APPLICATION OF AI IN THE NAS – THE RATIONALE FOR AI-ENHANCED AIRSPACE MANAGEMENT

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Abstract

This paper extends on the initial findings of "APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE NATIONAL AIRSPACE SYSTEM – A PRIMER" (Stroup & Niewoehner: Herndon, VA; ICNS-2019), and looks at why the current technologies, enterprise architecture, and future program plans may not be enough to address persistent operational challenges. This paper further explores why emergent operational concepts, business models, and demand profiles may necessitate Artificial Intelligence (AI)-enhanced Communications, Navigation and Communications (CNS) infrastructure to disrupt current operational impediments. European airspace, as well as the NAS, has similar challenges. Key challenges explored in this study include: traffic flow management of diverse users; UAS Traffic Management – Air Traffic Management (UTM-ATM) airspace integration; equitable access to airspace; information exchange networks and airborne-ground interoperability of AI applications. Finally, we examine why trustworthiness and resiliency will be key mileposts on the regulatory pathway to AI certification.

Background

The NAS is part of the transportation critical infrastructure sector **(1)** and concerns relate to sustaining minimum NAS operation. At issue within the broader aviation marketplace, is the continued search for a solution set to the persistent and evolving challenges that constrains the NAS capacity, efficiency and resiliency.

In 2017, a Strategic Outlook (2) (5 to 10 year look forward) analysis that complemented the more formal NAS Horizons (3) (20 to 25 year look forward) analysis within the International Civil Aviation Organization (ICAO) was conducted. These analyses provided the foresight to address, through enterprise analyses, the role of emerging technologies in the future NAS. These analyses provided insight into the longer-term vision to support risk reduction of disruptors that may impact the future NAS. As advances occur in smart surface transportation systems as well as the maturing of decision-support tools in National Defense and National Intelligence sectors acceptance of AI in critical infrastructure operational technology will become viable.

The NAS is a complex system-of-systems and may appear to be non-deterministic (4). However, ANSP's apply various techniques to bound the operations to make the NAS appear deterministic. These techniques consist of miles-in-trail, minutes-in-trail, low altitude alternate departure routing, capping, tunneling, ground delay program, time-based flow management, airspace flow program, ground stop, adaptive compression, and integrated collaborative routing to produce a safe, orderly, and expeditious flow of traffic while minimizing delays.

Is a non-deterministic system like the NAS just a very complex deterministic system that we don't know enough about? Can the application of emerging technologies like AI and Machine Learning (ML) enable us to know more of the parts to enough degree and their behaviors as well, then it should be possible to forecast its state with an increased level of confidence at any time in the future?

Since this work started in 2017, some additional events have reinforced the work:

FAA Reauthorization Act of 2018: (Public Law 115-254; 10/5/2018), SEC. 548. SENSE OF CONGRESS ON ARTIFICIAL INTELLIGENCE IN AVIATION. "It is the sense of Congress that the Administration should, in consultation with appropriate Federal agencies and industry stakeholders, periodically review the use or proposed use of artificial intelligence technologies within the aviation system and assess whether the Administration needs a plan regarding artificial intelligence standards and best practices to carry out its mission."

Executive Order on Maintaining American Leadership in Artificial Intelligence: February 11, 2019. "Continued American leadership in AI is of paramount importance to maintaining the economic and national security of the United States and to shaping the global evolution of AI in a manner consistent with our Nation's values, policies, and priorities." National Institute of Standards and Technology (NIST) is leading the effort per the Executive Order to develop a plan for federal engagement in AI standards. The standards must build trust and confidence in AI technologies and applications to meet the nation's needs. AI leadership will sustain with alignment to the Four Main Pillars of Emphasis: AI for American Innovation; AI for American Industry; AI for the American Worker; and AI with American Values.

Eurocontrol AI Conference: May 23, 2019. (5) This inaugural event focused on the how AI is driving business growth in general and the potential for AI to disrupt the aviation business models. The conference discussed key issues and challenges such as pilotless aircraft and automated Air Traffic Control (ATC).

Why AI may be leveraged to solve our complex challenges

There exist complex persistent and evolving challenges that will demand we look at applying emerging technologies to meet performance goals and mitigate chronic NAS performance issues. European airspace, as well as the NAS, has similar challenges. Key challenges explored in this study include traffic flow management of diverse users; UTM-ATM airspace integration; equitable access to airspace; information exchange networks and airborne-ground interoperability of AI applications.

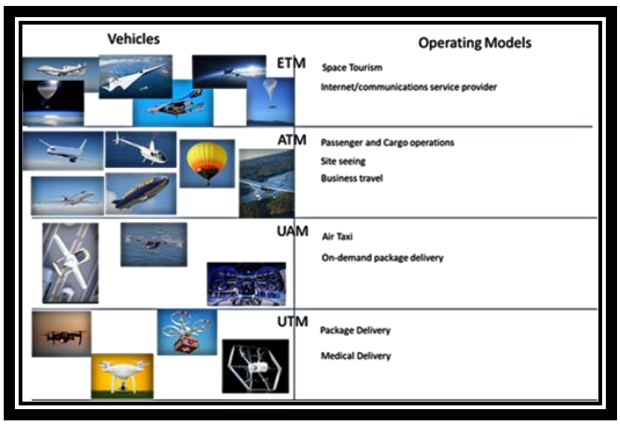

Figure 1 UTM / ATM / ETM Operations Concept

Traffic Flow Management of Diverse Users

The NAS users are becoming very diverse in terms of vehicles, their performance as well as their business models to meet their business goals. This is creating challenges with maintaining or improving capacity and efficiencies in the NAS. At issue within the broader aviation marketplace, is the continued search for a solution set to the persistent daily delays and schedule perturbations that occur within the NAS. The delays persist in the face of reduced demand for commercial routings. Every delay represents an economic loss to commercial transport operators, passengers, freighters, and any business depending on the transportation performance. (2) This is not unique to the NAS, the UK's air navigation service provider National Air Traffic Service (NATS) is trying to resolve capacity challenges at London's Heathrow Airport and have turned to artificial intelligence to reclaim lost capacity caused when the airport's 87m-high air traffic control tower is operating in reduced visibility conditions. (6) NATS is hoping the AI could be introduced into Heathrow's operation later in 2019. The first step will be to collect data on some 50,000 landings to ensure the accuracy of the system. The company's findings will then be presented to the UK Civil Aviation Authority. During the summer of 2018, Europe seen enroute delays peak compared to the summer of 2017. The contributing factors were traffic up 4%, lack of capacity by Air Navigation

Service Providers, (ANSPs), overall shortage of ATC staff, and weather. (7)

Key Question: Can AI help identify and reclaim lost capacity and reduce delays?

UTM-ATM-E-above A (ETM) Airspace Integration

The sheer number of drones will require machine-to-machine autonomy in the current Class G airspace, but these emerging users will not be satisfied with limited access to other parts of the airspace. This increasing demand will push into more controlled airspace with its business model and infrastructure. According to ICAO, "*establishing a comprehensive sectorial architecture will provide a secure foundation for air transportation interoperability*." (8)

Key Questions: Can AI help optimize integration and interoperability of diverse users in the NAS?

Equitable Access of Diverse Users to Airspace

The global navigable airspace is a limited resource. Each ANSP per ICAO is responsible to ensure the safety and efficient use of airspace they manage. In the U.S. the Airspace Access Priorities Aviation Rulemaking Committee is responsible for developing criteria that may be used to consider competing requests for airspace access (9).The ability to manage access of commercial transports, general aviation, unmanned aircraft, and commercial space operators as well as existing and emerging business models might constrain future air transport growth. (8) How do we balance the societal, operator, and end-users benefits while maintaining capacity, efficiency and resiliency of the NAS.

Key Questions: Can AI help to identify a strategy for equitable access of diverse users?

Information Exchange Networks

Overall worldwide civil air traffic growth is estimated to be 84 % more civil planes in the air when comparing 2017 and 2040, following

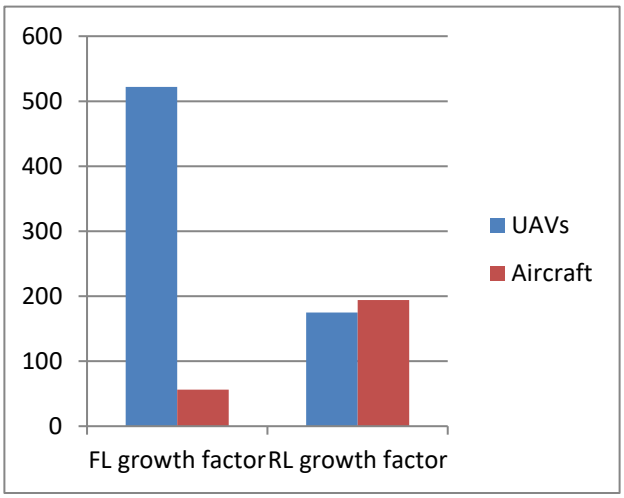

Figure 2 Growth factors of required data throughput to be able to cope with the growth of datalink requirements and flight movements worldwide.

EUROCONTROL's latest report on the growth of European and worldwide air traffic (10). With the increase in flight movements, new entrants, lower latency and increased data processing requirements in the future, legacy systems in the ATM will reach their capacity limit (11). Overall the transformation from analogue to digital communications services for manned and unmanned aviation poses the question how much data will be required per flight. This allows us to estimate the CNS data capacities of the future global airspace. After intense analysis, (10) the estimated growth of worldwide civil air traffic is 2.7% per year for manned and 13.1% per year in unmanned aviation and for civil aeronautical data link traffic the estimated growth is 16% per year.

We see in Figure 2 that an increase of up to a factor of 500 for the FL of UAVs is too large to be only handled by new data-links to realistically handle the exponential growth of new entrants. Thus, we conclude, we need a hybrid approach of new datalinks and new AI technology for smart selection of transmitted data to be able to handle this amount of new data and increase in flight movements per year!

Key Questions: Can AI help manage the volume and velocity of data exchange to optimize airspace operations?

Interoperability of Airborne and Ground AI Applications

The aviation ecosystem connects operations, capabilities, and infrastructure across the airborne, airspace, air traffic, and airport domains to support the future NAS. It includes all stakeholders as well as UAS and commercial space operations. (12) The application of emerging technologies, such as AI, is a multi-dimensional challenge. Simply applying AI to one of the domains may not be enough to leverage all the benefits. The interdependencies with the airborne, airspace, air traffic and airport domains, as well as other critical infrastructure sectors (e.g., energy, finance, communications) demand AI application standards across the domains in support of mission objectives. (13)

These applications and their role will be defined across a set of AI use cases linked to mission shortfall, mission objectives, type (advisory, decision), risk level, and data requirements. A comprehensive aviation ecosystem to support application of emerging technologies must be developed. The FAA is continuing to examine with external stakeholders exploratory AI concepts such as IA operations theory and *intelligent* CNS (*i*CNS), *intelligent* NAS (*i*NAS) and associated AI use cases.

Key Questions: Can AI help integrate enterprise applications across the aviation ecosystem?

AI-Enabled Infrastructure to Solve the Challenges

Infrastructure is a critical enabler to the delivery of ATC and ATM services. Many electronic systems are used throughout the NAS for airspace management and their reliable performance is required to keep the air traffic system operating safely and on time. AI-enabled infrastructure is a promising technological improvement that can benefit regularity of air traffic services, e.g. outage reduction and improved business management processes. At the core of an AI-enabled infrastructure initiative, is the desire to get insight into system performance to reduce uncertainty. Predictability improvement lends confidence to strategic planning and may decrease tactical adjustments. The introduction of AI-enabled systems into existing infrastructure and transitioning it into existing workflows and workloads will require addressing challenges in different areas that include acquisition, workforce culture, systems architectures and more. Overcoming these challenges will bring about the beginning of a Cognitive NAS.

Mission Effectiveness is a Key Measure.

The US ATC system requires numerous CNS systems to deliver services. As of 2017 the FAA had about 19,000 communications systems, 2,300 surveillance systems and 13,500 navigational systems, 2,400 automation systems, and 2,300 weather systems servicing the NAS. (14) There is a sizable amount of technical performance data collected on a regular basis for all CNS systems in service today. NAS maintenance practices and performance metrics and evaluation procedures are effective, however, services reductions that impact air traffic operations still occur. A predictive maintenance approach, as one example of a use case, coupled with preventive services will assist and yield NAS performance improvements. The use of machine learning where the learning set is comprised of different data collection events and real-time monitoring can enable an expert AI system to predict outage conditions and report it to technical operations for corrective investigation.

Data Management

In conventional computer programming, code is developed and data input into the code for execution. In artificial intelligence the inputs to the system is data plus a set of expected answers. The machine is trained rather than programmed. Rather than writing code for each specific task, lots of examples are collected that specify the correct output for a given input. The objective is to have the program work for all cases. In this approach training data is very important. Erroneous data and small amounts of it can yield incorrect results and limit the benefits of artificial intelligence. When preparing training data for neural network learning, consideration shall be given to the following factors:

Relevance - Irrelevant data attributes present a problem in that they can be misleading to the learning algorithm and unnecessarily consume computational resources. While all attributes are not relevant, the difficulty comes in identifying which are useful specially in large data sets. (15)

Consistency - Inconsistent training data and missing attributes throw off a training algorithm and will lead to a poorly trained intelligent system. It is important to eliminate redundant attributes to reduce unnecessary computational expense.

Data noise - Another source of error is noise in a data set. Data noise can be in the form of spelling errors, or systematic noise where an algorithm is influenced and swayed in a biased direction.

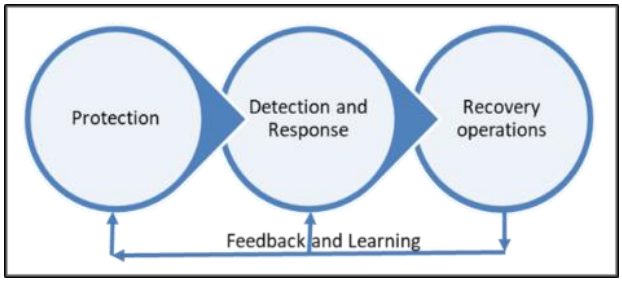

Figure 3 Risk-Based Resiliency Model

Data quality (cleansing, labeling and processing). The volume, protection and velocity of data is constantly changing. Much of the testing has been done on pristine data in a lab. Current deterministic systems account for this but how about non-deterministic systems.

Data poisoning – Techniques such as model reversion, and classification manipulation are key challenges to be addressed by risk and data management policy. (16)

Workforce Skill Set and Culture

In order to support an AI-enabled infrastructure, a workforce with skill sets associated with computer science, data science, psychology and domain expertise will be necessary. (17) Domain expertise consists of operational knowledge and sound system engineering practices to understand what AI is doing and how to maintain awareness of the current modes and system states. The right skill set will drive trust in the system as it relates to trust and resiliency. Understanding the design characteristics, training and procedures aspects related to AI systems will provide for human-system resilience. (18)

The cultural challenges stem from limited resources and budget to explore these emerging technologies, the heavy dependency on legacy systems and the perception that emerging technologies can result in job displacement. Historically the aviation programs have established qualitative goals (increase capacity, improve efficiency) at the concept level and quantitative benefits are defined during the investments analyses to support a cost-benefit report. During planning and development, that lack of quantifiable goals results in less than effective risk management process and output to inform management on the impact of possible planning and acquisition decisions. After deployment, many of these quantitative benefits have not materialized for one or more reasons, typically due to integration losses, and performance slippage. Resiliency is one area where the FAA Administrator has clearly defined performance objectives. (19) The application of emerging technologies into the NAS will take education to energize the workforce that technology will focus on mundane and repeatable tasks and free up the worker to focus on thinking and reasoning tasks. (20)

Architecture

The complexity and connectivity of our NAS systems as well as the volume and velocity of data presents an opportunity to apply emerging

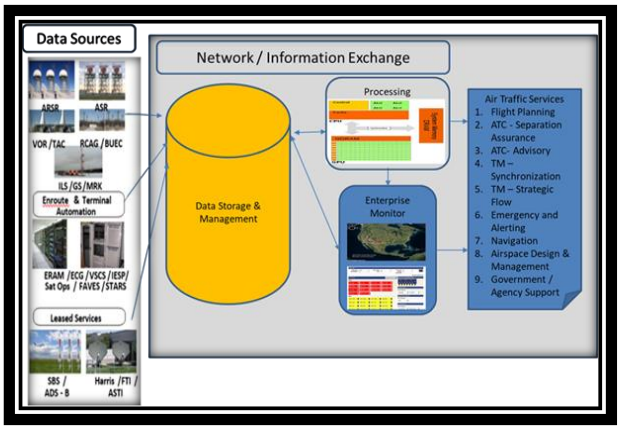

Figure 4 AI Enabled NAS Architecture

technologies to meet the future NAS needs. The

current NAS infrastructure will be challenged by the ability to handle the amount of data, the rate of change of the data and identifying unknown patterns and relationships across the data.

The NAS architecture must also be updated to meet these challenges. Figure 4 represents a notional AI-enabled architecture. It starts with data sources, both internal and external that provides insight into all aspects of the aviation ecosystem. That data is stored and prepared to be processed by applying various data management best practices. The data is sent to a processor as well as the enterprise monitor. The AI-enabled processor consists of a Central Processing Unit (CPU) and Graphics Processing Unit (GPU). The addition of the GPU (21) allows the system to take large batches of data and perform the same task over and over very quickly. The CPU is still the brains of the system but conventionally it can only handle of couple tasks at a time while the GPU can handle thousands of tasks at a time and therefore accelerate computational tasks. The enterprise monitor (22) provides and end-to-end monitoring capability. The AI-enabled monitor will apply the data to combine lower-level system status information and user experiences into service level indications and higher-level awareness and operational impact to inform decision-makers across the FAA in a timely manner to assure the capacity, efficiency, and resiliency of the NAS. The ability to collect, manage, process and monitor requires an architecture robust network and information exchange capability to handle the volume of information that is needed to support future NAS operations.

Safety, Security and Resiliency Aspects

The concept of resiliency takes a risk-based approach (23) to address the interdependencies among today's complex and critical infrastructure. Alignment of protection (safety cyber-security, information security, physical security, and human factors) mechanisms, detection and response (monitoring and contingency) methodologies and recovery (logistics and maintenance) techniques are key to improving the NAS resiliency posture (See Figure 3).

AI has also been shown to be able to detect and/or mitigate different kinds of attacks on information systems. This includes both higher layer attacks ("hacking") and physical layer attacks ("jamming") (24). AI can help with deep reinforcement learning to gather new information with each incident and help recover quicker.

Acquisition

The conventional waterfall methodology in program management may not be sufficient due to changing system requirements, application of models and algorithms, non-deterministic testing, and vague lifecycle planning. (25) AI-enabled machines are continuously in training. An agile methodology of program management, in which each stage building on successive stages, is more appropriate for an AI-enabled effort. (26)

The agile approach values adaptability, lean development, time, and sustainability to a dynamic environment. The current FAA Acquisition Management System is predominately a waterfall approach to acquisitions. These waterfall-based acquisitions take an extended period and often delivers minimal capabilities with outdated technology. A hybrid approach is worth evaluating to support an AI-enabled NAS.

Models/Algorithms

NAS functions that may be accomplished by AI will require different algorithm technologies and implementation approaches. A single learning model will not meet all classes and types of decisions required to predict and support numerous NAS functions and operations. The NAS will have to employ a combination of machine learning and deep learning models tailored to solve specific problems and meet different needs. AI development for NAS implementation can be achieved by conducting investigation in Data Sciences, Core AI and Applied AI. The NAS is a data rich environment and appropriate data needs to be selected to train ML and Neural Network (NN) models. Data Science investigates the correct features that need to be used to train models and evaluates data for bias removal and noise reduction. Core AI focuses on investigation and development of fundamental algorithms that solve specific problems. Core artificial intelligence includes development of algorithms with integrated safety features to yield a trusted system. Moreover, it concentrates on

fundamental development of NN/ML with safety assurance and, in some cases, the ability for machine intelligence to explain its decisions and actions (27). A NAS user should be able to interrogate the explainable model to understand why a prediction was generated. The system's ability to effectively explain decisions will provide an element of trust in a safety critical environment. An important question on explanation is; whether the system can provide a convincing reasoning on decisions taken. Applied AI concentrates on algorithm application investigation to address specific NAS needs and requirements. It focuses on identifying the optimal learning model for a given task and proper model implementation. The development of Core and Applied AI will result in the implementation of a machine learning enabled trusted service.

Why Emergent Technical Solutions Must Map to Airspace / Operations Classification

The CNS situation of today and the future can be described as follows:

Communication – Today and the Future

Nowadays communication in aviation is still unthinkable without analog voice radio (VHF audio) – a technology that goes way back into the beginning of aviation. Except for minor changes in the channel and frequency allocation, not much has changed over

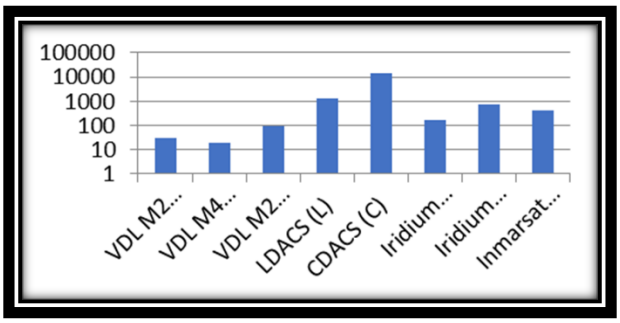

Figure 5 Logarithmic Scaled Throughput in kbit/s of Several Communication Systems used or foreseen in Aviation

the years, although the amount of aircraft in the air increased significantly. For the exchange of digital data, the VHF Data Link (VDL) is used, e.g. in Mode 2. However, it does not provide any mechanisms for authenticity checks and its data throughput is very limited (28).

Overall, two developments are going on:

First, more and more piloting tasks are done automatically by computer-based systems on board the aircraft. This is expected to lead to the single-piloted aircraft in the future.

Second, the field of unmanned aviation is growing tremendously (see Background). Both developments are expected to influence at least parts of the required CNS systems. ***Thus, the CNS technologies currently in use will not be able to handle the challenges of the future.***

Smart routing algorithms, probably enhanced by AI technology, may have the potential to increase the network capacity of nowadays systems. However, the current patchwork situation makes it challenging to optimize the routing – even for an AI (29).

To cope with the increasing demand of data throughput required for future aviation, communication systems are under development such as the L-band Digital Aeronautical Communications System (LDACS) and C-band Digital Aeronautical Communications System (CDACS); (30), (31) as well as the Iridium and Inmarsat satellite constellations.

LDACS is the future ground-based data link for aviation and has been developed within the last ten years by DLR and partners. Besides communications, LDACS enables navigation through an integrated ranging functionality. LDACS has already reached a high level of maturity. Demonstrator equipment is available and flight trials have been performed where all relevant LDACS functionalities have been proven in realistic test scenarios. Standardization within ICAO started in December 2016 and draft SARPs (Standards and Recommended Practices) were passed by end of 2018.

CDACS, a modern C2 data link with focus on highly automated aviation (like unmanned aviation) is currently developed at DLR. It makes use of state-of-the-art communication technologies and is designed with a focus on physical layer robustness while providing high data rates. Since CDACS is the first system targeting future highly automated aviation with a high demand for data throughput, it

is one of the key enablers for bringing disruptive technologies into aviation (32), (33).

Navigation – Today and the Future

Figure 6 Volocopter Avionics by Honeywell

The VOR and DME are still used as most prominent navigation aid in aviation. And even though GNSS-based navigation like GPS or GALILEO became part of people's everyday life, it is still not the primary navigation systems in aviation. The term to use here is APNT - Alternative Positioning and Navigation and Timing. Other APNT systems providing at least similar precision to GNSS are not available yet (34).

Fully integrated, intelligent CNS (e.g., see Figure 6) also allows for alternative positioning, navigation, and timing (APNT). For example, the ranging functionality of the communications system LDACS is foreseen to establish a future APNT capability. With improved AI algorithms for channel modelling, navigation based on communication infrastructure can be improved to very detailed levels, which is one possibility how AI can help solve the problem of precise navigation in aviation.

Also, Multi-Frequency, Multi-Constellation solution between all navigation systems worldwide highly improves availability and coverage of navigation aids and of navigation capabilities worldwide. For the interoperability of ground-based, air-based and space-based systems, also new, smart routing algorithms, enhanced by AI technology, may be key to interconnect all data from different system, uniform their data format and make it available for all entities in need of precise navigation on the spot.

Surveillance – Today and the Future

The most prominent cooperative surveillance system in aviation is the secondary surveillance radar (SSR). It is mostly used in Mode A which is facing problems not only but also because of the 12-bit limit of the aircraft identifier (35). A more modern cooperative surveillance system is Automatic Dependent Surveillance – broadcast (ADS-B) (36). Besides repealing the limit of the air craft identifier, it broadcasts the aircraft's position on a regular base. In a market space where 18-24 months is out of date, aviation CNS infrastructure is decades off the pace. In the future, we will see more and more systems being integrated into one another and thus classical surveillance approaches will also involve direct point-to-point communication, and surveillance data broadcast, and possibly multicast of the positions of these nodes. Again, to make this multi-hop arbitrary mesh network multicast routing even possible, AI will play a strong role here.

Spectrum Issues

As every wireless system, a CNS system depends on three resources: time, space, and spectrum. Especially the latter is a rare, valuable resource that should be exploited efficiently. AI has proven useful to support this task multiple times. In (37), an AI-based algorithm has been used to optimize radio cell and frequency planning considering interference. The concept of AI-based spectrum sensing, as a first step of increasing spectral efficiency, has been investigated in (38).

Nowadays, aeronautical CNS systems are restricted to certain frequency bands only. The mentioned AI-based approaches have the potential to enable coexisting systems in the same frequency band (spectrum sharing) resulting in more useable bandwidth for aeronautics. (39)

Integrated CNS – Today and the Future

In the past, CNS systems were designed to provide just one of the three services (either communication OR navigation OR surveillance). Furthermore, new systems popped up without outdated systems disappearing. These two factors led to nowadays situation: a patchwork of different systems, most of them decades off the pace compared to state-of-the-art cell phone industries.

No solution providing all three services at the same time while exploiting available synergies has been deployed so far. We call these kind of systems integrated CNS. However, on both sides of the Atlantic, projects are working on bringing modern

technology into CNS, namely NextGen in the US and SESAR in the EU.

LDACS (31), (32) applies modern digital communications technologies known from 4G mobile radio networks, including cyber security, and – to the best of the authors' knowledge – is the first aviation system so far providing true integrated CNS.

Currently under standardization by ICAO, LDACS is the upcoming communications data link for aviation, and therefore, an important part within the future communications infrastructure. LDACS has already been tested in flight trials (40), (41) and provides:

- Data rates between 550-kbit/s and 2,600-kbit/s in the Forward and Reverse Link respectively (31);
- APNT capability of RNP0.3 and better without the need for additional spectrum;
- ADS-C (Automatic Dependent Surveillance-Contract) service;
- ADS-B service within the currently developed LDACS air-to-air mode (42); and
- Non-cooperative surveillance is described in (43);

The next step after bringing true integrated CNS to the market, by e.g. introducing LDACS worldwide as the air-ground datalink in the Future Communication Infrastructure (FCI) in civil aviation, is to bring integrated intelligent CNS to life. This means enhancing CNS with AI, thus to enable the system to observe all incoming positioning and flight trajectory data from all participants in the network in real time to furthermore detect potential bottle necks and circumvent these by intelligent rerouting of air vehicles. It can also react on sudden emergencies, e. g. an ambulance helicopter that requires an unforeseen flight corridor.

Acceptance through Trust

AI today supports analytical-type functions (research, planning, post-ops analysis) but needs to evolve to support mission support/operational functions involving safety-of-life challenges. (44) The future of AI will evolve to mission support (i.e., priority and response maintenance, traffic flow management) functions and mission operations (i.e., separation management, sequence management, and spectrum management) functions. (2) In an effort to leverage artificial intelligence technology and support the certification of AI applications in the aviation (i.e., intelligent flight control systems, intelligent air traffic systems, and intelligent airport systems) ecosystem, sufficient processes and methods, need to be established. One possibility is a framework consisting of existing as well as enhanced verification, validation, metrics, independent verification & validation, and trust aspect for AI-enabled systems. (45)

- Verification: build the product right, of AI-enabled systems should include the following areas: contracts, process, design, code and documentation.
- Validation: build the right product, of AI-enabled systems should include the following areas: items (i.e., models and algorithms), the testing environment, and testing (i.e., unit, response times, failure modes, and utilization).
- Metrics for AI-enabled systems may include learning time, recall response, accuracy, repeatability, resiliency (46), integrity (47), and confidence. (48)
- Independent verification & validation of AI-enabled systems ensures the AI aspects are thoroughly tested against its complete set of requirements.
- Trust of an AI-enabled systems must also address the privacy (49) of data and the transparency (50) of the processing to mitigate human bias.

Conclusion

The NAS and European airspace are complex, and essential parts of the critical infrastructure sectors. The disruption of new users, technology and persistent and emerging challenges will continue to challenge our ability to effectively manage the airspace of the future. The application of emerging technologies, like artificial intelligence, may provide capability to leverage opportunities and mitigate risks to reduce the impact on NAS and European end-users in the future. This paper simply identifies

critical areas and proposes some ideas to drive further discussions. By addressing the application of AI in the NAS now, we can, as a community, make informed decisions about the path forward to an *intelligent* NAS (*i*NAS).

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