

Increasing Air Traffic Management efficiency by integrating manned aviation with unmanned aviation at civilian air traffic control tower

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Abstract: *The paper tackles the airspace integration of unmanned aviation with manned aviation within the Romanian airspace, a topic with a large coverage within Romanian society but insufficiently covered at the academia level and without a ConOps tailored for Romania. Article 8 of Chicago Convention and the geostrategic situation at the Black Sea are the main drives for researching a more efficient solution to integration. The research simulates the real unmanned flights done at scale in controlled and uncontrolled airspace with manned aviation flights at LRBC to identify best flight procedure, airspace design and ATCo capacity with the hypothesis that the two airspace users could be safely integrated. Agent based fast modelling is used to demonstrate how and in what conditions the unmanned aviation could be integrated with manned aviation in CTR. Data is collected from unmanned flights and BADA database provided by EUROCONTROL which are enough for the purpose of the simulation. Changes in variable values will determine what operational procedures, airspace design, certification and opportunities for automation of the ATM system are necessary. The research scope is to find the best present solution to safely integrate manned aviation with unmanned aviation, proposing a holistic air traffic management approach having as principles minimum system and technology changes.*

Key Words: *ConOps (Concept of operations), manned and unmanned aviation integration, drones, agent based fast modelling, air traffic controller, drone operator, air traffic management*

1. INTRODUCTION

The research has its roots in one of the main national responsibility for civil aviation, derived from article 8 of Chicago Convention signed on 7th of December 1944, which states: “No aircraft capable of being flown without a pilot shall be flown without a pilot over the territory of a contracting State without special authorization by that State and in accordance with the terms of such authorization. Each contracting State undertakes to ensure that the flight of such aircraft without a pilot in regions open to civil aircraft shall be so controlled as to obviate danger to civil aircraft.” [1] An old statement with relevance in present times, as in recent years managing drones within the airspace has become an opportunity and a concern. The air traffic management organizations and regulatory authorities within civil and military aviation

domain are dealing with ever-increasing requests for airspace usage from unmanned aviation stretching the ATM system capabilities to its limits and revealing system inherent problems.

As geostrategic situation around Black Sea becomes problematic with infringements of drones within Romanian sovereign airspace, posing threats to critical infrastructure and civil aviation, the “hot potato” starts to take a more prominent name and shape:

- Is the ATM system capable of integrating the ever-increasing unmanned aviation with manned aviation? What system changes are needed?

Recent developments in several European countries bring to public attention a series of events where unidentified drones pose threats to civil aviation and show an ATM system left without proper means to identify and manage this non-cooperative airspace user. In these cases, the ATM system only solution to maintain an acceptable level of safety was to shut down airports decreasing operational efficiency on the whole European air traffic network, causing delays and concerns over aviation and public safety.

Events like these could become more dangerous and frequent as the phenomenon cannot be contained and air safety assured without big disruptions. Consequently, NATO and the EU states are obliged to define and operate an ATM system capable to integrate unmanned flights and address the non-cooperative drones as stipulated in drone regulation which is fully developed and implemented to set the stage for an initial integration phase between manned and unmanned aviation.

Within the SAFE (Security Action for Europe) mechanism founded by EU Commission with € 150 billion, there is an opportunity to develop dual-use solutions to cope with non-cooperative UAVs, C-UAS equipment and protection of critical infrastructure being part of category 1 of priority for procurement within the Eastern Flank Watch and European Drone Defence Initiative. Within this framework Romania has at its disposal €16.7 billion to define and operate a drone-wall multilayered, interoperable and integrated with border countries to have a full situational awareness over its territory, as drone flights usually take place in very low-level airspace, below 120m AGL, a volume of airspace rarely covered by Romatsa R.A radars [2] and even military ones without proper means to detect such a small cross-section.

Addressing the non-cooperative drones by controlling, countering or denying them not only brings safety but also efficiency within the ATM network by avoiding unnecessary delays and airport closure that disrupts whole European ATM system. These new capabilities came to close a gap inherent to the ATM system which cannot properly integrate the unmanned aviation and deny non-cooperative flights for the moment, a gap in technology and procedures that are subject to this research paper.

The research addresses the ATM system and its components; ATS (Air Traffic Services), ATFM (Air Traffic Flow Management) and ASM (Airspace Management), performed at tactical level of coordination [3], determined as being the most relevant for drone operations in the ATM context. At tactical level all these functions are performed by Romatsa R.A in close coordination with COA (Operational Air Component), applying the principals of FUA (Flexible Use of Airspace) in safely and efficiently using national airspace resource.

Defining what needs to be changed to effectively integrate manned aviation with unmanned aviation is part of the Concept of Operations for unmanned flights within Romanian airspace, which has its roots in Corus XUAM [3] CONOPS developed by SESAR initiative. Being a comprehensive document, it critically observes the current state of integration of drones within the European ATM network and through research and development projects define solutions for ATM system adaptation to current and future airspace user’s needs.

At Eurocontrol level U-ELCOM [4] project provides necessary guidance for initial drone integration with manned aviation, being a civil-military organization is focused on dual-

use technology as drives for ATM system changes, in recent years border between civilian and military air activity is blurred by technology and operational developments.



Fig. 1 Levels of integration between ATM and U-space [3]

Moving to level U3 or U4 of integration requires automation and new technology like; automatically request flights approval and re-approval or to track the drone flights drones. SAFE mechanism being seen as the right financial opportunity for integration and implementation of technology around European ATM network, capable of providing a RAP (Recognized Air Picture) on the Low-level Airspace and around critical infrastructure.

Scalability of the UTM (Unmanned Air Traffic Management System) system and dual use technologies are principal Key Performance Indicators/KPI for UTM design and development, as new demands will extend the airspace volume demand for drone operations with a blurred border between civil and military activity.

The CONOPS for Romania starts with defining the current stages of integration which in this case are specific to level U1 for general drone flights and U2 for STATE flights [3], some U-space services are available for drone operators as: electronic registration, electronic identification, geofencing and aeronautical information service provided by Romatsa R.A and with possibility for STATE drones to be supported by C3 (Command, Control, Communication) modules which provides U-space services specific to level U2 of integration: automatic authorisation, drone flight plan tracking and mission compliance monitoring. Consequently, Romania it is the initial stage of integration between manned and unmanned aviation as seen in the figure below. Increase in operations efficiency come from integration and development of new U-space services for drone operators.

As the research started at LRBC with the intent to move to all the TWR in Romatsa R.A, can be observed a current analogical way of approving flights in CTR which is labour intensive for the drone operators and air traffic controllers. Airspace requests necessitate a long analysis and a negotiation process between civil and military air traffic controllers to assure the air safety with a high probability of human error caused by lack of situational awareness at drone operator level. There are many instances where the drone operator is not be able to fully grasp the aeronautical information relevance for its drone flights, in this context separation between manned aviation and unmanned aviation is assured by segregating the operations in time and space, segregation being the lowest form of integration with marginal efficiency for drone flights and with increased workload for air traffic controllers.

Being designated as a low priority airspace user in a CTR environment, drone flights are terminated or delayed when the workload increases, and operational complexity is high to ensure air safety or to follow procedural control of the airspace. FUA does not apply in LRBC CTR for civilian drone flights when military activity takes place, a rule that shows the lack of ATM system capability to precisely determine and control drone flights in CTR when military flights use the airspace below 120-meter AGL (Above Ground Level), thus decreasing civilian drone flights efficiency.

For STATE UAS there is situational awareness built at military ATS unit, both military manned and unmanned flights being backed by technology and certification, meeting NATO STANAG 4586, 4609, and 4671 requirements [5]. All military drone pilots being certified by AAMN (Military Aeronautical Authority) and the UAS platforms meeting NATO STANAG requirements.

As observed from data collected, STATE UAS perform tasks that are driven by two cycles (Fig. 2) which are complementing each other - the intelligence cycle and the targeting cycle. Both are part of tasks that provides actionable intelligence for police, troops, or other agencies meant to produce effects over designated targets, thus making STATE UAS flights very dynamic in nature.

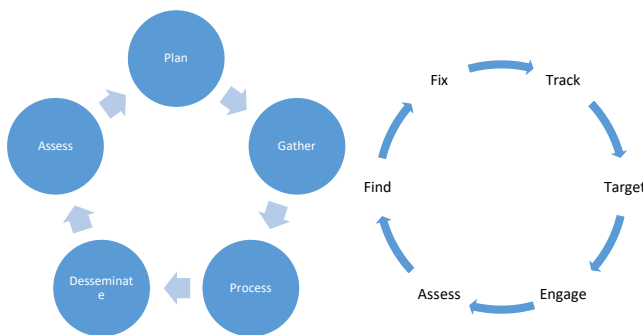


Fig. 2 Intelligence and targeting cycles

As observed in CTR Bacău STATE UAS flights are specific in operational category and performed with high end UAS technology like DJI Matrice 350T which support LTE transponder for BVLOS flights capable of delivering a RAP at military ATS unit and inform civilian ATS. UAS platforms like DJI Matrice 350T used for military ISTAR (Intelligence Surveillance Targeting and Reconnaissance) purposes being a very capable platform. At a cost of € 10.000 with a 55-minute maximum flight time per battery the UAS platform streams the information collected from multiple sensors to the C3 centres. Thus, a long planning phase and inconsistency of airspace allocation decrease efficiency of commercial and military UAS lowering industry expectations for future development of technology in an ATM environment that cannot fully integrate manned with manned aviation.

UAS ConOps for Romania shows drone airspace demand, technology availability and use-cases identified in collected database. A multiannual drone flights data from multiple Romatsa R.A ATS units constitute a necessary and sufficient database to evaluate trends and identify opportunities for further research and development.

1.1 Database

For the moment drone flights database is collected from LRBC TWR, being the ATS unit with civil-military specificity and a medium to low operational occupancy, making it a perfect candidate for observing the current analogical integration of manned and unmanned aviation. Data collected so far shows a multitude of use-cases for unmanned flights - recreational, operational, agricultural works, inspection of infrastructure or cartography. These use-cases have different airspace demands and are operated as VLOS (Visual Line of Sight) or BVLOS (Beyond Visual Line of Sight) with air safety being assured by segregating the operations at

air traffic controller level and by applying SORA (Specific Operations Risk Assessment) [6] at drone operator level.

From year 2022 almost 400 drone flights took place in LRBC CTR which does not represents a relevant sample for the whole Romanian ATM system, an extension of data collection ATS units is needed. Extension of data collection makes the research relevant for the entire ATM system and showing patterns, gaps, and different ways of assuring air safety within the legal and procedural framework.

Usage of a multitude of civilian UAS platforms increases the integration complexity for the civilian ATS unit, knowing each platform capabilities is necessary to determine the air and ground risks associated with each drone and how it performs in given weather condition. UAS manuals and procedures are necessary database to define system workflow and capability limits and combined with specific maps and weather data represent an opportunity of automation of SORA process at drone service provider level/ USSP (UAS Service Provider) [7].

BADA database provided by Eurocontrol [8] is used to replicate manned aviation characteristics in simulation, being one of the most accurate and complete aircraft databases used by research and development institutes and other interested parties in the aeronautical domain all over the world.

CTR airspace design and aeronautical information data [2] provided by Romatsa R.A for civilian air traffic and COA for military ones, complete the CTR environment for a synthetic representation of air traffic in CTR.

To determine the CTR capacity to integrate manned aviation with unmanned aviation BlueSky [9] ATC simulator is used. Being an open-source tool with the possibility to modify the simulated environment and compatible with BADA aircraft database. BlueSky ATC simulator is determined for the scope of this research a capable tool to determine CTR capacity.

2. METHODOLOGY

The research methodology is mixed with both quantitative and qualitative methods being used to identify the best solutions to integrate manned aviation with unmanned aviation, the ATM system components being both technical and human related. For the scope of the research a methodology similar with CAPAN, developed and owned by Eurocontrol, used to determine capacity at ACC (Area Control Centre) and TMA (Terminal Area) level. This methodology is pattern is chosen for the scope of this research is not airport capacity, which is usually used in determining TWR capacity, but the volume of airspace within CTR that is used by manned and unmanned civil-military flights. In this conditions CTR performs as a TMA with IFR traffic and a lot of VFR traffic simulating drone flights.

For the scope of the research the following variables are defined. Air safety is assured if capacity is below 70% [10] in CTR Bacău, triggering UAS flights cancelation if needed, to assure ai safety. If capacity is reached often, at a value not established yet, then there are meet the conditions for automated subsystems like CISP (Commun Information Service Provider) and USSP (UAS Service Provider) [7] to reduce civil ATC workload following military ATS example.

For simulation purposes UAS VLOS and BVLOS flights will be subjected to VFR minima, with BVLOS flights subject to conspicuity in CTR.

Runways protection zone will be permanently designated as no-fly zone for UAS, thus making CTR a volume of airspace where maned flights are constant and ATC workload for dealing with manned operations is constant in value. UAS flights will change capacity levels,

use-cases and airspace demands will define the workflow and ATC workload to efficiently integrate manned with unmanned aviation [11].

Current ATM system gaps will be identified during capacity simulation and will represent opportunities for automation and technological improvement. An example of a formula is presented below and shows the vastness of ATM system which uses complex variables.

$$C = f(W, S, T, E, P) \tag{1}$$

C = capacity of CTR,

f = represents a complex function that models the non-linear relationship between the factors,

W = is controller workload, which is the most critical variable,

S = is the set of sector characteristics (eg. size, layout),

T = is the traffic characteristics (eg. density, complexity, flow patterns),

E = represents the operational environment (eg. weather, regulations),

P = represents the controller team composition and proficiency.

To simulate ATM system at tactical level, there is a need to define two agents to run the system processes and workflow of the system within the modelling; one is the air traffic controller and the other one the drone operator. Both with complex tasks and linked to create situational awareness being feed by the same information within the CTR environment.

In figure below a notional ATCo process is defined for the air traffic controller agent. It shows how it gains situational awareness feed by data take decisions and execute to assure air safety and efficiently conduct air operations.



Fig. 3 ATCo process. Study

ATCo process shows how complex the operations in CTR are and how hard situational awareness is gain in an operational environment with multiple airspace users with different tasks and purposes. Human error is a constant threat to air safety and multiple layers of redundancy are needed increasing capacity usage when automation do not provide layers of redundancy [12], [13], [14].

The drone operator is the second agent, a certified one, trustworthy and competent performing tasks like surveillance, targeting, policing, SAR, infrastructure inspections.

Having these two agents defined to reproduce system workflow and processes, thus conditions are set for simulation to identify opportunities for automation in the workflow and technological advancement for systemic improvements.

3. FUTURE RESEARCH AND DISCUSSIONS

Defining a Concept of Operations for UAS usage of Romanian airspace based on data collected from multiple TWRs produce a relevant and comprehensive picture over the UAS flight, both civilian and military within Romanian airspace. Corus 4 XUAM clearly defines the ATM system requirements to integrate manned aviation with unmanned aviation at U3 level of integration, which meet the level of ambition of this research that tries to define Key Performance Indicators for the ATM system to integrate unmanned aviation at level U2 at best level U3. This level of ambition is below European ConOps [3] which necessitate a lot of systematic and technology changes which for the current UAS airspace demand in Romania is considered non-feasible and is not the scope of this research.

Fast modelling simulation will determine CTR capacity will determine the number of specific drone use-cases that can be managed by air traffic controller in usual IFR traffic conditions and as the agent-based modelling provides systematic improvements within ATM capacity could increase by validation of new automation and technology improvements.

4. CONCLUSIONS

For the moment the ATM system can cope with the increasing unmanned flights requests with minimal disruptions for the UAS operators and with air safety assured by segregation in time and space. More data needs to be collected from unmanned flights in CTR to have a real picture over the current situation at national level.

This study provides a framework to work on in developing the ConOps tailored for Romania, with unique solutions provided by simulation and operational expertise. Personal experience in the operational environment brings a unique opportunity to see integration from both perspectives; as an air traffic controller and as a drone operator a valuable insight in assessing the qualitative variables of the research.

The ATM system shows its limitations when addressing UAS BVLOS operations, as they are high risk ones without proper measures to mitigate risks at this stage. Automation of processes like drone flights approval requests, dynamic reconfiguration of airspace, SORA methodology and conspicuity technology for BVLOS drones are systemic changes that are identified as needed for further integration of manned aviation with unmanned aviation.

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