Journal of Convergence for Information Technology
Vol. 11. No. 9, pp. 35-42, 2021
e-ISSN 2586-4440
DOI : https://doi.org/10.22156/CS4SMB.2021.11.09.035

Safety Risk Management Policy of United States small unmanned aerial system

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미 소형 무인비행체계의 안전성 위험관리 정책

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Abstract The purpose of this paper is to review the small unmanned aerial system (sUAS) safety policy promoted by the United States(US) government. Therefore, in this paper, along with sUAS risk factors, the risk factors of sUAS that the US government is interested in are described. In addition, the risk factors were classified into physical and non-physical factors, and provisions mentioned in the Federal Aviation Administration(FAA) Relicensing Act were reviewed. Other risk scenarios were analyzed focusing on target scenario items that the FAA is interested in, such as flight operation disruption, infrastructure damage, and facility trespassing. Of course, we looked at the risk management principles promoted by the US FAA. In this paper, as a research method, the direction and contents of the FAA's sUAS policy were studied and reviewed from the analysis of major foreign journals and policy. In the research result of this paper, by analyzing the FAA sUAS safety risk management policy, the integrated operation and safety policy, physical risk management policy, operation and safety regulation, and sUAS policy and technology direction necessary for establishing the sUAS safety risk management guide in Korea are presented. The contribution of this study is to identify the leading US sUAS safety policy direction, and it can be used as basic data for deriving future domestic policy directions from this. Based on the research results presented in the future, policy studies are needed to derive detailed implementation plans.

Key Words : Safety, Security, UAV, Risk, Operation

요 약 본 논문의 연구목적은 미정부가 추진하는 sUAS 안전성 정책을 검토하는 것이다. 그래서 본 논문에서는 sUAS 위험 요소와 함께 미 정부가 관심을 가지는 sUAS의 위험 요인들에 대해 살펴보았다. 아울러 위험 요소는 물리적인 요소와 비 물리적인 요소에 대해 분류하였고, FAA 재허가법에서 언급하는 조항들을 살펴보았다. 그 외 위험 시나리오는 비행 운영 방해, 인프라 구조 피해, 시설 무단침입 등 FAA에서 관심을 가지는 대상 시나리오 항목을 중심으로 분석하였다. 물론 미 FAA가 추진하는 위험관리 원칙을 살펴보았다. 본 논문에서 연구방법은 국외 주요 저널 분석과 정책 분석으로부터 FAA의 sUAS 정책방향과 내용을 연구 검토하였다. 본 논문의 연구 결과에서는 FAA sUAS 안전성 위험관리 정책을 분석함으로써, 국내에 sUAS 안전성 위험관리 가이드 수립에 필요한 운영과 안전성 통합정책, 물리적인 위험관리 정책, 운영과 안전성 규정, 그리고 sUAS 정책과 기술 방향을 제시하였다. 본 연구의 기여도는 선도적인 미 sUAS 안전성 정책 방향을 파악하는데 있고 이로부터 향후 국내 정책 방향 수립을 도출하는데 기초 자료로 활용될 수 있다. 향후 제시된 연구 결과를 바탕으로 세부 실행 방안 등을 도출하기 위한 정책 연구가 필요하다.

주제어 : 안전성, 보안, 무인기, 위험, 운영

*This paper is supported of funding of Project of Baekseok University
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Received August 13, 2021 Revised September 6, 2021
Accepted September 20, 2021 Published September 28, 2021

1. Introduction

The Federal Aviation Administration (FAA) expects the number of small unmanned aerial systems (sUAS) to increase to 420,000 by 2021. The number of users of sUAS will increase to 3.5 million to include hobbyists, 3 times increase from the number of unmanned aerial vehicles(UAVs) in 2016. However, this increase in the number of UAVs imposes responsibility on stability and security for organizations. Risk issues in utilizing sUAVs require urgency in establishing policies and strategies for risk management frameworks for sUAVs. In this paper, the interest is in the risk management and safety regulation policies of the sUAS, which are centered on the US government, particularly the FAA. The study of sUAS risks is reviewed as a safety example of sUAS in cities by Michael et al. [1]. This study presents a safety assurance case with the need for safety mechanisms in the airspace. Natasha et al. also studied the risk-based evaluation of small UAS logistics delivery operations in proximity to urban areas [2]. The composition of this paper will conclude related research in Chapter 2, the risks and scenarios of sUAS in Chapter 3, the sUAS safety risk management policy in Chapter 4, and Chapter 5.

2. Related researches

Jeremy et al. also has a study of risk-based planning for sUAS rooftop landings [3]. This study focuses on quickly identifying and evaluating risks to landing points and orbits. Lakshmi et al. studied the issues of safety and risk management for the operation of unmanned aerial vehicles in urban airspace [4]. This study discusses sUAS operations in urban airspace on a risk-based approach. Niklas et al. studied the minimum risk in low altitude of UAS[5]. In this study, we are interested in integrating large drones into national airspace. Fabrice studied the risk-based performance variation and interoperability requirements framework for unmanned aircraft system traffic management (UTM) aviation [6]. Zhaoyue et al. studied UAV aircraft risk identification and evaluation techniques [7]. This study focuses on risk prediction and safety assessment on UAV flight risk management. Xinting et al. studied the risk assessment model for UAV cost effect path planning in urban areas [8]. The study focuses on a comprehensive risk assessment model for safe flight to urban environments. Huang et al. studied risk management and application models of UAVs [9]. This study discusses third-party insurance and related risk management of UAVs. Wang et al. proposes a novel aviation risk analysis technique based on coincidence theory in which probability theory and uncertainty theory are both born [10]. Most of those sUAV risk studies are approached from a technical point of view. Of course, the issue of sUAV risk should be discussed from a policy perspective. Therefore, in this paper, we would like to discuss the policy direction of regarding sUAS safety of the United States government. In practice, the US FAA collects safety-related information related to sUAS, but asks questions about the accuracy and completeness of the data [11]. The real risk of sUAS lies in the fact that manned aircraft pilots cannot clearly identify sUAS and are not captured by radar. Of course, it is not clear whether the FAA official was involved in the sUAS sightings.

Charles et al. review about risk elements and policy of small UAS[12]. This study are presented about risk assessment and mitigation, countermeasure, risk management, risk categories and so on. Jonathan R. et al. analyzed about privacy impact assessment for the small unmanned aircraft systems [13]. This study is analyzed about issues of privacy risk amd mitigation, such as data quality and integrity, auditing, and so on.

3. sUAS risk element and scenarios

3.1 Risk elements

Generally, sUAS hazards can be classified as physical and non-physical hazards in Table 1.

Table 1. Risk elements and measures

Risk	Elements	Risk measure
Physical	Damaged Assets(Drone) (Processor,sensor,communication,SW/Firmware)	Checklist activity/monitoring, (Anti spyware/Malware, blacklist/whitelists)
	Damaged Assets(GCS) (Processor,sensor,ommunication,SW/Firmware)	Checklist activity/monitoring (Anti spyware/ Malware, blacklist/whitelists)
	Bomb, Bio on Chemical materials	Counter IED identification and monitoring
	Aircraft Crash	Checklist activity/monitoring (Counter drone) (blacklists/whitelists)
	Fire	Checklist activity/monitoring (blacklist/ whitelists)
	Safety Zone Violation	Checklist activity/ monitory (blacklist/ whitelists)
Non Physical	Operation security	Checklist activity(Access control) / monitoring
	Privacy	Checklist activity (Access control, Confidentiality Integrity Availability(CIA) /monitoring
	Intellectual property	Checklist activity(IP protection) /monitoring
	Contents of R&D and meeting	Checklist activity of CIA, authentication
	Data related of moving trace	checklist activity of autopilot, monitory
	Data related of disclosure	Checklist activity of CIA, authentication

Physical risks include the risk of damaging assets such as drones or GCS (Ground Control Facility) assets. There is a risk of damage with explosives, biologically damaging materials or other harmful substances. It can cause aircraft interference and cause damage by forest fires or by invading security zones.

Non-physical risks include damaging operational security, privacy and intellectual assets, research and development(R&D) and risks arising from information disclosures, such as documents, or threats to track assets or personnel movements.

Clearly, the US government is particularly sensitive to the collection, use and protection of data operated by public institutions. In this respect, promoting risk management policies for sUAS is a very important issue.

Currently, the US government considers safety, security, privacy and other risk factors. In addition, related agencies, including the FAA, United States Department of Homeland Security(DHS), federal and local governments, are working together to integrate the UAS at a national level.

For example, the FAA 2018 Reauthorization Act contains a number of provisions related to UAS integration, including remote tracking, empowerment of identification requirements, and establishment of a risk-based standard development process for airworthiness certification. The need for airworthiness certification is also raised for sUAS above a certain standard. Currently, all aircraft must be issued a certificate of airworthiness. Type certification data is issued for aircraft models approved by the FAA. In addition, regular maintenance and inspection are required, maintenance or inspection compliance standards are in place, airworthiness guidelines are issued and managed, and management policies are in place.

However, sUAS does not follow the criteria and guidelines applicable to existing aircraft for design certification or related maintenance or inspection requirements. This issue is being assigned to individual operators. The ultimate responsibility for sUAS is based on the operator and his judgment.

To date, most of the risk management designs targeted at sUAS are based on ground or cyber-based access detection and prevention.

However, what is now emerging as a major threat is the design to prevent access from unauthorized aerial threats. The government and public institutions shall determine and prepare specific measures to raise awareness of these risks, establish countermeasures, and implement them.

3.2 Risk Scenarios

sUAS risk scenarios include obstruction of flight operations (military, flight transport, law enforcement, healthcare, energy/oil/gas, other business), infrastructure damage (military, government, energy/oil/gas, manufacturing, communications, other business), facility trespass(military, government, flight/gas, business, etc in Fig, 1.

Obstruction of flight operations, damage to infrastructure, and trespassing on facilities can be caused by malicious and unintentional actors. However, intelligence collection, illegal material smuggling, explosives injection, chemical biological spraying, and assassination can be caused by malicious agents.

However, the risk management process of sUAS can be distinguished into determining-identifying-evaluating-prioritizing-responding-monitoring, reporting, and iterating.

Risk management promoted by the US government defines appropriate roles and responsibilities for safety risk management and complies with the following three principles: The principles are safety risk analysis and resolution, and implementation of controls to mitigate risks, and finally monitor the effectiveness of controls and coordination as needed.

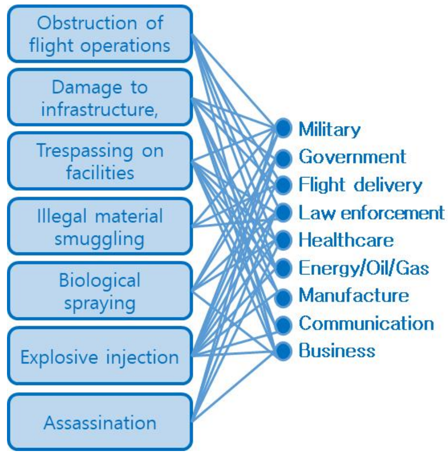

Fig. 1. Risk Types and Applied Area

4. sUAS safety risk management policy

4.1 sUAS operation and safety integration policy

Safety cannot be guaranteed in the operation of sUAS because there are limitations in the collection of information about sUAS sightings and operations. In response, the FAA is reviewing UAS detection and remote identification technologies by promoting the development and operation of a web-based monitoring system. The United States controls UAS operating areas and airspace with a limited overall and onboard weight of 55 bls, and controls operator and pilot licenses based on weight. The operator shall maintain the aircraft beyond a line of sight (BLOS) and the operating hours are also limited [12]. The US Department of Homeland Security Cybersecurity & Infrastructure Security Division plans to integrate programs that provide training, evaluation, practice, and performance-enhancing training for critical security personnel [13]. The US FAA is conducting integrated tasks based on Fig. 2.

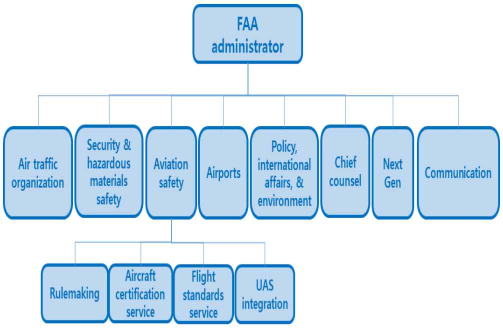

Fig. 2. UAS Integration of US FAA

Details related to the development of the Federal Aviation Administration (FAA) regulatory framework are shown in Table 2.

Table 2. Regulation Framework Development of FAA of sUAS

Item	Contents
Potential impact of property rights in airspace, government (federal, etc.) jurisdiction and regulations on UAS operations	- Discussions on government (federal, state, etc.) complementary and conflictable legal issues (civil UAS operation regulations) - Describe the application, implementation and enforcement of UAS specific laws - FAA and officials' positions on the scope of the FAA authority, its influence, and federal preoccupation of landowner property rights in airspace on land - Present concerns about the use of UAS countermeasures and remote identification (ID) tools.
Additional UAS property rights considerations in airspace	Presentation of rights in assets (property rights) and airspace, private claims against unconstitutional government acquisitions, etc.
Considerations of personal privacy rights related to UAS under government (Federal, State) Act	Presentation of legal considerations, privacy issues, legal countermeasures, additional protective measures, etc. on the impact of UAS operations on personal privacy
UAS related laws, resolutions and executive orders	Summary of UAS laws, resolutions, and executive orders
Evolution of property rights in airspace	Provide background for evolution of private property rights in sUAS operating airspace and explain the impact of manned aircraft on development of airspace property rights

For low altitude flights, the US government's efforts to integrate national airspace relate to the drone traffic management system, and National Aeronautics and Space Administration(NASA) and related industries are working together. The pilot has been completed and is pushing for a technology evaluation and implementation plan based on the results. For safe integration of drones, the FAA is pushing for legislation or technology and policy-making, and legal issues regarding drone jurisdiction and privacy issues are developing safety and security requirements from the US federal perspective. Of course the requirements are fluid. The FAA Reapproval Act (2018) relates to the regulatory framework for safe integration of sUAS. The focus is on introducing sUAS into the national airspace system. The federal government is developing key aspects of UAS requirements. The US Department of Transport is conducting legal discussions through a team of lawyers' task force on how federal priority and jurisdiction-related principles will be applied to UAS. Currently, unresolved legal issues discussed in low-altitude UAS operations include: It includes the impact of legally protected property rights on governments (federal, state, local), federal preoccupation of regulations affecting UAS operations, responsibility of landowners against trespassing, adequacy of federal and privacy laws, and establishment of additional measures required by governments. The national sUAS airspace regulation framework includes, as shown in Table 3, whether legislation is defined, permits for the use of specific airspace, pilot training and qualification, permits operations in beyond line of sight(BLOS) areas, limits airport proximity, and requires registration.

Table 3. Comparison of sUAS regulation on each nations

item	US	China	Germany	Israel	Poland	South Korea
Legal compliance	⦿	⦿	⦿	⦿	⦿	⦿
Specific airspace use permit	⦿	⦿	⦿	⦿	⦿	⦿
Pilot training	⦿			⦿	⦿	⦿
BLOS operation permit	⦿	⦿	⦿		⦿	⦿ (Approval)
Altitude limit	⦿		⦿	⦿		⦿ (150m)
Airport proximity limit	⦿	⦿	⦿	⦿	⦿	⦿ (Radius 9.3Km)
Registration necessity	⦿	⦿				⦿ (Business)

4.2 Physical risk management policy

The physical anti-drone policy is to establish measures such as dynamically impacting aircraft flying across the fence line, and to come up with countermeasures. This requires monitoring of illegal flights and monitoring of deliveries to sUAS. Of course, a risk management framework should be established to illegally transport drugs using sUAS or to prepare for internal and external UAS risks.

4.3 sUAS operation and safety regulation

It can refer to Table 4 below for the US government's regulations on sUAS.

Table 4. sUAS Regulation of US Government

Regulation	Contents
B-330570	Jurisdiction, Property and Privacy Legal Issues, Current Drone Legal Issues
GAO-20-29	Improve FAA compliance, enforcement approach, and FAA safety risk management
GAO-20-97	Drone Integration Improvement Testing Program, FAA Compliance and Enforcement Access
GAO-20-136	Improved drone cost information, considering recovery cost options
GAO-21-165	Implementation of Drone Traffic Management System (Improvement of Communication and Performance Measurement)
GAO-18-110	Improve safety risk management

Where, the Government Accountability Office(GAO) recommends the use of guidance and improvement of drone-related cost information.

4.4 sUAS policy and technology establishment Direction

The following derived policies are based on the FAA GAO guidelines, and it is judged that their validity can be recognized, and the directions are as follows.

The following are representations of the policies and technologies of sUAVs ongoing to address the risks posed by sUAS operations at the national level: Currently, the US FAA is developing policy directions focusing on the following items:

- Airspace design (airspace restrictions and flight separation between sUAS and UAS, flying less than 400 feet, special approval is required for restricted airspace)
- Flight preparation (preliminary checklist - check operating area including local weather conditions, local airspace and flight restrictions, ground human and asset locations, and ground hazards)
- Pilot certification (passing knowledge and skills tests, certification)
- Operator certification (operating permission or application for certification)
- User education and training (relevant information provision, operating principles and rules, airspace rules and procedures related knowledge and technical training, forums, meetings)
- Permanent and temporary no-fly zones (e.g. special no-fly zones within 30 miles of airport)
- UAS certification (FAA certification - including approval of aircraft design, manufacturing and operation, certificate of conformity, FAA requires certification of

manned aircraft, but requires certification for some UAS (type, type of operation))

• UAS registration and indication (FAA requires registration of sUAS for commercial and recreational use, registration number indication)

• Sensor and avoidance system (collision avoidance function, FAA does not require this technology for sUAS, but cooperates with relevant industry to develop standard technology for national use)

• C2 link (providing BLOS and improving reliability)

• Geofencing (classification of areas allowed /unacceptable for operation - setting and defining geographic boundaries, determining whether software-based flight operations are permitted or not, FAA believes that sUAS does not require this technology, but provides a function among sUAS manufacturers)

• Radio frequency(RF) detection (detection of aircraft with radio signals emitted by sUAS, not yet applied by the FAA or federal agencies - due to technical, legal and operational issues)

• Electro optical(EO) detection (detection of sUAS with visible light emitted or reflected by aircraft, not yet applied by the FAA or federal agencies - due to technical, legal and operational issues)

• Infrared detection (gas detection with heat emitted from aircraft, not yet applied by the FAA or federal agencies - due to technical, legal and operational issues)

• Acoustic detection (detection of vehicles through the sound produced by them, not yet applied by the FAA or federal agencies - due to technical, legal and operational issues)

• Radar detection (transmitting radio waves are sent to and reflected from the vehicle and received to detect the vehicle, similar to the principle of aircraft detection, not yet applied by the FAA or federal agencies - due to technical, legal, and operational issues)

• Vehicle deactivation technology (when detecting a vehicle, using physical or electronic means, trapping or destroying it, performing a forced landing, not yet applied by the FAA or federal agencies - due to technical, legal and operational issues)

5. Conclusion

In this paper, we approached the risk factors of sUAS, along with the risk elements of sUAS that the US government is interested in. Risk elements were classified for physical and non-physical factors, and the provisions referred to in the FAA Reauthorization Act were examined. Risk scenarios are also organized around the target scenario items that the FAA is interested in, such as obstruction of flight operations, damage to infrastructure, and trespassing on facilities. Of course, we looked at the risk management principles and regulatory frameworks pursued by the US FAA. In addition, sUAS safety risk management policies were analyzed, including integrated operations and safety policies, physical risk management policies, operations and safety regulations, and finally, the sUAS policies and technology directions promoted by the US FAA. It is judged that the results of this study can be broadly applied from unmanned aerial vehicle to unmanned underwater vehicle or unmanned ground vehicle safety field.

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