined concept of operations for a new operational enabler - will be very useful to establishing appropriate performance-based criteria.

B.4.2 In establishing performance-based criteria, it is of paramount important that the target level of safety is well-established. This target level of safety should be realistic, measurable, clearly understood and achievable throughout the life cycle of the proposed solution.

B.4.3 While it is sometimes tempting to over-prescribe a performance criteria to future-proof a proposed solution, it is necessary to carefully balance between the potential benefit of the marginally superior performance and the cost implications related to the development, the certification, the deployment and the maintenance of the solution, Especially when the superior performance criteria is not going to be utilized operationally in a realistic, foreseeable timeframe, over-prescribing the performance criteria will often delay - and sometimes reduce the possibility for - a successful implementation of the solution.

B.4.4 Similar to earlier Steps, an effective consultation process among stakeholders including, at the minimum, a group of regulators, equipment and aircraft manufacturers, air navigation service providers and airspace users are necessary for this Step. Direct inputs and participations from air traffic controllers, pilots and engineers can also be very helpful. Moreover, to ensure the feasibility and timely availability of technical solutions that are capable in meeting the performance-based criteria, a close consultation with equipment manufacturers, CNS service providers and airspace users during this Step is highly recommended.

B.4.5 Consistent with the supporting safety cases, while developing performance-based criteria for a CNS solution, the following technical parameters need to be considered and prescribed as appropriate. When supporting same operations under similar airspace environment, these performance-based criteria should be consistently applied globally.

- Accuracy
- Availability
- Continuity
- Latency

- Reliability
- Throughput
- Security (cyber resilience)
- Interoperability
- Co-existence

B.4.6 Sometimes, certain constraints are identified, and it becomes clear that the constraints will result in difficulties to routinely meet the performance criteria. These constraints include, but are not limited to,

- Service coverage and Range
- Impact of aircraft speed
- Height
- Geographical location (e.g. over land, sea, polar, etc.)

Once identified, these constraints and their safety and operational implications should be publicly documented and carefully reviewed by aviation safety operators. Any subsequent acceptable mitigations or operational limitations should be included in ICAO standardization documents.

B.5 STEP 4: Consider Alternative Solutions

B.5.1 Once the performance-based criteria are established and relevant constraints are understood and documented, various technological and operational alternatives that may address, either fully or partially, the improvement opportunity should be explored and evaluated. Often, more than one solution is capable of satisfying the performance requirements.

B.5.2 In evaluating various alternative solutions, pro’s and con’s of each alternative should be analysed and documented. A thorough comparative study, including cost-benefit analysis, evaluating each alternative solution is necessary to identify the most appropriate solution. During this comparative study, technical, operational, financial, regulatory and implementation risks identified in earlier Steps should be reviewed and, where possible, mitigated.

B.5.3 Additionally, for each alternative solution, the comparative study should also review and document the effort that will be required for standardization and global harmonization. Very importantly, ease of implementation and deployment and suitability to the targeted timeline should also be studied and recorded. Moreover, issues related to the transition from and the interoperability with existing infrastructure and operational procedures should be carefully considered and documented. As in earlier Steps, all aviation stakeholders are encouraged to actively participate in this comparative study.

B.5.4 While exploring various technical solutions, different technologies and approaches should be evaluated in context of operational scenarios and use cases. Both existing and upcoming technologies should be explored considering the targeted and realistic timeline. For each alternative technical solution, it is also necessary to identify threats and potential mitigations to sufficient availability of spectrum necessary to support the life cycle of each proposed solution.

B.6 STEP 5: Select Solution

B.6.1 Following the completion of the comparative study for potential alternative solutions, a decision-making process including robust engagement with all stakeholders is required to decide on the most appropriate solution. The comparative study, the cost-benefit analysis and the risk evaluation developed in Step 4, if completed appropriately, should provide a solid foundation supporting this decision-making step.

B.6.2 When selecting the most appropriate solutions, it is important to consider the following:

- Overall cost and benefit considering all stakeholders.
- Capability to meet the performance-based requirements

- Ease of and effort required for standardization, harmonisation and implementation
- Availability of Tools to support validation/certification
- Timeframe
- Transition strategy and Issues related to interoperability with existing infrastructure and procedures.
- Remaining risks and their mitigation
- Alignment with the ICAO long-term vision and ICNSS roadmap

Once the decision is made, it is very important to document the rationale behind the decision.

B.7 STEP 6: Update roadmap

B.7.1 Once ICNSS solutions are selected and agreed, it is necessary for relevant global and regional ICNSS roadmaps to be reviewed, updated and adopted in a timely manner to reflect changes needed to standardise, certify and implement the selected solutions. This Step of updating roadmap(s) is very important for ensuring that the implementation and deployment of the new ICNSS solutions is globally harmonised and that global interoperability is well maintained.

B.7.2 Information provided in updated roadmaps should be clear and sufficient for the intended audiences, who may not have had opportunity to participate in the earlier Steps indicated in this Appendix. Additionally, some material developed and documented during the earlier Steps may serve as useful background material and should be made available as appropriate.

B.7.3 Coordination needs to be made at the regional level, as the ICAO Planning and Implementation Regional Groups (PIRGs) serve as the focal points for updating ICAO regional roadmaps. The Regional PIRGs and ICAO Regional Offices should be well informed and engaged in the process so that all necessary information can be distributed to all States and aviation stakeholders within each ICAO Region.

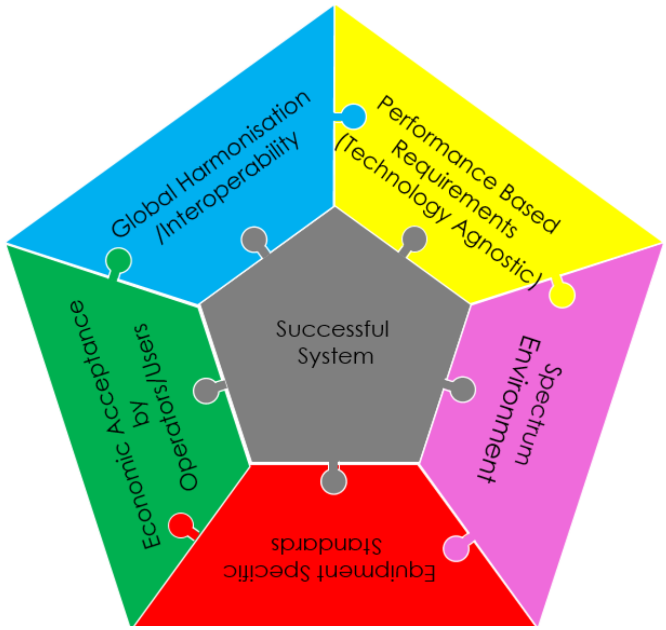
B.7.4 In addition to ICAO roadmaps, States, SMOs, relevant industry and regional organizations are also encouraged to review their existing roadmaps as appropriate to ensure alignment and, as much as possible, synchronisation.

B.8 STEP 7: Standardize

B.8.1 Standards are developed by ICAO and other standardization bodies (SMOs) both at the global and regional level. In the standards, consistency and adherence to the Radio Regulations/best practice needs to be ensured.

- Write the relevant regulatory material that ensures:
  - Global Interoperability
  - Performance-based requirement (technology agnostic)
    - ✓ Operational environmental range
    - ✓ Variation with environment (traffic/complexity etc.)
  - Various technical solutions
    - ✓ Minimum requirements at system level
    - ✓ Peak Instantaneous Aircraft Count (PIAC) and increased traffic considerations
  - Spectrum
    - ✓ Characteristics of Signal in space (should be placed in SARPs/ICAO documentations)
    - ✓ Definition of prioritization or real-time pre-emptive access between different networks
    - ✓ Compliance with applicable radio regulatory requirements (airborne, ground and space components) including local and regional ones
    - ✓ Identification of justified spectrum planning/allocation and protection criteria considered worldwide (ITU Recommendations or Resolutions)
    - ✓ No harmful interference
    - ✓ Efficiency
  - Long term life cycle

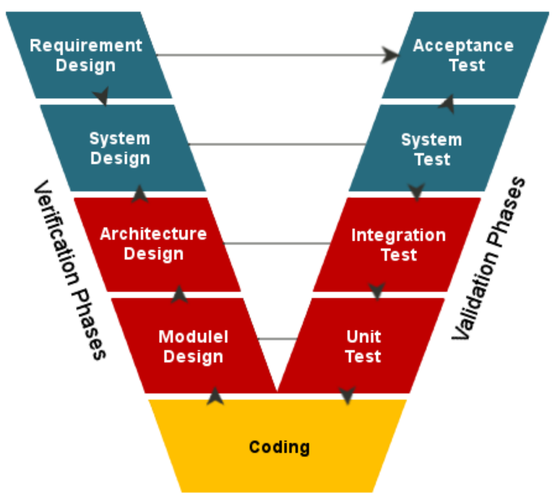
- Balancing Act



- Usual Verification and Validation process

Verification

- *Does the product meet the requirements?*
- *Are we building the product right?*



Validation

- Does the product meet the needs of the customer?
- *Are we building the right product?*

- It is key to get an early engagement by all stakeholders to help streamline the process.
- SARPs are regulations, the uniform application of which is recognized as necessary for the safety and/or regularity of international air navigation.

- SARPs focus on the ICAO <u>validation</u> criteria instead of the verification to provide a given level of safety and/or regularity of flight.
  - Interoperability depending on CNS system may call for some verification, too.
  - SARPS are technology agnostic

- *How can ICAO contribute to the validation process?*
  - ICAO can ensure that test results or simulations results demonstrate that the various CNS SARPs are valid and implementable through matrixes checks or check lists.

- ICAO can ensure that there is due process to demonstrate test or simulation results meet the operational behavior requirements.
- *Demonstration that the intent of SARPs is satisfied both operationally and technically*
- For SARPS to be "approved", they must be shown to meet an operational requirement, which improves or at least maintains the safety and/or regularity of flight.
  - While achieving the balance called for under standardization.
  - (What about impact analysis? : Efficiency, cost, …)
- Link with other Standard Making Organizations to ensure compliance with MOPS as well as identification of gaps and overlaps a must
- *Well formulated SARPs can achieve this!*

B.8.2 Because of the high-cost to develop ground and airborne systems for aviation safety applications, stability in standards is needed so that investment costs can be recovered. Although all standards should be expected to evolve over time, major updates to standards should only be implemented when required for safety or as justified by benefits to stakeholders.

B.9 STEP 9: Implement including transition

B.9.1 Having validated that the system will deliver the performance and expected operational benefits, a transition plan needs to be developed, either regionally or preferably globally, for the roll-out of the new equipment and where appropriate the subsequent decommissioning of existing equipment within agreed timescales. Given that the roll-out of a new system may benefit certain sectors of the industry or regions more than others, consideration may need to be given to incentivising those who do not obtain a benefit within a reasonable time period in order to ensure the benefits envisaged are achieved within the desired timescales.

B.10 STEP 10: Compliance check and Integration

- Either a declaration of compliance with the applicable performance requirements must be issued by the manufacturer or through an equivalent third-party process to certify that the performance is consistent with the applicable SARPs, regulations and other relevant requirements.
- Any non-compliance shall be clearly identified and assessed.
- Networks qualification (terrestrial and satellite).
- Validation of a network at all layers (aircraft sub network, ground sub network, service providers network, third party sub network etc.).
- Within operational environment, Integration check.

B.11 STEP 11: Maintain/Update

B.11.1 Both CNS ground/space-based systems and CNS airborne systems must be designed with long-term maintenance objectives and growth in mind. History suggests that CNS systems must serve a very long useful life, in many cases the full lifespan of a specific airplane type design and production. This period of time is much longer than the design cycles of systems used in other industries. Therefore, designers must be aware of the probability for hardware component obsolescence during the lifecycle of a CNS system. The hardware should be upgradable over the life of the system. Designers must also be aware that software solutions have limited life and will need to evolve during the overall system lifecycle, for both ground systems and airborne systems. Therefore, a modular design approach is recommended for both ground and air, and for both hardware and software. CNS ground system maintenance and update must be possible independent of the airborne side and vice-versa.

B.11.2 Ground systems are unique compared to airborne systems in the sense that they may be commissioned by individual States and operated by independent air navigation service providers (ANSPs) or other entities that maintain these systems. The maintenance cycle for one ANSP may be different from the next. Likewise, growth in the CNS ground/space-based system necessary to support new entrants will evolve by economic regions that accept and support new entrants. Maintenance and upgrade cycles are ultimately determined by the ANSP.

B.11.3 Airborne systems tend to be global in the sense that CNS capability is expected to support the aircraft within all regions that the aircraft operates. The required CNS capability may be different for domestic aircraft versus long-range aircraft. The latest aircraft and most modern aircraft type designs will often have more capability than older aircraft. The cost to update an older aircraft with a long service life will require an in-depth cost/benefit analysis, often unique for each airframe.

B.11.4 To support ICAO interoperability goals, an agreed CNS roadmap must be available and made current to serve as a guidepost for both CNS ground/space-based system providers and CNS airborne users. It is recommended that the CNS roadmaps(s) be reviewed on a frequent basis and agreed by all stakeholders.

B.11.5 Early implementers of system-wide upgrades will need to be incentivized due to the risks associated to being first to implement. The incentives may come in many forms, with the ultimate goals of timely implementation of the new capability and to ensure a speedy transition.

B.11.6 In summary:

- Update roadmap
- Identification of emerging threats and solutions
- Feedback to standards & implementation/transition strategies

B.12 STEP 12: Remove/Decommission

B.12.1 All complex systems are subject to long-term operating requirements that will involve routine maintenance and planned updates requiring capital expenditure and periodic recommissioning over many years. This will continue ultimately to the point where the system is no-longer economically viable to the service provider. New technology will eventually come along to replace the existing system. One such example is the decommissioning of OMEGA navigation following the arrival of GNSS.

B.12.2 Decommissioning is largely an economic decision that must be agreed upon by all industry stakeholders. This decision must be taken as a minimum of [TBD] years prior to actual removal from service. The legacy CNS capability must be shown to be available by an alternate CNS capability, or in some cases, that legacy CNS capability is no longer necessary.

B.12.3 For decommissioning to be effective, an alternative solution must already be available as discussed in Steps 1 and 2 of this Design Cycle. The replacement for the system to be decommissioned must already be available, shown to be viable (both operationally and economically), and the plan for its implementation in place. In many cases, operational experience will be desired with an overlap and transition period that is widely agreed by the stakeholders. This transition period is inevitable, and every effort must be made to minimize the time required for the transition.

B.12.4 Considerations are as follows.

Ground systems must be available to operators until the final sunset date with all routine maintenance and upgrades available to meet the required capability.

Airborne equipment removal may be the desired path forward. However, in many cases it is not that simple. For example, should the decommission of one ground system require replacement by a new system, then old equipment on the aircraft will need to be replaced with new equipment on the aircraft. The aircraft operator must consider the cost of retrofit, flight crew training and other costs required for the remaining life of each airframe that is affected. New aircraft type designs are often the best opportunity to introduce new technologies and new operating capabilities. Older aircraft are the least likely to be modified if it is known they are to be retired in a few years. Especially as the return of investment for operators is unlikely to be positive given the short time to recoup their capital investment coupled with the need for more resources for the integration of new equipment into typically older avionics suites.

In summary:

- Agreed sunset dates are required.
- Remove any equipment identified as being made redundant.
- Complete removal within defined time frames.

Appendix C

Scope of Tasks/GAP analysis

(To Be developed)

Appendix D

Relevant Assembly Resolutions

A35-14: Consolidated statement of continuing ICAO policies and associated practices related specifically to air navigation

…

Appendix A Formulation of Standards and Recommended Practices (SARPs) and Procedures for Air Navigation Services (PANS)

…

3. SARPs and PANS shall be drafted in clear, simple and concise language. For complex aeronautical systems, SARPs shall consist of broad, mature and stable provisions specifying system-level, functional and performance requirements that provide for the requisite safety levels and interoperability. For such systems, any technical specifications necessary to achieve these requirements shall be appendices to Annexes. Any related detailed technical specifications shall be placed in separate documents and be referenced in Annexes by means of notes.

….

A35-15: Consolidated statement of continuing ICAO policies and practices related to a global air traffic management (ATM) system and communications, navigation and surveillance/air traffic management (CNS/ATM) systems

…

Appendix B: Harmonization of the implementation of the ICAO CNS/ATM systems

…

3. Urges the Council to ensure that ICAO develop the transition strategies, ATM requirements and SARPs necessary to support the implementation of a global ATM system;

4. Urges the Council to continue considering without delay the economic, institutional, legal and strategic aspects related to the implementation of the ICAO CNS/ATM systems;

5. Urges the Council to take the steps necessary to ensure that the future global ATM system is performance based and that the performance objectives and targets for the future system are developed in a timely manner;

A36-13: Consolidated statement of continuing ICAO policies and associated practices related specifically to air navigation

…

APPENDIX A

Formulation of Standards and Recommended Practices (SARPs) and Procedures for Air Navigation Services (PANS)

…

3. SARPs and PANS shall be drafted in clear, simple and concise language. SARPs shall consist of broad, mature and stable provisions specifying functional and performance requirements that provide for the requisite levels of safety, efficiency and interoperability. Supporting technical specifications, when developed by ICAO, shall be placed in separate documents to the extent possible;

4. in the development of SARPs, procedures and guidance material, ICAO should utilize, to the maximum extent appropriate and subject to the adequacy of a verification and validation process, the work of other recognized standards-making organizations. Material developed by these other standards making organizations may be deemed appropriate by the Council as meeting ICAO requirements; in this case such material should be referenced in ICAO documentation;

A39-22: Formulation and implementation of Standards and Recommended Practices (SARPs) and Procedures for Air Navigation Services (PANS) and notification of differences

…

The Assembly:

…

3. Agrees that subject to the foregoing clause, a high degree of stability in SARPs shall be maintained to enable the Member States to maintain stability in their national regulations. To this end amendments shall be limited to those significant to safety, regularity and efficiency and editorial amendments shall be made only if essential;

4. Reiterates that SARPs and PANS shall be drafted in clear, simple and concise language. SARPs shall consist of broad, mature and stable provisions specifying functional and performance requirements that provide for the requisite levels of safety, regularity and efficiency. Supporting technical specifications, when developed by ICAO, should be translated in all working languages of ICAO in a timely manner and shall be placed in separate documents to the extent possible;

5. Instructs the Council to utilize, to the maximum extent appropriate and subject to the adequacy of a verification and validation process, the work of other recognized standards making organizations in the development of SARPs, PANS and ICAO technical guidance material. Material developed by these other standards-making organizations may be deemed appropriate by the Council as meeting ICAO requirements; in this case such material should be referenced in ICAO documentation;

..

Note. - A39-22 is still in force as of 40th session of the Assembly in 2019.

Appendix E

Examples of Voluntary Industry Standards/ Specifications published by other organizations

(To Be Developed)

Appendix F

References

Existing ICAO publication

- Air Navigation Commission Guide to the Drafting of SARPs and PANS FINAL (Rev.1.5)
- https://www.icao.int/about-icao/AirNavigationCommission/Pages/how-icao-develops-standards.aspx

The Technical Instruction

- Air Navigation Commission WP/9313 in 2018
- AN-WG/PM WP/550
- ANWG/PM WP/551
- Guide to the Drafting of SARPs and PANS, Air Navigation Commission

CORSIA Implementation Elements

- Annex 16
- C-WP/14674
- https://www.icao.int/environmental-protection/CORSIA/Documents/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions.pdf
- https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx
- Introduction to CORSIA: What is it and how to prepare? (https://blog.openairlines.com/introduction-what-is-corsia)