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OPERATION SCENARIOS OF UNMANNED AIRCRAFT SYSTEMS INTEGRATED INTO THE KOREAN NATIONAL AIRSPACE SYSTEM

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Abstract

This paper proposes scenarios for operation of unmanned aircraft systems integrated into the Korean National Airspace System (NAS) by any operator that is capable of meeting the requirements. The Korean NAS in the timeframe of this paper sees introduction of several key enabling technologies including ADS-B, GBAS, SBAS, and BLOS communication. Each of these capabilities is considered in describing the scenarios. Detailed tasks to do in successive missions in the scenario, from certification to ground operation, for the target UAS are given.

1 Introduction

Unmanned Aerial System (UAS) is used to be applied in military purposes when it was in the quickening period. In this days, however, development of associated technologies and increase of civil demand on UAS lead rapid growth of civil application and market of UAS. The civil application of UAS includes shipment, agriculture, police hunt, surveillance, rescue and recovery missions. According to this rise of demand, the scale of the market is growing steadily. For instance, Teal group - an American professional consulting company for defense industry - expects the scale of global UAS industry will rise over 10% per each year, from 2014 to 2023. Especially, the percentage of civil application in this market will grow up from 1% to 7%, which means 35% of growing per every year.[1] Federal Aviation Administration (FAA) also predicts that civil UAS demand will exceed military's UAS demand after 2028.[2]

Meet to this global increment of demand and market value, research and development (R&D) over various field of UAS such as guidance, navigation and control have been conducted. Recently, however, combining UAS into National Air Space (NAS) becomes remarkable issue in both social and academic area. FAA published the concept of operations (ConOps) document[2] which describes set of operations of UAS in NAS by civil and public operators in 2012. In case of International Civil Aviation Organization (ICAO), they published a manual on Remotely Piloted Aircraft System (RPAS) in 2015, which suggests an international regulatory framework to manage RPAS. Moreover, as a part of Aviation System Block Upgrade (ABSU) project, ICAO aim to realize international controlled flight of UAS in NAS before 2028.[3] Ministry of Land, Infrastructure, and Transport of Korea also prepares integration of UAS in their own NAS based on ASBU project.

This paper describes operating scenarios of UAS in Korean NAS. So the background research about Korean NAS is preceded. The target of the scenarios is limited to UAS which has weight over 150kg. Complete integration of a UAS in existing NAS is expected after ten to fifteen years later, so we assume that the expected environment of operating UAS is more advanced. Concretely, we regard the technologies such as ADS-B, GBAS, SBAS, BLOS communication technologies are already commercialized in the scenarios. Basing on these background research and assumptions, we partition the operation into 5 phases – 1) certification phase, 2) path planning phase, 3) ground mission phase, 4) flight phase which based on specific purpose, 5) Landing phase. The research result and series of scenarios can act as a guideline of henceforth research and development of a combined system of UAS and manned aircraft.

2 Korean NAS

2.1. UAS Airworthiness Certification

Airworthiness certification is a certification process which inspects whether an aircraft has appropriate stability and reliability. This is necessary to both civil and military purpose aircraft. The target UAS system of this paper which has weight over 150kg is not classified to a flying device but a small airplane. This weight limitation is generally used in UAS classification in many nations such as USA, UK, Italy, and members of NATO (North Atlantic Treaty Organization). When a UAS classified into this grade, we can regard the UAS as a latent hazard which can harm people or property.

Table 1. List of UAS related STANAG

STANAG Code	Application Criteria	Note
4671	- Fixed wing UAS - MTOW 150~20000kg	- For military - 399 rules - Part 23 based
4703	- Fixed wing UAS - MTOW < 150kg - Collision energy under 66J	- For military - Hazard Reference System under MTOW - Light version of 4671
4702	- Rotary wing UAS - MTOW 150~3750kg	- For military - 297 rules - CS-27 based
4746	- Rotary wing UAS - MTOW < 150kg	- For military - Inherit STANAG 4703
4586	- Communication interface b/w Air and surface Component of UAV	

Thus airworthiness certification is necessary for target UAS system. In addition, UAS over 150kg is considered to be capable of long range flight which requires integration of airspace.

The well-known examples of UAS airworthiness certification are Certification Specification of Light Unmanned Rotorcraft Systems (CS-LURS) and STANdarization AGreement (STANAG). They both inherits CS-27, which is generated by European Aviation Safety Agency (EASA) to certificate UASs lighter than 3175kg. The CS-LURS is enacted by Joint Authorities for Rulemaking of Unmanned Systems (JARUS). This set of regulations is composed of 210 rules, which are subdivided into flight rules, solidity rules, equipment rules, GCS rules and etc. STANAG is set of documents which delineate military or technological rules among NATO member countries. Especially, STANAG 4586, 4671, 4702, 4703, and 4746 are related to military UAS certification. The details of each are shown in table 1.

In Korea, airworthiness certification on UAS is in its initial step. There are only two certification examples. The first example is TR-100, also known as Smart UAV. This UAS is not certificated by a regular certificate which is specified by Korea civil aeronautics law item 2 of Art. 17 but obtained a special airworthiness certificate. The special certificate is issued when stability and reliability of the airplane are satisfied under limited conditions such as research or development. The second example is Camcopter S-100, which is certificated by STANAG 4586. As table 1 explains, however, STANAG 4586 is certification about data link, command and control, and human/computer interfaces between UAV Air Component and UAV Surface Component but not a certification about stability and reliability of UAS itself.

In consequence, there is no example which conducts regular airworthiness certification on civil UAS.

2.2. Korean National Airspace system

2.2.1 Korean Air Control Zone Definition

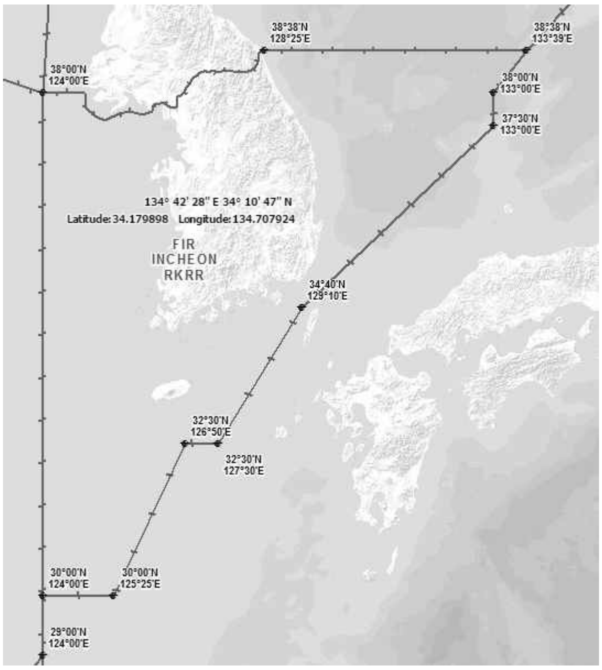

Fig. 1 Covering region of Incheon FIR

As a definition of airspace under ICAO, global airspace is divided into sub units which are called Flight Information Resign (FIR). In a FIR, the host of the FIR has responsibility to offer flight information to all aircrafts which

Table 2. Classification of Korean NAS

Air Space Class	Allowed	Provided Service	Provided Separation
A	IFR	Control	From each other
B	IFR	Control	From each other
	VFR		
C	IFR	Control	From IFR&VFR
	VFR		Separation from IRF&info Advisory regarding others
D	IFR	Control	Separation from IRF&info Advisory regarding others
	VFR		Information regarding other flights
E	IFR	Control	From IFR & Information regarding others
	VFR	Information	None
F	IFR	Information Advisory	Separation from IFR
	VFR	Information (on request)	None
G	IFR	Information (on request)	None
	VFR		

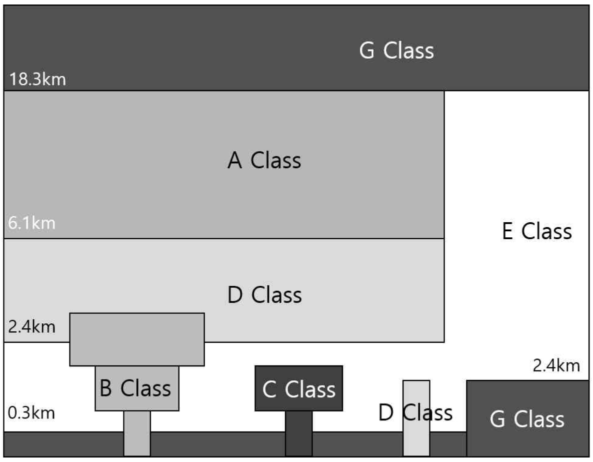

Fig. 2 Korean NAS

traversing the FIR. The main control center of a FIR is called Air Traffic Control Center (ACC) or Air Route Traffic Control Center (ARTCC), and it is subdivided to several Approach Control Centers (ACs). In case of Korea, whole national airspace composes of one FIR, called Incheon FIR which is controlled by Incheon ACC located on Incheon National Airport. The ACC belong to Ministry of Land, Infrastructure, and Transport's Korea Office of Civil Aviation. This Incheon ACC is segmented to 8 control sectors and 14 ACs. Finally, the aircraft traffic control task is given to 23 local Control Towers. This composition of Korean Air Control Zone, Incheon FIR, is shown in Figure 1.

2.2.2 Korean National Airspace System

Korean National Airspace is classified into A to G class, which is based on Korea civil aeronautics law item 1 of Art. 116-2. The law specifies each class of airspace as Table 2. and Figure 2. shows.

Class B, C, D airspaces represent airspaces near airports. Thus they called Air Control Zone in another name. The size of the airport determines the class of airspace and the information offered from each ATC. There are 29 airports in Korea and 3 of them such as Incheon, Gimpo, and Jeju airports are an international scale which is included in Class B airspace. 11 middle size airports such as Seosan, Gwangju airport are classed as Class C and the remnants are Class D.

Table 3. Detailed Work of ATFM along aircraft position

Position	Management	Detail
On ground	Surface Operations Management	Rapid irregular operation recovery Surface movement optimization Automated Airport CDM
Departure & Climb	Departure Flow Management	Optimized Taxi routes Minimized departure queues Overhead traffic flow merging
EN Route Cruise	Traffic Flow Management	System-wide efficiency Airline CDM slot substitution Trajectory-based operations support
Descent & Approach	Arrival Flow Management	Optimized arrival sequencing Arrival capacity optimization En route delay reductions
On ground	Surface Operations Management	Complete situational awareness Predictive gate conflict detection Reduced taxiway queuing

2.2.3 Air Traffic Flow Management

Air Traffic Flow Management (ATFM) is a business aim to avoid overflow of airport handling capacity or air traffic controlling capacity. Under this purpose, ATFM center monitors demand of airport and real-time air traffic, and predicts possible overflow of air traffic managing capacity. When the possible air traffic overflow is perceived, appropriate flow management treat is offered.

In Korea, Air Traffic Flow Management operates according to its operational regulation which is established by enforcement regulation of Korea civil aeronautics law item 17 of Art. 210-2. The control center of ATFM is Flow Management Units (FMUs) which located in Seoul, Jeju ACs and Incheon, Gimpo, Jeju Control towers. According to operational regulation item 17 of Chap. 4, all aircraft desire to perform Instrument Flight Rules (IFR) has to submit flight plan at least one hour before the flight. If one does not submit the plan, priority of desired flight plan could be arbitrarily adjusted by ATFMC. When possible air traffic excess is predicted, air traffic managing telegram will be sent to corresponding airports and FMUs. The details of ATFM based on flight status is shown in Table 3.

2.3. Supporting Technology

2.3.1 ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is an active communication method which an aircraft uniformly transmits its ID information, position, velocity, destination of the flight, and etc. Differ from existing Ask-Question communication method, information of ADS-B is based on GNSS system rather than radar, which can provide more precise navigation data. Furthermore, information of the aircraft is transmitted to air traffic controller, nearby other aircraft, ground mission state aircraft simultaneously. This allows ADS-B applied to air traffic control system to prompt and precise data communication.

This system is almost necessary to perform self-positioning and collision avoidance of UAS in the ground mission, taxi mission, and flight mission. Because existing aircraft control system which is based on radio contact and radar is not capable of detecting UAS in low altitude trajectory. According to this superior performance, America will obligate all aircraft and ground control systems to install ADS-B system from 2020. In case of Australia, ADS-B system is completed to commercialize on all of their territory over 30,000 feet altitude. China also operated test mission to verify the performance of ADS-B system since 2007. In Korea, the system is installed in Goheung aviation center and used in test missions of UASs or small aircraft.

2.3.2. GBAS, SBAS, ILS

Ground-Based Augmentation System (GBAS) and Satellite-Based Augmentation System (SBAS) are used to compensate position error of GNSS information. In order to compensate the error, GNSS uses error correcting data from a ground control system and SBAS uses data from a satellite. The introduction of GBAS can improve the performance of landing of UAS, and SBAS can improve overall navigation performance during beyond line of sight (BLOS) flight of UAS. Over 80 global airports installed GBAS and other 30 are plan to install GBAS to supply takeoff and landing mission of an aircraft. In case of Korea, GBAS is installed in Gimpo airport to test the system.

Instrument Landing System (ILS) is an alternative system which can support takeoff and landing mission. This system consists of localizer receiver, glideslope receiver, marker beacon to measure angle and distance between runway and aircraft. This system can cover only one runway at once, and limited in takeoff and landing mission. This system is already commercialized and installed on airports mostly, so UAS can use ILS to operate takeoff and landing mission immediately.

3. UAS Operation Scenario

3.1. Target UAS Description

The target UASs which are used in civil instrument and correspond to weight limitation of this paper are CTLS of Korean Aerospace Research Institute and 500MD of Korean Air. The two UASs are representatives of fixed wing UAS and rotary wing UAS. The detailed Description of two UAS is shown in Table 4.

3.2 Operation Scenario

Operating scenario of UAS is subdivided into several phases as mentioned in the introduction. The summary of the full mission is shown in Table. 3.

3.2.1. Certification

Table 4. Target UAS describtion

Name	**CTLS**	**500MD**
Developer	KARI	Korean Air
Aircraft Type	Fixed wing UAS	Rotary wing UAS
Dimension	Main wing : 6.8m Fuselage : 6.6m Height : 2.3m	Length : 9.39m Width : 2.65m Height : 8.05m
MTOW	600kg	1364kg
Max. speed	222 km/h	280 km/h

As discussed in subsection 2.1, every UAS has to be certificated under appropriate criteria such as STANAG or CS-LURS. Before the flight, certifications of UAS, GCS and pilot have to be completed. Certification of UAS and GCS can be fulfilled by applying rules such as rules introduced in section 2.2.1.

However, under current Korea civil aeronautics law, there is no official certification of UAS pilot. Korea civil aeronautics law item 1 of Art. 25 which defines qualification of flight practicians. For example, Korean Airline made an announcement of recruitment of UAS pilot in 2015. However, the requirements of applying were private pilot license and experience of operating Radio Control (RC) airplanes. The requirements are not a direct certification for the ability to conduct UAS but indirect ones. This is because there is no exclusive certification of pilots who manipulating UAS in Korea.

3.2.2. Flight mission planning

All aircraft flies in an airspace has to submit

Table 5. Operation scenario of UAS in Korean NAS

Mission	Airspace	Summary
Certificaation	-	- Preliminary certification about UAS, GCS, Pilot. - All component has to be certified to operate the system.
Flight mission Planning	-	- Decide Detailed mission - Communicate with ATC, ATFMC and renew the plan.
Ground Operation and Take off	Goheung Airport (Class D airspace)	- Move into runway - Combine with existing runway traffic sysem
Specified missions	Depend on mission	- Point-to-point mission - Surveillance - Pattern Searching
Loiter and Landing	Class B, C, D Airspace	- Maneuvering in high traffic airspace - Loiter
Ground Operation and UAV return	Class B, C, D Airspace	- Land on activated runway or landing field - Taxing or transportation to hanger of UAS

flight operation program at least 48 hours before the flight. Submitted flight program includes initial 4D flight plan which represents the intent of the flight. After submission of the plan, ATC evaluates the effect of the flight on NAS to determine whether aircraft clearance and separation service are necessary or not. At the same time, ATFMC predicts the effect of the flight on air traffic and potential hazard of collision. As a result of evaluating the plan and prediction of air traffic condition, ATC and ATFMC can offer an alternative plan. And the flight planner can accept the alternative or suggest a new alternative plan. These series of communication among the flight planner, ATC, and ATFMC occurs until 2 hours before the flight and the final 4D flight plan is decided.

3.2.3. Taxi and Take off

When the UAS is in taxi mission, the UAS pilot requests ATC to activate a runway. Answer to this request, ATC check other airplanes in waiting and potential hazard of collision. After checking, initial taxi route is given to UAS pilot and UAS starts to taxi. During taxi, potential conflict situation such unexpected and do-not-response airplane on initial route. In this case, ATC suggests an alternative route and UAS pilot will follow the new route to avoid a collision.

After taxi mission, the UAS pilot waiting for a clear sign from ATC. When the clear sign is given, the UAS pilot activates take off sequence and take off.

3.2.4. Specified Missions.

After take-off, the UAS begins to climb up until it reaches to target altitude and pre-determines mission maneuver is started. In this paper, three specific mission is considered. They are point-to-point mission, surveillance mission, and pattern searching mission. Missions of UAS are basically operated in IFR flight, which means separation service of ATC is always given to the UAS. In IFR flight, the UAS is served separation services from ATC so that any modification of flight path from initial flight path needs confirm of ATC. During IFR flight, ATC and ATFMC monitor potential chance of collision and air traffic to optimize operation efficiency and traffic margin of NAS.

3.2.4.1 Point to Point mission

The point-to-point mission represents a move from one airport to another airport. In the scenario, departure airport is Goheung aerospace center, which is not an airport but D class airspace. The destination airport is Yeosu airport which is evaluated as potential UAS integrated airport.

In flight mission planning phase, ATC suggested low altitude IFR flight using E class airspace is appropriate to the mission and the UAS pilot accepted it. In this flight process, the UAS can meet some unexpected situations. One example is deteriorating weather and another is an airplane which is in VRF flight.

In case ATFMC detects high traffic region due to deteriorating weather in prearranged flight path, it informs this traffic to ATC and tries to control air traffic of the region. Answer to the information, ATC generates an alternative path and issues the new 4D path to the pilot. When the pilot faces undetected deteriorating weather region which is judged to be avoided, the pilot can request new path to ATC. According to the answer of ATC, the flight path will be changed or not.

Similar to bad weather region, UAS can meet aircraft in VRF flight. When ATC detects approaching VRF aircraft which have potential collision probability with the UAV, it notifies both pilots. If the separation between two aircraft is sufficient, pilots can maintain their initial route or can choose evasion flight route under See-And-Avoid algorithm or pilots' judgment.

3.2.4.2 Surveillance

When the UAS is planned to perform a surveillance mission, loiter or hovering maneuver has to be included in the flight plan. After flight mission plan is accepted by ATC, the UAS take off and fly into planned operation area. The operation area is class E airspace and ATC provides separation service to the UAS.

Before the transition to pre-planned surveillance maneuver, the UAS pilot calls ATC to request starting mission maneuver. Under acceptance of ATC, UAS starts surveillance mission for scheduled duration.

In case of appearance of suspicious ships or cars, the UAS has to change the planned trajectory and trace the target. The ground agent of UAS reformulates new trajectory to trace the target and report the trajectory to ATC. ATC check the trajectory with surrounding circumstances and accept the plan.

After surveillance mission is completed, the UAS returns to planned airport and starts landing sequence.

3.2.4.3 Pattern Searching

Assuming a ship incident is occurred at East sea of Korea. Authorities of the nation decide to detect mission people and sufferers by UAS. According to the search plan, ATC guides the UAS to the accident scene.

The UAS maintains communication with the unmanned ship and accident control tower to transmit images of the scene and searching result. During searching maneuver, ATC offers separation service to prevent collision of UAVs.

3.2.5. Loiter and Landing

When the individual mission of the UAS is completed, the UAS returns to the airport and performs landing sequence. UAS approached to the pre-determined airport where it will land and requests permission of landing. The airport will give landing permission or instruct loiter maneuver. The loiter maneuver is due to temporary conflict of air traffic is occurred in the airport. The ATC guides the UAS to loiter the airport in fixed altitude and turning radius until traffic is slackened enough.

ATC transmits go sign to UAS when the traffic of airport and the runway is ready. According to the approval, the pilot of the UAS starts landing sequence.

3.2.6. Ground Operation and return

The last part of the scenario is taxi and return to a hanger. Similar to taxi mission before take-off phase, ATC leads the UAS to prepared taxiway and informs possible conflict. The UAS returns to the hanger and the flight mission is completed.

4. Conclusion

This paper described operation scenarios of the UAS integrated into the Korean NAS. After a detailed introduction to NAS, ATFM, and supporting technologies in Korea, operation scenarios for the target UAS are given. The missions include certification, flight mission planning, ground operation and take off, specified missions, loiter and landing, and ground operation and return. As a future work, the scenarios will be assessed in aspects of access and equity, efficiency, safety, security, and environmental impact.

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