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EDITORIAL

From the Managing Editor: Dr. Andrew D. Shepherd

Welcome to the fourth edition of the Journal of Unmanned Aerial Systems. It is hard to believe that we are already in our fourth year as a trusted resource for those in academia, government, and industry seeking to contribute, share, and learn from each other through the publication of peer-reviewed and open-source UAS content. The speed of change and growth in the UAS industry is amazing and the work of those authors selected for inclusion in this edition has surely contributed to that continued momentum.

The Journal of Unmanned Aerial Systems would not be possible without our volunteers working as Reviewers, Editorial Board, and Publishing Board members. Their depth of knowledge, commitment to quality, and enthusiasm for the broader topic and specific domains is commendable and appreciated. As the Journal continues to grow and mature, we invite all with an interest in the advancement and sharing of knowledge to submit their work for review consider volunteering to join us. It is truly a rewarding experience.

The publication of Volume 4, Issue 1 of the Journal of Unmanned Aerial Systems adds to the growing repository of world-class scholarly work housed in our archives and available to all at no cost. We are grateful to the authors who have entrusted our publication for the distribution of their work and look forward to all that the future holds.

andrew D. Shepherd

Andrew D. Shepherd, PhD – Managing Editor Executive Director and Chief Scientist, Unmanned Aerial Systems Sinclair College National UAS Training and Certification Center

PEER-REVIEWED ARTICLE

DEVELOPMENT STAGES OF TRAFFIC MANAGEMENT SOLUTIONS FOR UNMANNED AIRCRAFT SYSTEMS

Dr. Sandor Zsolt Independent transportation expert

ABSTRACT

The increasing number of unmanned aerial vehicles requires a traffic management system which provides safe separation and safe operations for the new airspace users as it has already been used in the conventional air traffic. These management systems work as a combination of independent systems. The technical solutions and the offered services can be classified according to several dimensions. In this article, the possible solutions are presented based on the technical development stages, in line with the industrial development possibilities.

Keywords: unmanned aerial vehicles; traffic management; drones; air traffic

Introduction

See all the abreviations indicated by number at the end of the article. Due to the increasing number of unmanned aircraft systems (UAS^1 or common terms: drones), there is strong need for specific aviation related technical solutions which guarantee the safe operations of the new remotely controlled devices in the very low level (VLL^2) airspace similar to the conventional air traffic management. These systems are called UTM systems – unmanned aircraft system traffic management – which are created by the combination of several systems, thus they can be considered as complex system combinations or System of Systems (*SoS*). They comprehensively handle the flight mission related tasks executed by the UAVs at all phases of missions – from the preparation to the fulfilment and in case of advanced solutions these system can support even the post flight activities like administrative and evaluation tasks (Kopardekar et al., 2016; Spriesterbach et al., 2013).

By the increasing spread of commercial and non-military drones, a highly heterogeneous user community is emerging – it can range from the professional users who have high level aviation knowledge to the hobby users, who have only limited knowledge about the rules and regulations. Differences relate not only to the knowledge of the users but to the capability of the applied devices by the users. UTM systems has to be prepared for the management of these heterogeneity. The technical solutions covered by the UTM solutions have already mentioned in previous articles, in which the functions (*information management operations*) provided by the service have been defined (Sándor, 2017).

Due to the different technical needs it is expedient to modularize the set of the system of system in accordance with the development of UAS solutions and the needs of different user groups. From user side, the development of UAVs and the connecting devices is continuous, but the rate is not so fast that the UTM solutions would not follow.

UTM solutions are continuously evolving within the aviation industry by the spread of UAVs. The expansion of this market segment is beginning nowadays through the development of connected services and technology. Nowadays there is no UTM service provider in the world yet – similar to the ATM, with national coverage –. The available solutions are working as pilots. Within the developers there are small and big companies who are continuously investigating the implementation possibilities. The scope is wide, it ranges from the start-ups until the market leader ATM developer companies (Global UTM Association, 2017; Wargo et al., 2016; FAA Aerospace Forecast, 2016).

In this article only the civil use and its background of the UTM is presented. Military and state activities require other f regulation and the integration of these missions into the conventional aviation system requires a different approach.

Description of UTM services and the definition of service levels

The different development solutions provide an opportunity to identify those development levels which can help to categorize UTM solutions. UTM systems can be grouped according to the covered information services (functions and operation) and the technical implementation stages. It results two separate dimensions. The information services have already been analysed (Sándor, 2017), while the development and implementation stages are explored in this article. The two analysis and comparison approaches can be handled independently because the one correlates to functionality and the other to the technical implementation possibilities.

This article describes the different development/implementation stages (otherwise called: *service levels*). Depending on the applied technical solutions, five stages have been defined from the registration systems to the fully autonomous control system.

Service levels – solutions with different information provision and different intervention functions – **are built up modularly**. The higher service levels include the services of the underlying levels. Figure 1 illustrates the structure of levels. Table 1 illustrates the functions and features of each service level.

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It should be emphasized that, service level 1 (registration and static information provision platform), – which does not require active user interaction – separates from the UTM solutions regards its functionality and operation. Level 1 cannot be considered as a UTM solution, it only provides basic static information and supports the registration tasks performed by the authority. The static information provision and the registration tasks are separate from each other.

During the implementation and installation of UTM solution it is not necessary to start with the highest service level. The starting level can be chosen according to the actual user needs and the technical possibilities. In case of the development of an operating UTM system service levels can be developed during the complex development activities. Thus significant expansion can be reached in the services.

As a result of the technological innovations in the mobile data communications – mostly with the emergence of the 5th generation solutions – appearance of new and innovative application solutions are expected, which are now only in the boldest ideas. These solutions will focus on the control (between the centre and the vehicle based on advanced algorithms taking the environmental data coming from several sources into consideration), data collection and the management of the available data, and not on the base components of the UAS systems. Energy storage, propulsion, vehicle control (radio control, etc.), structural design, etc. are not based on the communication, so their development can be facilitated by other industrial solutions in the long run.

The role of UTM service providers will be valorised in the future, because the traffic management of the increasing UAVs must be guaranteed for safety and security reasons. Central, interactive (with multi-directional communication), integrated, real-time control / management solutions will come to the fore.



Figure 1. UTM service levels

Service levels:

Service level 1: Registration and static information provision platform

Registry system that stores registered airplanes and user data. It supports the authority operations and controls. Provides base static aviation data like AIS³ and static geofencing data. Users use the UAVs in accordance with the rules.

Service level 2: Mission planning and reporting system

System which provides mission planning and reporting functions with expanded, semi-dynamic information (like air space management – AMC –, meteorology and other static or semi-dynamic data which can influence the mission planning for. e.g. NOTAM). System supports only the mission planning from software side. The operational execution of the mission is provided by the applied UAS platform, which is completely independent and it is not connected to the mission planning and reporting system.

Service level 3: Platform dependent, mission related data sharing system

Real-time sharing of active mission related data of users by the applied communication network. This solution, – which operates within the users who are using the same UAV control and operation platform – provides automatic warnings about the emergency and its avoidance and it can force the automatic Emergency Response Manoeuvre (platform dependent dynamic geofencing).

Service level 4: Central information provision and automatic emergency response system

Central tracking system that provides traffic information and navigation services as well as automatic emergency management (collision prevention - dynamic geofencing) for the users based on the real-time location data of aerial vehicles generated by the surveillance and identification activities.

Service level 5: Fully automated, autonomous control system

Autonomous UAV management system, which can manage the incoming user's needs in real-time. Based on the needs the autonomous system prioritizing and authorizing the mission requests (flights) and according to the available data it controls the UAVs. Thus users are free of the control obligations. The central control system performs all tasks related to the mission, expect the destination input and the UAV launching. This solution is feasible and suitable for industrial applications, where easy-to-automate tasks are emerging in large quantity (e.g. parcel delivery by large companies, like DHL, Amazon, etc.).

Table 1: UTM service levels

Service level	Rate of automation during the operations*	Timeliness of information and the available services**	Area covered by the operative operations	Active communi- cation	Control	Responsi- bility for operating UAS	Affected UAS user commu- nity	Temporal support of missions
1.	no automation	static	no coverage	no commu- nication	manual	user	all users	only prepa- ration support
2.	no automa- tion	semi-dynamic	no cover- age	one-way (between the user and the centre)	manual	user	mixed (from the recreation- al activity users to the special industrial users)***	pre-flight activities
3.	partial au- tomation of emergency avoidance	dynamic between the platforms and real-time within the same plat- forms	local plat- forms	one-way within the operation platforms	manual, automatic warning about the avoiding manoeu- vre in case of emer- gency (platform depen- dent)	user	mixed (from the recreation- al activity users to the special industrial users)***	support of in-flight activities
4.	partial automation for multiple functions	real-time	global, platform indepen- dent	global, two-way (between the user and the centre)	mixed control	mixed (collision avoidance UTM service provider, UAV usage user)	mixed (from the recreation- al activity users to the special industrial users)***	support of pre-flight, in-flight and post- flight activities
5.	fully au- tomated control	real-time	global, platform indepen- dent	global, mul- tidirectional	auton- omous control	UTM service provider	industri- al users with high number of mission requests, where the active con- trol is not necessary	support of pre-flight, in-flight and post- flight activities

* Availability of automatic control functions provided by the central UTM system.

** Necessary data should be available with relevant content and temporal validity connected to the functions. Based on it *static*⁴, *semi-dynamic*⁵, *dynamic*⁶ and *real-time*⁷ data can be distinguished.

*** Differences can be found in the development of the UTM system, which is not influence the use of UASs.

Structure of the UTM System of systems

UTM can be defined as a Systems of Systems (*SoS*) which evolves from the cooperation of the users (*entities affected by the use of UAVs*) and their systems. Its aims to maintain the necessary separation between the UAVs and the conventional airspace users, moreover the maintenance of the order flow of traffic in the VLL airspace segments (Global UTM Association 2017; Report Joseph L. Rios et. al, 2017).

The UTM SoS consists of the following components (Figure 2.):

• Technical infrastructure elements: components, which provide the accessibility of UTM functions

• Communication infrastructure (*COM*) – base part of the UTM service which can be found between all components, without this, the service could not work.

- Navigation infrastructure (NAV)
- Surveillance infrastructure (*SUR*)
- AIS infrastructure (AIS)
- Meteorological infrastructure (MET)
- ATM connection
- · Operational support systems: components with human interfaces
 - Unmanned aerial vehicle system (UAS)
 - Record systems with user and aircraft data (REG)
 - Traffic management system (UTM)
 - Authority / State Information Systems (AUTH)

In order to ensure safe operations with high availability (24/7), key elements have adequate redundancy for maximum availability (*e.g. UTM*).



Figure 2. Simplified structure of the UTM system of systems

Operation of the UTM system of systems

The UTM system of systems should have several information management capability – so called *functions*. These functions support the safe and efficient organization of the total air traffic (*together the conventional aircrafts and the UAVs*) (Prevot et al., 2016). Differences can be found in the available functionality at a given development stage (*service level*). Table 2 contains the covered functions and definitions in accordance with the temporality of the operations offered by the complex UTM services (*pre-flight, in-flight and post-flight functions*). Figure 3 illustrates the simplified operational model of the services. Current level of technical development was considered during the creation of the definitions of the functions. Table 2 shows also that a given function is available from which level. Grey cells indicate such additional activities which go beyond the UTM service, but in order to execute comprehensive services they should be provided by UTM side, especially at higher service levels to ensure the autonomous control. At lower service levels the production of information connected to a non UTM related function is not the responsibility of UTM service provider, it only uses the already produced information to fulfil it.

New functions are emerging connected to the use of UAVs, which have to be fulfilled by the remote (user) station / terminal, however the independent communication of the platforms should be solved in order to avoid the possible conflicts. Functions of the user terminal, which are basic tasks:

- UAV control (one station one vehicle),
- control of autonomous flights / missions programmed by the user (the user control terminal will guide the UAV on a pre-programmed three-dimensional trajectory taking the possible obstacles into consideration which is sensed by the UAV or the platform contains some obstacle data),
- simultaneous control of multiple vehicles (flocks),
- conflict resolution between vehicles by the common communication in case of using the same platforms or different but communicating platforms.

Integrated information management operations offered by the UTM SoS can be fully available only if users submit the details of the missions before the operations cooperatively.

The operation of the UTM system is independent of the ATM systems, however it overlaps with it due to the speciality of the information management operations and the centralized processing of the flight information. In point of the managed data, the UTM systems use several data, which are in the ATM systems. Such data are the AIS, AMC, meteorology, flight plan and traffic related data. These data are used on several sides with the emergence of new services.



Figure 3. Simplified functional model of the UTM system of systems

Temp.	No	Function	Availability	Definition
	1	Registry	From level 1	State registration of UAVs after submitting all the necessary documents and providing them with unique identifier.
	2	Static geofencing	From level 1	Designate of airspace segments for UAV flights / missions and definition of No-fly zone, where the flying is not permitted (around a given object – for e.g. airports, nuclear power plant, etc.). The timing of the function is static or semi-dynamic, because the modification of the airspace structure requires longer periods.
t functions	3	AIS provi- sion*	From level 2	Collection and publishing of necessary information for the planning and execu- tion of the mission, which are support the safe operations. Information contain all data about airspaces, terrain, obstacles, airspace usage, forecast meteorology and other regulations.
e-fligh	4	User regis- tration	From level 2	Independent registration of users (pilots / operators) into the UTM system by entering personal and UAV related data. Assignment of users and aircrafts.
Pre	5	Mission reporting	From level 2	The sum of all activities on which the user plans the operations (vehicle usage, geographic place, operational altitude, date and time), and submit it to the relevant service provider. The submission might apply for airspace reservation > ad hoc segregated airspace.
	6	Mission approval	From level 5	Central cross-check of the submitted request with the previously received request, airspace structure, needs of conventional airspace users, airspace usage data, higher level activities (e.g. state flights, security acts, etc.) and based on them assessing the request, which can be authorized or denied.

Table 2 Functions of the UTM SoS in accordance with the temporality of the operations

Temp.	No	Function	Availability	Definition
	7	Meteo- rological service	From level 2	Real-time data delivery about the current and forecasted weather.
	8	Dynamic geofencing	From level 4 on the same platform from level 3	"No-fly zone" around a particular airspace or aircraft, which changes dynamical- ly in space and time. It may be over an artificial infrastructure.
	9	Surveil- lance	From level 4	Detection of cooperative and non-cooperative vehicles with different technical solutions. Result is a target signal (position, speed, direction).
	10	Identifica- tion	From level 4	Ensures availability of data and display the details of the authorized operations for each detected aircraft.
	11	Two- and multi-di- rectional communi- cation	From level 3	Ensures the communication between the UTM centre and the UAS devices (sending and receiving instructions, messages, telemetric data, etc.).
	12	Telemetry data man- agement	From level 5	Provides the transmission of flight and operation related data to the monitoring tool through the automated communication procedures and it allows the remote control, the take-over of control in case of necessity moreover it supports the fleet management too.
suc	13	Real-time navigation support	From level 3	Display of information about the operational environment (terrain, obstacles, airspaces, etc.).
ight functio	14	Real-time traffic in- formation	From level 4 on the same platform from level 3	Display of information about other airspace users, where the mission is executed.
lh-fl	15	Conflict resolution	From level 4 on the same platform from level 3	Detection of conflicts (possible collisions, loss of separation, etc.) between UAVs, aircrafts, flying vehicles and artificial / natural infrastructure. Based on the predefined algorithm enforcement of the deconflict manoeuvre. Traffic control supplemented with dynamic geofencing.
	16	Emergency manage- ment	From level 4	Central information provision about events, which endangering the missions (emergency broadcast); depending on the severity of conflict, central and emer- gency intervention in the missions; ensuring the priority of public service RPAS vehicles, immediate appointment of ad hoc segregated airspaces.
	17	UTM- ATM inter- face	From level 4	Transmission of significant information between the UTM and ATM systems, which provides that the conventional airspace users can access to the information that increase the situational awareness and necessary for the safe conduction of flights.
	18	Fleet man- agement	From level 5	Simultaneous control of multiple vehicles and complex management of teleme- try data. Not necessarily means flying in flocks.
	19	Record of mission data	From level 4 full func- tionality from level 5	Data recording by the UTM system, where telemetry data transmitted by the aircraft is stored for further use or monitoring (like a black-box).
	20	Control and in- spection of rules and regulations	From level 4	Detection and identification of irregular user.

Temp.	No	Function	Availability	Definition
unctions	21	Analysis of mission data	From level 4	Ex-post analysis of aircraft parameters based on the stored mission related data; management of registers, sending notifications, etc. The sum of all account activities after the use of UTM services in case of <i>val-ue-added services</i> .
Post-flight f	22	Enforce- ment	From level 4	Registration of the against the regulations behaviour, take the necessary adminis- trative actions (e.g. denunciation) and inflict the punishment.

* service is currently available connected to the ATM system, which is part of the air navigation service provider's tasks.

Outlook

The prerequisite of the achievement of higher service level is the stable, high bandwidth telecommunications network with fast response time. Based on the current expectations in the next 3-5 years the 5G mobile communication may provide breakthrough opportunities, which revolutionize the application possibilities through a completely new telecommunications backbone network. Currently applied 4G solutions can serve the needs only limitedly. In contrast, the 5G has so high capacities that are almost inexhaustible according to the present knowledge.

New communication solutions provide the basis of the advanced UTM services, thus the spread of these services – and the foundation of development centres – is expected at those geographical regions, where the network providers will get the opportunity to elaborate the 5G network and where they can ensure the civil use of these newly installed networks. At present, the United States of America is the only country where by 2020, the nationwide full-access 5G network will be developed (T-Mobile 5G, 2017).

In the next few years the technological developments will lead to significant expansion in the industry, which justifies that new solutions and applications should apply as soon as possible. As a result of the emerging applications and increasing usage of UAVs, the importance of UTM will be valorised and these systems have to be used in order to guarantee safe operations (Parker & Jaewoo, 2016).

Summary

The efficient management of activities related to the use of UAVs is challenging the roles of aviation sector. The continuous development of UAS solutions and the increasing spread of UAVs can fully redraw the service map in the future. The market of UAS is currently unfolding, thus the emergence of new and extreme services are expected, which can revolutionizing the freight and even the passenger transport, as they can put the logistics on a new technical base, which can shorten the time of transportation (FAA Aerospace Forecast, 2016). With the application of new sensors and their application on small UAVs new services will evolve. In order to ensure continuous technological development a legal framework should be created which provides that is more accessible for the industry users and supports the development and application of UAVs.

Information which have been published in this article are initial findings. Due to the fact that the industry is continuously developing and evolving some of the above mentioned might change in the future through the further technology development.



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APPENDIX A – ABBREVIATIONS

- ¹ Unmanned Aircraft System: contains the unmanned aerial vehicle and the control infrastructure, which consists of the technical and human parts.
- ² Low altitude, near the ground; a few 10 meters above the ground level
- ³ Aeronautical Information Service
- ⁴ Data are not changed for longer periods, their validity are longer or at least equal with an AIRAC cycle.
- ⁵ They may contain frequently changing content, thus their validity are between and AIRAC cycle and a few hours.
- ⁶ Data with low temporal stability, they can change even every second.
- ⁷ Data which is continuously changing.

PEER-REVIEWED ARTICLE

MODEL OF THE SYSTEM OF INFORMATION FOR THE TRAFFIC MANAGEMENT OF UNMANNED AIRCRAFT SYSTEMS

Dr. Sandor Zsolt Independent transportation expert

ABSTRACT:

The traffic management of unmanned aerial vehicle (UAV) can be successful only if the data are available in order to determine the actual and future position of the vehicles. With these data the operations of UAVs can be suit to the conventional airspace users. Data generated by the different users groups and the information management operations of the traffic management systems are contribute to the increase of the safe operations of the Whole air transportation system. Necessary data for the processes can be identified by the functional modeling of the UAV usage. Since modeling and analysis of particularly complex systems requires different techniques depending on the application purposes new methods have been introduced in order to facilitate the integration intentions. The elaborated model – which was created by the identification of the UAV related activities and its data needs contain the detailed data structure – provides the basis for the establishment of complex content provider systems which can manage information regarding the UAV usage jointly moreover it supports the operations of the management system. By the application of the system the availability of the necessary data in a unique and standardized format for the safe operations can be provided.

Keywords: unmanned aerial vehicles, air traffic management, drones, information system, system of information, air traffic control, planning of flight operations

Introduction

This article is the continuation of the previously published topic by the author about the traffic management challenges caused by the unmanned aerial vehicle. In the former publication the base problems have already been identified and the main conventional features of a complex control and traffic management system have been introduced. Not indicated technical background and definitions about the traffic management of unmanned aerial vehicle can be found in (Sándor, 2017).

Due to the fact that this topic is quite novel and recent, thus detailed scientific publications and research materials are not available numerously yet. The existing documentations are mostly limited to the physical implementation of the flying devices and to the control methods, not to the integrated solutions. The emergence of UAV usage requires breakthrough operational solutions that manage the safety and operational risks by the sharing of operation related data. The applicable solution, which realizes the traffic management of UAVs should cover the environmental and operational issues too.

In the everyday terminology the use of Unmanned Aircraft Systems (UAS) and Unmanned Aerial Vehicles (UAV) are often confused, or they are used as synonyms. In this study they are differentiated. The UAV is the flying object, while the UAS is a greater technical solution, which includes the UAV plus the sum of the control infrastructure (it may consist of human and technical parts).

Several scientific articles have already dealt with the functionality of the traffic management solutions of unmanned aircraft systems (UTM - Unmanned Aircraft Systems Traffic Management). Within these articles the functions – information management activities – for the integration of UAVs into the conventional airspace users have been discussed (Prevot et al., 2016; Kopardekar, 2014; UTM Global, 2017; Sándor, 2017; Jiang et al., 2016; Clothier et al., 2015; Barmpounakis et al., 2017). They discovered the essential operation functions and the limited operation environment, where the application can be performed. The results are referring to a specific implementation not to a general operation environment, which would be the basis of the widely usage. However these studies did not analyse the data and the data structures which are necessary for the fulfilment of these functions. It should be covered, because the industry is in the beginning of a significant change, where the number of Unmanned Aerial Vehicles (UAVs) is going to increase rapidly in the future (Wargo et al., 2016; FAA Forecast, 2017; Vascik and Jung, 2016). In case of the operation of a complex system the identification of the data is of paramount importance, because the structured data systems is the basis of the information management for which the full functionality can be built.

UTM is a dynamically developing area of the aviation. This development is significantly influenced by the available technology and legal environment. UTM system with full functionality and national / regional coverage does not operate in any single country, but initial solutions with platform dependent real time information sharing between users about their flight operations have been already exist. Developments will be accelerated in those areas where the legal regulation supports the industry and in these areas is expected the emergence of the UTM systems with full functionality (UTM Global, 2017; FAA Forecast, 2017; Rao et al., 2016).

UTM can be defined as a Systems of Systems (SoS) which evolves from the cooperation of the users (entities affected by the use of UAVs) and their systems. Its aims to maintain the necessary separation between the UAVs and the conventional airspace users, moreover the maintenance of the order flow of traffic in the VLL airspace segments (low altitude, near the ground; a few 10 meters above the ground level) (Prevot et al., 2016; Kopardekar, 2014; UTM Global, 2017; Gupta et al., 2013; Rios et al., 2017; Barmpounakis et al., 2017; Clothier, et al., 2015; Yanmaz et al., 2018).

In 2017, NASA conducted test flights to demonstrate the UTM capability. For the test, NASA used an own developed UAS Service Supplier (USS) and Flight Information Management System (FIMS) architecture, that collects, monitors and processes flight related data about the UAVs. Data were captured at different places at different time during several test flights. Collected data covered the following areas: UAV position and movement data, UAV status data, UAV type related data (static data), mission related flight plan data (Jung et al., 2018; Aweiss et al., 2018). These data were concerned only for the vehicle, and they do not contain any environment related data, which is relevant for the safe operations. These tests proved that a UTM architecture can collect UAV related data and it can manage it, but in the future it is important to integrate these data with other environment related data like airspace information, conventional air traffic information, terrain information, etc.

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Nowadays it is a problem that the UAV related data are not available on a single platform and the available data are not comprehensive, because several data are stored or managed at different sites in different time. The aim of this article is to present the system of information model of the UTM solutions, which contains systematically and comprehensively the managed information related to the use of UAVs. The goal of the model is to ensure a complex overview approach for the UAV data management through the synthetized and predefined data structure.

The information structural model can provide a basis for the development of such complex implementations, which can manage data coming from several different sources complexly in the field of the application of UAVs and makes it possible to manage them simultaneously. Thus, the integration of UAVs into the conventional airspace users can be implemented more efficiently, which contributes to a safer, more efficient and economical air transport from the viewpoint of operational aspects. Integration can be done either with the conventional air traffic management solutions or alone for the unmanned aerial vehicles that are operating in the VLL (Very Low Level) airspace.

The development of the comprehensive integration consists of several steps and requires significant time (Abou-Senna et al., 2017; Valavanis & Vachtsevanos, 2015; Sándor & Csiszár 2015; Sándor, 2017; UTM Special, 2017; Spriesterbach et al., 2013; DoD, 2011; Madaan et al., 2018). This is supported by the system of information model from the side of data. The current goals of the integration from the viewpoint of the UTM are to maximize the operational efficiency by the availability of flight and mission related data and minimize the risks caused by the uncertain, wrong and inconsistent data.

The development steps of the integration cover the following phases from the emergence of an idea to the execution of the automatic data exchange:

- 1. Emergence of an integration need
- 2. Analysis of the operational processes, human and technical components
- 3. Design of the desired technical solution, with the development possibilities
- 4. Considering the data mapping and synchronization, as well as the operation with the quality assurance processes
- 5. Off-line and limited on-line test and trial operation
- 6. Further development based on the results of the trial operation
- 7. Full functionality on-line test
- 8. Further refinement
- 9. Start of the live operation

The operational steps of the data exchange between different systems may cover different implementation possibilities based on the applied technical solutions:

- 1. Manual data exchange between the systems
- 2. Semi dynamic data exchange by manual intervention with human approval
- 3. Time based semi dynamic data
- 4. Event based semi dynamic data exchange
- 5. Automatic data exchange

In this article only the civil use and its background of the UTM is presented. Military and state activities require other regulation and the integration of these missions into the conventional aviation system requires a different approach.

Information system of UTM solutions

During the elaboration of the model for the UTM solutions, the information system and the system of information were analysed from the aspect of the structure and operation in order to identify those entities that are used to describe a fully functional system (Sándor, 2017; Sándor & Csiszár, 2015). Previously findings about the structure (already identified technical components) and the operations (functions – information management activities – which must be provided by the system) were used for the analysis (Prevot et al., 2016; Kopardekar, 2014; UTM Global, 2017; Valavanis & Vachtsevanos, 2015; Pappot & Boer, 2015).

In order for the better understanding of the technical content of the article, it is important to determine two special terms:

- **Information system**: is part of the company (subsystem), which provides procedures for creating, recording, processing and accessing the information. It is related either to the organization or to its specific part and it assists the organization to reach its goal. Information systems are the representations of the organizations, which provide information about the status of the organization for the managing elements located at different levels in the hierarchy. For this purpose the machine system of the organization is used, which may consist of several subsystems.
- System of information: is a structured system of data, a set of well-structured and well-systematized information considering certain aspects. Part of the information system

The total air transportation industry as a global system is formed together by the actors involved in aviation processes and the information systems of the several industry partners, which influence base operations. The UTM systems of systems locates within this huge formation, which is the subject of the current research. Information systems provide the management of core processes, building on them, serving the industry partners.

Figure 1 illustrates the information system model of the air transportation and within it's the UTM SoS. The air transportation system consists of the vehicles of the base processes, the information system, which is influencing the operations (the UTM SoS, as the basis of current research and it is a fully functional system, which is part of the whole air transportation system) and the human components (users of the UTM SoS). The information system provides the management of the base processes built on it organically.

Figure 1. illustrates the system components according two dimensions:

- subsystems that provide functional operations from the technical side;
- basic components describing functional operations, which provide the full functional operation of the entire system.

Subsystems connect the components of the information system and ensure the collection, storage, transmission, and processing of the information that are needed for the operations, moreover the system disaggregate the functional dependencies between the components for more simple contexts by the use of processes. In addition, during the execution of certain functions, they act as interfaces between the users and the information system.

The whole system of the air transportation is extremely complex, it is formed by the several industrial partners jointly. Each partner has an own and independent machine system (and its subsystems), which provides the efficient management of the base processes on their own area of competence (e.g. ATM systems, airport systems, etc.). In order to ensure the ease of the global operations these systems are in continuous contact with each other, thus they are indicated in the figures, because the UTM SoS has contacts with the systems of other industry partners too.

Due to the high degree of standardized processes, in the field of aviation, the information management operations are well-defined and, they can be clearly assigned to the information management elements (human components) in most cases (Sándor, 2017; Sándor & Csiszár, 2015). This result that the connections are not overlapping. Subsystems perform single functional activities, thus there is no overlap between the fulfilled functions.

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Based on the dependencies of the components the system of information for the traffic management of UAVs was elaborated. Scope of information management activities were revealed and analysed by the identification of the necessary data. With the integration of the data into a predefined structured, the information structural model for the UTM solutions was formed.

Information management activities are fulfilled in the information system, which is the result of a high-level functional planning. Its basis is the system of information, which contains the data and process structure necessary for the functional solutions. Information structural model is part of this, which provides the structured data storage and systematization. The realization of the information structural model is the information structural matrix, which systematically contains the managed data handled by the users connected to the execution of the functions.



Figure 1. Model of information system for the UTM SoS [own source]

Method - Modeling the system of information

In order to elaborate the model, the operation of the air transportation system was analysed. Modeling based on the information system and system of information approach means a universal tool for the analysis of complex systems and processes (Sándor, 2017; Sándor & Csiszár, 2015). The model provides a general framework for the general components but is should be tailored to the application area and for the industry. Human users, technical parts, operational solutions, functions and restrictions have to be taken into consideration during the work. By the help of this approach human components and data can be identified which are generated during the operations in a complex system. The modeling provides possibility to group these data systematically, which is an abstract modeling. Thereby the data needs of certain information management tasks are knowledgeable, that can contribute to the developments and it can increase the efficiency of the operations. Thus, during the initial or even the further development of the systems, not only the functionality but also the data structure can be configured or fine-tuned, which is organically linked to the whole operation and is found on it.

Irrespective of the universality of the model, it is necessary to indicate the industrial specific needs and implementations inside it. This is not the case in the air traffic industry either. At the first step of the application of the model the modeling and resolution depths (the analytical depth of the components and the vertical dimension of the study) have to be clearly defined, which will be the basis for the analyses. The time scale of the activities in the different industries and the different temporal validity of the data are justify the necessity of this step.

Thus the UTM is close to the conventional air traffic management, the elaboration of the model was started with the analysis of the air traffic control and quasi parallel activities, data, systems and human components were identified through the possible effects of UAV usage. Use of UAV means the main process, because all model components were deduced from it.

Analyses were initiated at the side of the air traffic control, because the majority of the control and operative traffic organization tasks, linked with the operation of UAVs are emerged at this side. User groups, data connected to the information management activities and the machine systems were identified which are necessary for the operation of the UTM SoS.

The components of the model:

- Users
- Functions
- Datasets
- Functional subsystems

Users (U_n)

Table 1. contains the stakeholders in high-level groups, who are affected by the use of UAVs. They are the human components of the system, who handle the information management connected to the service of the UTM SoS. The list and the resolution depth might be modified according to the implementation of the applied UTM SoS. When users form a greater task based group like in the air traffic control than this user group can be called as a service.

Notation	User group	Description	
U_1	UAV operator	A person, who provides the control of an unmanned aerial vehicle at the place of use.	
U_2	Pilots	Conventional aircraft commanders.	
U ₃	Air traffic controllers and flight informa- tion service officers	Officers of the air traffic and flight information services, who are in direct radio contact with the conventional airspace users in the controlled and non-controlled airspace.	
U4	UTM operator	Officers of the UTM SoS, who provide the operative operations.	
U5	Air traffic officer	People, who are responsible for the management of the air traffic, availabil- ity of the information materials and all other aviation related information (supporting officers of the air traffic control and aeronautical information services).	
U ₆	Ground officer	Supporting staff for the execution of conventional and UAV flights (gener- ally the airport and field ground staff).	
U ₇	System operators	Specialist, who are operating the technical systems of the UTM solutions.	
U_8	Authority officers	Staff of the Aviation Authority, who control the supervision over the area.	
U9	Emergency service officers	Staff of the state services, like police, fire, disaster and rescue services.	
U10	State administrators	Staff for the state registry and other state related administration actions.	

Table 1: Human components of the UTM SoS [own source]



Functions (F_n)

Functions are the information management activities. These were previously identified (Prevot et al., 2016; Kopardekar, 2014; UTM Global, 2017; Gupta et al., 2013; Rios et al., 2017; Barmpounakis et al., 2017; Clothier, et al., 2015). Table 2. contains the 22 functions according to the temporality of the flight / mission (definitions of the functions can be found in (Sándor, 2017)).

Functions can be realized by the help of data. These functions provide the appropriate operation of the whole UTM system, which accomplish the UTM services that are based on the UTM functions. The functions may form service on a higher level, but here the service is the traffic management of the UAVs, and all function imply an independent function which is necessary for the operation of the UTM and may be used by other industrial partners (like the surveillance, which is also used by the air traffic control).

Temporality Notation		Function
	F_1	Registry
	F ₂	Static geofencing
Dra flight functions	F ₃	AIS provision
Pre-ingit functions	F_4	User registration
	F_5	Flight / mission reporting
	F ₆	Flight / mission approval
	F ₇	Meteorological service
	F ₈	Dynamic geofencing
	F ₉	Surveillance
	F ₁₀	Identification
	F ₁₁	Two- and multi-directional communication
	F ₁₂	Telemetry data management
	F ₁₃	Real-time navigation support
	F_{14}	Real-time traffic information
	F ₁₅	Conflict resolution
	F ₁₆	Emergency management
	F ₁₇	UTM-ATM interface
	F ₁₈	Fleet management
	F ₁₉	Record of flight / mission data
	F ₂₀	Control and inspection of rules and regulations
Doct flight functions	F ₂₁	Analysis of flight / mission data
Post night functions	F ₂₂	Enforcement

Table 2: Functions of the UTM SoS (own source)

Datasets (Din)

The managed data were sorted into groups by the content and the temporal validity in order the conformability and the orderliness. Table 3 illustrates the results with examples according to the dynamism and the datasets. Due to space limitation the table does not include all the data in depth. In this way, the data which are similar but map different content can be managed together.

Notation of the data:

- *n* indicates the number of the dataset (refers to the type of the content),
- *i* indicates the dynamism (temporal validity).

Type of content:

- registry data: data in connection with the registry, which cover the process and the equipment as well as the people as the subject of process.
- user data: data of the UAV operators, that are in connection with the flight missions.
- AIS data: data for the air navigation, most important data about the air traffic information provision (rules, regulations and other relevant information about the operative environment that is necessary for the airspace user).
- aeronautical infrastructure data: basic data of the air infrastructure, which describe the operative environment affected by the UAVs, moreover based on these data the missions executed by the UAVs become plannable.
- flight / mission planning data: similar like the conventional flight plan, it contain all detail about the mission executed by the UAVs.
- traffic data: position data for the effective traffic management of UAVs and conventional aircrafts that are formed by actual and predicted status information. Data are available regardless of the surveillance devices.
- flight operations data: mission data generated during the execution of the flight / mission. They are in connection with the given mission and they may be different according to the aim of the mission. They are mainly telemetry data, completed with position data in case of UAVs that describe the actual operative environment.
- equipment data: data of the off-board equipment required for UAVs (navigation, control, communication). Based on these data, it can be decided whether the operation of the required infrastructure for the execution of the mission is fulfilled or not.
- **contingency data**: Procedural, traffic, and operational data related to situations which require special handling (contingency, special priority rules, etc.).
- surveillance data: Data in connection with the surveillance infrastructure and the data about its operation. Data connected to surveillance and identification functions.
- authority data: the sum of all aviation authority surveillance and control data. Based on them the checks can be done, and their results can be recorded.

Dynamism (i):

- *S* static data (data are not changed for longer periods, their validity are longer or at least equal with an AIRAC cycle).
- *SD* semi-dynamic data (they may contain frequently changing content, thus their validity are between and AIRAC cycle and a few hours).
- D dynamic data (data with low temporal stability, they can change even every second, or continuously).

Table 3:	Datasets	of the	UTM SoS	(own source)
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	static data	semi-dynamic data	dynamic data
	D_1^s	D ^{sd}	D_1^d
registry data	procedures, metadata of the central database (how to store data, what data have to be stored, how to applicate and submit, etc.)	data of the registered people and equipment (type of UAV, regis- tration ID, devices, enabling of the opera- tors, etc.)	-
	D_2^s	D_2^{sd}	D_2^d
user data	personal base data of the UAV operators (name, identification data, address, etc.)	connection and notifi- cation data of the UAV operators, licenses, assignment data of UAVs and operators	-
	D_3^{s}	D ^{sd} ₃	D_3^d
AIS data	regulations, rules, AIP publi- cations, communications data (frequencies, locations, etc.)	procedures, data of the pre-planned limita- tions (closed airspaces, etc.)	NOTAM, meteorological data, etc.
	D^d_4	D ^{sd}	D_4^d
aeronautical infrastructure data	base data of airspaces, land- ing sites and sectors, previous sector capacity data, strategic airspace management and strategic airspace usage plans, obstacle data	static geofencing data, map data, planned airspace restrictions	predicted and actual sector load data, restrictions, predicted and actual sectorization data, predicted and actual airspace usage data (needs and reservations), dynamic geofencing, conflict resolution (anti-collision) data, trajectories
	D_5^d	D ^{sd} ₅	D_5^d
flight/mission planning data	data of the mission planning procedures (general submission procedural data, methodolo- gies, etc.)	-	reported and approved mission data, execution data, temporal and spatial data in connection with the execution of the mission
	D_6^d	D ^{sd}	D_6^d
traffic data	-	-	expected traffic situation data, actual UAV and conventional aircraft po- sition data, trajectories, restrictions, conflict prediction data, conflict resolution data
	D_7^d	D ^{sd}	D ^d 7
flight operations data	-	_	performance data, sensor data, imag- es, videos, etc. actual position data, environment data (wind, temperature, pressure, obstacles, other detected airspace users), data of the on-board devices, etc.

	static data	semi-dynamic data	dynamic data
	$D^d_{\ 8}$	D_8^{sd}	$D^d_{\mathcal{B}}$
equipment data	base data of the mission supporting equipment (type, location, etc.)	preventive mainte- nance data, operation parameters, limita- tions, expected out of service times, etc.	current operating parameters, opera- tion monitoring data, availability data of services, predicted and current data of accessibility-limiting phenom- ena, etc.
contingency	D^d_{9}	D ^{sd} 9	D ^d 9
data	description data of contingency processes	contingency plans	contingency broadcast data, interven- tion data, traffic priority data, etc.
	D ^d lo	D ^{sd} 10	D ⁴ 10
surveillance data	base data of the surveillance infrastructure	preventive mainte- nance data, operation parameters, limita- tions, expected out of service times, etc.	radar data, position data, identifica- tion data, data about the infrastruc- ture operations, status data, etc.
authority data	D ^d ₁₁	D ^{sd}	D ^d ₁₁
	procedures, authority metadata	sanctioning, violation and enforcement data	control data, observation data, evi- dence, etc.

Functional subsystems

The UTM SoS with full functional provides their services by the continuous cooperation of several separate subsystems (UTM Global, 2017; Sándor, 2017; Gupta et al., 2013; Rios et al., 2017; Spriesterbach et al., 2013). Subsystems support the operation of the given functions.

The applied systems can be divided into two main groups and several functional sub-units within the two main groups:

• **Technical infrastructure elements** (components, which provide the accessibility of UTM functions from the infrastructure side, without human intervention):

• **Communication infrastructure**: base part of the UTM service which can be found between all components, without this, the service could not work. Ensures the data transfer between the different sub-units. *E.g. radio, data transfer network, etc.*

• Navigation infrastructure: necessary for the UAVs in order to navigate in the airspace. *E.g. Global Navigational Satellite System, radio measurement beacons, etc.*

• Surveillance infrastructure: provides the availability of position data about the UAVs, irrespective of the vehicle based localization solutions. *E.g. short wave radars, sonars, holographic radars, etc.*

• AIS infrastructure: provides the necessary information for the execution of the missions. *E.g. databases, database interfaces, etc.*

• **Meteorological infrastructure**: provides the necessary meteorological data for the execution of the missions. *E.g. sensors for the monitoring, etc.*

• **ATM connection** platform: UTM SoS and the conventional air traffic control system share the relevant flight data mutually. Thus the necessary separation can be fulfilled between the conventional airspace users and the UAVs. *E.g. data connection solutions, procedures for the data exchange, etc.*

• **Operational support systems:** (components with human interfaces, services offered by the systems are not available when the human contribution is missing):

• Unmanned aerial vehicle system: contains the UAV, the operator and the infrastructure, which is necessary for the control (flying) of the vehicle.

• Record systems with user and aircraft data: state registry database.

• **Traffic management system**: interconnects the users, thus it collects, processes and shares all mission related data with the users. By these data the safety can be increased.

• Authority/State Information Systems: In order to ensure safe operations with high availability (24/7), key elements have adequate redundancy for maximum availability (e.g. UTM).

The system of information

In view of the information management activities made by the users the managed data were identified. The information structural matrix contains these data. Table 4. illustrates the structure of the matrix. Line header shows users and features. Cells of the vertical columns contain the managed information listed into datasets connected to the executed functions done by the users. The cells of the matrix contain the managed part data groups. When a given user cannot access to a function or when it is not available, the cells can be empty. The index (i) ranges from I to n for each component. Value of n assumes a different value for each component and it depends on the detail of the model, moreover depending on the flexibility of the model, it can be freely increased in the future, thus enlarging the detail within the given component. The breakdown illustrated in Table 1., 2. and 3. are initial implementation based on the currently identified components and the currently available technical development.

User	Function	static data	semi-dynamic data	dynamic data
Ui	Fi	D_i^s	D ^{sd} _i	D_i^d
	F ₁			
U ₁				
	Fn			
	F ₁			
	Fn			
	F ₁			
Un				
	Fn			

Table 4: Structure of the UTM SoS information structural matrix (own source)

Result – The information structural model

The information structural model is the structure of the managed information according to the components. The model summarizes what kind of datasets is required for the operation of a certain function in a given service. The representation of the model is a matrix.

The model is a structured data structure for the identification and classification of the managed information related to UTM services. The cells of the matrix contain the managed information (Figure 2.). Machine components may be indicated in the matrix connected to the managed information, in view of the information managing actions fulfilled by the machines.



Figure 2 Information structural model of the UTM service (own source)

Discussion

In order for the safe execution of the missions made by UAVs, it is important for the UTM user community that they can access to the necessary data in an integrated way. With the integrated data management the efficiency can be increased (the uncertainty and the information acquirement time is reduced), thus the safety can be developed. The elaborated model contributes to these successes through the availability of necessary information at the right time in any place.

The integrated data management can be achieved by the elaborated model, thus providing the quick and cost effective information flow between the industrial partners in a uniform format by the use of a common platform. The integration needs time and it consists of several steps. The elaborated system of information model contributes to the first steps.

Operation of the information structural model provides comprehensive data sharing among the partners about the UAVs and their operations.

Future outlook

5th generation communication solutions will significantly contribute to the success of the industry, because the operation of this services are based on the well-organized data flow and transmission. The new services enable the remote processing of the data and the increasing spread of cloud-based solutions.

The UTM operates similar than the ATM nowadays. Due to the fact that a full functional UTM solution is not available now, the business model and the operation methods of the system are currently not known. Future research should answer these questions and address the elaboration of such measures. Two ways are considerable depending on the operational environment:

1. Independent UTM platform that operates without an ATM system / solution.

2. ATM integrated UTM platform, which operates jointly with the ATM system / solution and it amends its functions.

Future industrial developments will focus on these solutions and the integrated air traffic solutions lay down the necessary basis.



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PEER-REVIEWED ARTICLE

HAS THE BIRD FLOWN THE COOP? Obsolete Unmanned Aircraft System Export Control Policies Undermine United States' Industry and National Security Objectives

Lieutenant Colonel Calvin Powell United States Air Force

Ambassador Douglas Griffiths U.S. Foreign Service, retired

ABSTRACT

Many near-peer competitors are rapidly eroding overall U.S. unmanned aircraft systems (UAS) supremacy. Most notably China and Russia, although not yet matching U.S. UAS capability, threaten U.S. security interests by encroaching on areas of traditional U.S. influence. The United States' restrained posture towards UAS sales has cost U.S. dominance of the relative market and undermined opportunity for broader strategic partnerships. The United States released in April 2018, an updated *Conventional Arms Transfer Policy* and *U.S. Policy on the Export of Unmanned Aerial Systems*, which provide the opportunity to cultivate greater trust with close partners and exploit the inevitable future of unmanned aerial technology. The United States should now: 1) lead significant changes to the *Missile Technology Control Regime's (MTCR)* unmanned aerial vehicle (UAV) definitions; 2) cultivate increased UAS collaboration and sales to develop cultural interoperability and solidify normative behaviors of use and export; and 3) anticipate and capitalize on the results of the policy shift. Such efforts are necessary for the U.S. to preserve a majority share of the international UAS market opportunity and strongly influence the remainder, protect the United States' defense technological advantage, and counter market subjugation by near-peer competitors.

Keywords: unmanned aerial vehicles; security interests, defense technology, partnerships, obsolete policies

For nearly two decades, the United States maintained a decided advantage in unmanned aircraft systems (UAS)¹ technology and capability. Although the United States retains superiority in certain military employment capabilities, such as across-the-globe satellite operations, many near-peer competitors are rapidly eroding overall U.S. UAS supremacy. Most notably China and Russia, although not yet matching U.S. UAS capability, threaten U.S. security interests by encroaching on areas of traditional U.S. influence. "In fact, every international transfer of an armed drone to date with the exception of the U.S. transfer to the United Kingdom [and now Italy] has been from China."² The United States' hesitancy to sell UAS to allies and partner nations creates a void readily filled by emerging competitors³ willing to take the lead for UAS sales most anywhere the United States will not.⁴ Export control restrictions further impinge on the United States' ability to develop relationships through follow-on sales and long-term sustainment. Such international arms export competition is not new; the ability to challenge U.S. UAS technology and capability dominance, however, is developing far quicker than U.S. policy and standing international agreements can adapt.

The United States' restrained posture towards UAS sales has cost U.S. dominance of the relative market and undermined opportunity for broader strategic partnerships. Refreshingly, the United States released in April 2018, an updated *Conventional Arms Transfer Policy* and *U.S. Policy on the Export of Unmanned Aerial Systems*, which provide the opportunity to cultivate greater trust with close partners and exploit the inevitable future of unmanned aerial technology. Well-coordinated implementation could disrupt the surge of near-peer competition, solidify global norms, and ensure a competitive U.S. defense and civil industry advantage in this burgeoning niche market. The United States should now: 1) lead significant changes to the *Missile Technology Control Regime's (MTCR)* unmanned aerial vehicle (UAV) definitions; 2) cultivate increased UAS collaboration and sales to develop cultural interoperability and solidify normative behaviors of use and export; and 3) anticipate and capitalize on the results of the policy shift.

Obsolete Policies Impede Progress

In April 2018, the United States released an updated *Conventional Arms Transfer (CAT) Policy* which "provides a framework under which all U.S. government agencies will review and evaluate proposed arms transfers and approve commercial defense sales by American companies."⁵ The United States simultaneously released a new *U.S. Policy on the Export of Unmanned Aerial Systems*, replacing the 2015 *U.S. Export Policy for Military Unmanned Aerial Systems*, replacing the 2015 *U.S. Export Policy for Military Unmanned Aerial Systems*⁶ and loosening previous restrictions with a new focus on "delivering a crucial military capability to [U.S.] allies and partners."⁷ U.S. military UAS are traditionally sold via the Foreign Military Sales (FMS) program, overseen by the Defense Security Cooperation Agency (DSCA), as authorized by the *Arms Export Control Act*.⁸ The 2018 UAS export policy will bolster U.S. UAS sales' opportunities by "enabling U.S. firms to increase their direct sales to authorized allies and partners," according to Dr. Peter Navarro, Assistant to the President for Trade and Manufacturing Policy. Regardless of the new language, the *Conventional Arms Transfer Policy* continues to provide balance between meeting "legitimate security requirements of [U.S.] allies and partners in support of [U.S.] national security and foreign policy interests" and actions "destabilizing or dangerous to international peace and security."⁹

In late 2016, the United States led 52 other nations in negotiating the *Joint Declaration for the Export and Subsequent Use of Armed or Strike-Enabled Unmanned Aerial Vehicles (UAVs)*. Although specific to strike-enabled UAS, this joint declaration is a critical and positive move towards appropriately scoped and flexible policy governing UAS export and use. The states agreed to the broad principles of adhering to international law, promoting responsible export control and transparency consistent with existing multinational agreements. The parties also committed to continued dialogue on the subject.¹⁰ The 2018 policy updates remain supportive of this *Joint Declaration*.

Both the 2018 U.S. UAS export policy and 2016 joint declaration were carefully drafted to adhere to, or at least not contradict, U.S. commitment to the *Missile Technology Control Regime (MTCR)*. The *MTCR* is a 30-year old multilateral agreement between 35 nations—the United States being one of the original seven adherents—to counter proliferation of weapons of mass destruction (WMD) delivery systems and related technologies. The agreement has no legal binding or formal consequence apparatus. Instead, it relies on good faith in a "strong presumption of denial" to abate proliferation and influence export decisions. In 1992, UAV were added to the *MTCR*'s Categories I and II and are now the blanket terminology for "cruise missile systems, target drones, and reconnaissance drones."

Category I accounts for "complete delivery systems," of both rocket systems and UAV, "capable of delivering at least a 500 kg [1102 lb] 'payload' to a 'range' of at least 300 km [162 nm]."¹¹ Category II includes, again, both rocket systems and UAV "not covered in Item I, capable of a maximum range equal to or greater than 300 km."¹²

Although the *MTCR* accounts for a relatively small subset of large UAS, it is often critiqued for providing inadequate and outdated guidance for UAS transfers, unnecessarily restricting exports.¹³ The inclusion of UAV in the *MTCR* represented good intentions in the 1990s, but lacked clear understanding of the rapid advances in technology and subsequent conventional military and commercial dual-use possibilities divergent from missile systems. Furthermore, the prescribed weight and range limitations defining UAV categories were carried over from earlier, arguably conservative, parameters for nuclear-capable ballistic missiles.¹⁴ As a result, conventional UAS sales are constrained by the arbitrary language of an overly restrictive international agreement designed for a wholly different purpose restricting the proliferation of MWD delivery systems.

Arms export control policy should set the conditions for a dynamic market environment and encourage the defense industrial base to innovate, take risks, and anticipate new challenges and opportunities in the interest of U.S. national security. Instead, complying with the "strong presumption of denial" under the *MTCR* consistently shrouds UAS export discussions in negative tones. According to the Aerospace Industry Association, the *MTCR* has become the "big barrier"¹⁵ and one of "several anchors"¹⁶ to constructive U.S. UAS export control. These are strong phrases for an agreement with no legal bounds but accurately represent UAS industry perceptions. As with any multilateral agreement, the ends should justifiably affect all participants fairly. With respect to restrictions placed on UAS technologies, the United States has far more to lose than any other *MTCR* adherent.

During the *MTCR* annual plenary meeting in October of 2017, member states specified their intent to "intensify the efforts of Partners to prevent the proliferation of unmanned delivery systems capable of delivering WMD." The partners also stressed the "*MTCR Guidelines* are not designed to impede technological advancement and development" or "hinder legitimate trade."¹⁷ Such official disclosure provides some clarity of intent but fails to adequately improve the agreement's effectiveness.

The disruptive nature of UAS innovations offer tremendous military and commercial opportunities well into the future. UAS are far from single-purpose cruise missiles, as insinuated by the *MTCR*. Ironically, the *MTCR* overtly provides concession for advances in legitimate, non-WMD space programs. It also omits *manned* aircraft not converted for unmanned flight,¹⁸ even though many manned fighters and bombers are capable of delivering nuclear weapons. Unfortunately, it does not offer similar concession to *unmanned* aerial capabilities. Instead, the Partners continue to devote "increased attention to…Unmanned Aerial Vehicles."¹⁹ In an effort to correct these apparent limitations, according to Defense News, the United States circulated a white paper on potential *MTCR* adjustments governing UAS technologies during the 2017 plenary meeting.²⁰ Unconfirmed sources indicated the recommendations center on adding further speed restrictions to the UAV categories, a position also advocated by the Aerospace Industries Association (AIA) ²¹, the self-proclaimed "voice of American aerospace and defense."²² This is a positive step, and the United States must capitalize on every opportunity to negotiate substantial policy change in advance of the 2018 *MTCR* plenary meeting.

Unfortunately, UAS speed, although a valid discriminator, is just as insufficient as the current restrictions of payload and distance. In the 1990s, the categorizations seemed appropriate for the existing capabilities; just as today, speed seemingly differentiates most UAS from cruise missiles. For example, Lockheed Martin's hypersonic SR-72 unmanned aircraft should not be considered a cruise missile *ex ante*, just because it is "conceivably capable of topping Mach 6 (4,000 miles per hour)."²³ A UAS's ability to exceed manned flight performance does not mean it is particularly culpable of WMD delivery. Instead, the United States should lead the change to discount specificity towards UAS platform capabilities in the *MTCR* in favor of accounting for intended use and effects of the technology. This would allow the *MTCR* to focus on its true intent of preventing WMD proliferation.

Why It Matters

Market Opportunity

"Like the internet and GPS [Global Positioning System] before them, drones are evolving beyond their military origin to become powerful business tools...creating a market opportunity that's too large to ignore," totaling \$100 billion between 2016 and 2020, according to Goldman Sachs Research.²⁴ A maturing military UAS market will likely account for \$70 billion of the anticipated \$100 billion market. Such opportunities represent "only the tip of the iceberg," as the "ripple effects [will surely continue to] reverberate through the economy."²⁵ The challenge for the United States, of course, is to preserve a majority share of this market opportunity and strongly influence the remainder. The threat to success is the United States' general "acceptance of lowered expectations" for remaining king of the advanced-technology hill.²⁶ Steve Zaloga, a Teal Group senior analyst, characterized this concern in the *2017 UAV Market Profile and Forecast*, predicting "the [United States] will account for 57% of total military worldwide [research, development, test, and evaluation] spending on UAV technology over the next decade...[yet only] about 31% of the [global] military procurement."²⁷

Responding to the challenge, Lieutenant General Charles Hooper, Defense Security Cooperation Agency's (DSCA) Director, is keen on extending the U.S.'s fiscal year 2017, \$41.93 billion FMS market by continuing to provide U.S. partners the "total package...of training, maintenance, and sustainment."²⁸ While the overall U.S. aerospace industry exported over \$90 billion in civil and military systems in 2016, with similar expectations in 2017, AIA President and Chief Executive Officer (CEO), David Melcher, cautioned industry leaders in December 2017, to not become complacent: "The recent track record of defense export success does not address the growth of foreign competition and influence in the global defense market. Nor does it answer the question of whether we are missing opportunities to build partner capacity in the manner and timeframe most beneficial to American interests."²⁹ Insufficient and slow to adapt policies only exaggerate surging foreign competition and waning U.S. influence, particularly in the UAS industry. The United States must act decisively to maintain global UAS market dominance as, "The UAV market continues to soar," according to Philip Finnegan, Teal Group's director of corporate analysis. "Increasing trade in costly high-altitude, long-endurance systems, demand for armed UAVs, the development of the next generation of unmanned combat systems, and potential new applications such as missile defense continue to drive the market."³⁰

Industry Relevance & Innovation

Keeping pace with disruptive innovations, such as UAS, requires consistent market awareness and capability relevance. "The U.S. defense industrial base must remain competitive and technologically relevant at all times. It is not a just-in-time resource," according to Kelvin Stroud, AIA.³¹ The *Summary of the 2018 National Defense Strategy of the United States of America* reiterates this point, highlighting dependence on "a healthy and secure national security innovation base that includes both traditional and non-traditional defense partners" to protect the United States' defense technological advantage.³²

The new paradigm where many defense-related technologies are developed or advanced by the commercial sector and outside of governments continues to accelerate technology transfer and challenge the North Atlantic Treaty Organization (NATO) and many sovereign militaries, according to Admiral Manfred Nielson, NATO's Deputy Supreme Allied Commander Transformation. He believes the prevalent but fading mindset of the Cold War era, where government often led technology advancement, still involves long and often expensive timelines and limits the technology adaptation rate. To modernize at a rate Admiral Nielson considers the "speed of relevance,"³³ a phrase also used in the United States' *2018 National Defense Strategy*,³⁴ defense and security policy must acknowledge the non-defense industry more often sets the relative pace of modernization. Unfortunately, in regulating evolving and, potentially, disruptive technologies, policy makers are at a disadvantage, as the cycle of innovation can outpace the U.S. government policy, budget, and acquisition cycles.³⁵

As a result, the commercial sector is leading many of the current UAS technology innovations. One example is a small start-up company called Natilus, developing an unmanned Boeing 777-sized cargo transport UAS.³⁶ Such an aircraft could prove very valuable to both commercial and military logistics. If Natilus subsequently desired to

export this UAS, surely capable of traveling more than 300 km and carrying more than 500 kg, it would be subject to the *MTCR* Category I restriction of "strong presumption of denial." While liable to plenty of suitable export laws, the innovative minds at Natilus and the multitude of other U.S. commercial UAS start-ups should not have to concern themselves with a WMD counter-proliferation international agreement for what are essentially commercial aircraft.

The U.S. UAS defense sector's need for flexibility to innovate with relative assurance of global market accessibility is no different. Given more favorable export control policies, increased foreign sales will likely "create additional demand for support infrastructure, including 'training; service, support and maintenance; and data management," as seen with the U.S. UAS industry's rapid growth over the last decade.³⁷ Long-term customer support for foreign military sales is often considered a U.S. competitive advantage used to grow and nurture international partnerships, establish normative behavior in line with U.S. interests, and ensure future market opportunities.³⁸ As a market-driven industry, aerospace defense relies on those future opportunities, or at least optimistic market signals, for continued production and increased research and development.³⁹

The U.S. aerospace industry's "passion to invent, innovate, and imagine paths never taken," according to Melcher of AIA, "…helps explain why [the aerospace industry is] such a critical contributor to U.S. leadership in the global economy."⁴⁰ Government regulations should fuel this passion and encourage the defense establishment to help refine future policy and drive perpetual ambition for further transformation and the resulting technology. Facilitating international commercial partnerships only enriches such imagination. "The modern economy," according to Yuval Harari in *Homo Deus*, "needs constant and indefinite growth in order to survive."⁴¹ The UAS commercial and defense industries, as part of this modern economy, do as well. Without consistent global market access and intellectual cooperation, the U.S. UAS defense industry risks losing its competitive advantage.⁴²

Emerging Foreign Competition is Eroding U.S. Influence

Global UAS spending is exploding, estimated at \$40.2 billion between 2017 and 2021, excluding the United States' \$17.5 billion.⁴³ Most concerning to the United States' market dominance should be Russian, Chinese, Israeli, and Iranian indigenously-developed UAS.⁴⁴ Of these four nations, none signed the 2016 Joint Declaration, and Russia is the only MTCR Partner.⁴⁵ As the third highest global UAS investor (\$3.9 billion) and second largest military systems exporter behind the United States, Russia continues to be a strategic threat as it "pursues veto power over the economic, diplomatic, and security decisions of its neighbors." China, "a strategic competitor using predatory economics,"⁴⁶ is second only to the United States in UAS investments (\$4.5 billion).⁴⁷ Along with Israel, China claims to adhere to most of the MTCR Guidelines⁴⁸ but demonstrates no particular restraint with respect to armed UAS exports.⁴⁹ Israel, the world's leading exporter of military UAS,⁵⁰ provides one of the highest quality combat-tested products on the market. Although not a significant UAS exporter or investor, "Iran continues to sow violence"51 by providing UAS, to include reversed-engineered advanced stealth UAS, to Lebanese Hezbollah.⁵² "The reemergence," according to the United States' 2018 National Defense Strategy, "of long-term strategic competition, rapid dispersion of technologies, and new concepts of warfare and competition," require U.S. adjustments.⁵³ Furthermore, the U.S. defense industry "no longer enjoys the [traditional] level of dominance...in technical innovation, in their applications, or in the processes or practices by which they are brought into use," in great part due to "institutional and policy reasons."54 Continued policy reform is therefore fundamentally critical for the United States to counter market subjugation by near-peer competitors.

The *MTCR* Category I threshold causes the greatest negative pressure on U.S. UAS sales, as the United States maintains a significant market share of medium and high altitude, long endurance, large UAS.⁵⁵ These UAS also tend to garner significant negative attention due to the rapid, effective, and often secretive use by the United States over the last two decades.⁵⁶ However, small UAS, a commercial market dominated by the Chinese—Chinese small-UAS developer, D.J.I., alone commands 72% of the global market⁵⁷—reflect a growing dual-use market opportunity and threat to U.S. and partner security.⁵⁸ Small UAS are affordable, accessible, simple, expendable, and adaptable. There is also significant overlap of commercial and military small UAS technology.⁵⁹ Small UAS reflect many of the same positive technological advances and negative threat capacities as their larger counterparts. Although small UAS are not, and should not be, restricted by the *MTCR*, UAS of all sizes should be considered under the auspices of the 2016 *Joint Declaration* and any U.S. UAS-specific export policies.
Even with substantial market share, China's efforts are not restricted to small or unarmed UAS. China consistently fills the void left by the United States, with several traditional U.S. military sales partners included in the list of Chinese UAS exports.⁶⁰ China, however, does not have to usurp U.S. influence through long-term sustainment contracts. Instead, they simply need to block market access through an initial military sales deal.⁶¹ This is particularly critical in nations with relatively small defense budgets, only able to procure systems once every several years. Such cycles limit the opportunities for U.S. influence. Furthermore, China's military-grade UAS, although less capable than similar U.S. products, are sold at a "fraction of the cost," further exaggerating the challenges. The Chinese CH-4 Rainbow is advertised at \$1 million compared to the near \$15 million price tag of the "similar" U.S. MQ-9 Reaper.⁶² When the United States seems unwilling, is policy-restricted, and sells a product costing fifteen times more, even a sub-optimum capability is better than no capability for many nations.⁶³ This is particularly compelling when buying initial entry to the UAS game. When allies and partners buy elsewhere, U.S. security objectives are threatened as the United States loses long-term influence over UAS end-use, additional transfers, research and development stimulation, and secondary regional market opportunities. "When [the United States] enables [its] allies and partners to more easily obtain appropriate American defense articles and services," however, U.S. national security improves.⁶⁴

In the *2018 National Defense Strategy*, Jim Mattis, U.S. Secretary of Defense, writes: "Failure to meet our defense objectives will result in decreasing U.S. global influence, eroding cohesion among allies and partners, and reduced access to markets that will contribute to a decline in our prosperity and standard of living."⁶⁵ Each viable U.S. competitor approaches the problem differently and requires uniquely flexible U.S. engagement strategies to avoid Secretary Mattis' warning. Even though long-time European allies seem the obvious first step to increased U.S. UAS FMS efforts, the European Union continues to push for sole indigenous UAS production, "full operational sovereignty," and independent intelligence management for future UAS capabilities.⁶⁶ Israel will continue to exploit their historic geographical linkage to Europe and the Middle East. Russia's policy of western alliance destabilization also extends to FMS, as demonstrated by the recent agreements to sell S-400 air defense missiles to Turkey and Saudi Arabia, both historic U.S. FMS partners.⁶⁷ China, on the other hand, gains from European stability and seeks to exploit the market through cheaper wares and a "no strings attached" policy. Unlike the United States and European Union, China "[does] not ask the difficult questions, preach, or push for privatization and restructuring of inefficient state-owned enterprises."⁶⁸ As a result, the United States must enhance the value of its often more expensive products while balancing European Union market competition with enhanced collective trans-Atlantic security.

Multinational Industry Collaboration

Market competition and a degree of uncertainty does not indicate a complete lack of international cooperation but does demonstrate the existing friction when establishing and cultivating international relationships. Three examples where U.S. UAS manufacturers were able to overcome policy impediments and achieve preliminary success exist in Australia, with Insitu and General Atomics-Aeronautical Systems Inc. (GA-ASI), and in Japan, with GA-ASI. First, Insitu established an international business-to-business relationship with Queensland Gas Company (OGC). a Shell-owned natural gas company in Australia. Insitu, a subsidiary of Boeing Corporation, builds the low altitude long endurance Scan Eagle UAS—an airplane used extensively in the U.S. military. QGC plans to fly the Scan Eagle to inspect wells, pipelines, facilities, and the surrounding environment to "drive improvements in our safety performance, more efficiently and effectively survey our infrastructure and reduce our footprint on the environment," according to a QGC general manager.⁶⁹ Such breakthrough dual-use examples are no longer unique for UAS. Although the largest financial opportunities remain in military contracts, Goldman Sachs predicts the highest UAS job growth in the next five years in non-military construction and agriculture sectors.⁷⁰ Insitu's U.S. military UAS role should not limit international commercial or military cooperation. U.S. leadership in the military and commercial UAS sectors are more critical today than ever, as there are few examples of dual-use technologies where the thin line of civilian from military separation-weaponization-is more prevalent than with UAS. Therefore, the United States should promote an example of partnership and cooperation to firmly establish international standards of use and proliferation and to maintain innovative relevance in this rapidly progressing field.

The second and third partnerships involve GA-ASI, the U.S. makers of the U.S. Air Forces' medium altitude, long endurance (MALE) UAS-of-choice, the MQ-1 Predator and MQ-9 Reaper. In September 2017, GA-ASI expanded its "Team Reaper Australia" to nine companies in an effort to provide solutions to Australia's "Project Air 7003" UAS requirement.⁷¹ These arrangements are intended to spark greater innovation and technical knowledge sharing through expanded access while capitalizing on the "rise of the globalized [research and development] complex."⁷² If successful, such a business-to-government partnership will also firmly secure U.S. influence in the Australian military's fledgling armed UAS program and greatly strengthen the capabilities of one of the United States' most trusted allies in the Pacific.

In mid-2017, GA-ASI also entered a business-to-multiagency research collaboration agreement with a diverse Japanese team, representing Japanese industry, government, and academia with an objective to "accelerate operational approval for MALE UAS to fly in non-segregated Japanese civil airspace."⁷³ Expanding beyond the traditional business-to-business and business-to-government relationships, this collaboration demonstrates the powerful potential of the U.S. defense industrial base's normative influence on foreign UAS use and civil integration. No less crucial in this example is how "different fields influence one another in such intricate ways that even the best minds cannot fathom how break-throughs" in one emerging technology might impact other fields.⁷⁴

It is tempting to tout these three cases as examples of success under recent conservative policies in argument against the need-for-change. No doubt these represent U.S. industry success and future possibilities. However, such intimate international multi-functional cooperation is far from normal, only occurring after 20 year of U.S. UAS dominance and with a very limited subset of the most-trusted allies. The opportunity for change is fleeting as the U.S. UAS industry faces reduced available global market space considering, "'UAS activity is already globalized, with basic technical and industrial capability widely spread and ubiquitous," according to the Royal Aerospace Society. Recent export restrictions on U.S. UAS only further exaggerate the challenges with the "unintended effect of advantaging foreign UAS manufacturers."⁷⁵ U.S. government and industry must work together quickly under the authorities of the 2018 policy updates to reduce lost opportunities.

Indeed, it seems the United States often tends toward transactional relationships, expecting clear answers to: 1) what is the United States providing the other party; 2) what is the other party providing the United States; and 3) what are the associated United States' costs.⁷⁶ To continue to promote collaboration in the future similar to the highlighted cases, U.S. UAS export policy makers should take comfort in the response: 1) sharing lessons from decades of UAS experiences, establishing norms of use and export, and securing regional influence; 2) gaining critical transnational commercial access and valuable technical collaboration; and 3) in the long-term, improving the foreign policy objectives of sustained partnerships and enhanced U.S. business opportunities,⁷⁷ that if carefully managed, will outweigh most any U.S. financial costs or security risks.

An Example of Future Possibilities: Denmark

Denmark provides an instructive example of UAS sales' opportunities the United States is failing to exploit. Denmark boasts one of the world's highest incomes per capita. But with a relatively small population, it programs a similarly small defense budget.⁷⁸ Even with limited defense resources, Denmark consistently provides high quality niche capabilities to coalition efforts around the globe. Furthermore, their national defense strategy accounts for gate-keeping the Baltic Sea and the defense of Greenland and the Faroe Islands, providing sovereign access to the Arctic Circle.⁷⁹ The combination of consistent and trusted coalition participation, a willingness to share resources and intelligence, and a highly professional and interoperable military, all bolstered by their strategic geographic sovereignty, make Denmark a perfect target for increased strategic partnership through UAS sales.

Denmark's small defense budget but vast geographic responsibility drives their willingness to cooperate for collective defense and information sharing. The austere conditions and increasing importance of monitoring activity in the Arctic, creates an opportunity for UAS activity. Owning a fleet of UAS outright, however, is unrealistic with their current defense spending priorities.⁸⁰ In this scenario, relaxed U.S. UAS export policies create an environment to entice Denmark to partner with one or more close U.S. North Atlantic partners to share assets and intelligence. Denmark demonstrated their willingness to enter such agreements over the last few years by leading an eleven nation buy of U.S. precision guided munitions.⁸¹ The United States should facilitate a similar relationship for UAS, likely

with fewer partners, to improve the northern tier information network. In doing so, the United States gains greater access to the intelligence gathered in and around Denmark's territories, reinforces the desired normalization of UAS operations, sets a favorable precedent for pooled and shared UAS assets, and actively expands the UAS market.

The opportunity is not free of challenges. Any agreement must reconcile releasing technical *MTCR* Category I information and capability (until changes are made to the *MTCR*), adjudicate third-party sharing agreements, and arrange mutually beneficial information sharing. The Arctic weather poses great mechanical challenges as well. In this environment there is opportunity for significant long term technological advances though. Despite these challenges, a Denmark-United States-multilateral UAS arrangement remains a relatively low-risk U.S. investment-in-change and sets a clear avenue for future arrangements. Facilitated by existing North American Aerospace Defense (NORAD) and NATO structures and agreements, Canada might prove the perfect initial partner for a shared U.S. built-and-exported Danish UAS fleet supporting collective Arctic security and intelligence gathering and sharing. Lastly, Denmark's responsible UAS partnership and use in the Arctic becomes a key and favorable norm-setting example for Russia. Perhaps a tertiary effect of existing Denmark-Russia cooperation, this collaboration even facilitates, in time, a healthier United States-Canada-Russia relationship in the Arctic.

Recommendations

"It is imperative the United States remain the center of gravity for UAV doctrine, innovation, utilization, and employment."⁸² Security cooperation, including UAS foreign sales and sustainment, is a critical enabler to retaining the lead. U.S. UAS export policy must, therefore, allow sufficient flexibility for each foreign sale opportunity to account for the diverse objectives of the involved sovereign entities while fulfilling U.S. national security strategy.

Lead significant changes to the MTCR

"Individual partners are responsible for implementing the [*MTCR*] *Guidelines and Annex* on the basis of sovereign national discretion and in accordance with national legislation and practice."⁸³ Although this passage would allow the United States to discount *MTCR* language on UAS transfers, it would be preferable for the United States to lead *MTCR* rewrites on behalf of evolving UAS technology. Leading significant *MTCR* rewrites will prove quite challenging, as agreement between 35 nations is never easy. Naturally, after 26 years, many nations have grown comfortable with the language, and likely even adjusted their systems to account for *MTCR* provisions. Others unfortunately might use the push for significant edits to weaken the *MTCR*, take advantage, or even gain in other, perhaps less scrupulous, matters.⁸⁴ However, this is not the time for diplomatic compromise in the guise of progress. Incremental change will only continue to plague productive UAS advancement. The United States, instead, should pursue major changes to the accounting methods for UAS in the *MTCR* for long-term success.

Omitting every reference to unmanned aerial vehicles from the *MTCR* is not necessarily the best approach. Neither is adding further detailed discriminators, such as additional speed restrictions. Inclusion of UAV as written in today's *MTCR* no longer, if it truly ever did, accurately represents the threat associated with non-missile unmanned aerial WMD-delivery systems. In the place of the existing language, the *MTCR* should be modified to better account for primary intent or purpose. If, like cruise missiles and ballistic missiles, the primary or sole intent of the entire system is to deliver an integrated WMD-capable warhead to a specific target, then the *MTCR* should account for the associated threat of such unmanned vehicles. Likewise, delivery mechanisms, such as the aerosol dispensing systems in Item 19, should remain but be considered agnostic of delivery platform (manned versus unmanned, small versus large, etc.). Merely being an unmanned aerial platform does not specifically pose a greater WMD threat than a manned platform. Therefore, the majority of descriptions and suggestions of unmanned aerial vehicles and systems in the current *MTCR Annex* and, particularly, the U.S.-produced *Annex Handbook*, for both Categories I and II (Item 1 particularly) and associated subsections (Avionics, Software, etc.), should be deleted.

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Inaccurate terminology choices perpetuate misperceptions regarding these aircraft and their use. A sensor ball or a missile is agnostic as to the platform to which it is attached. Whether discussing the act of intelligence, surveillance, and reconnaissance (ISR) operations or the employment of munitions, the end effect has little to do with whether a manned asset or a remotely piloted one is used. The effect is the same.⁸⁵

As previously mentioned, the 2017 MTCR Plenary agreed to "intensify the efforts of Partners to prevent the proliferation of unmanned delivery systems capable of delivering WMD." This is the ideal window of opportunity for the United States to aggressively shape the definition of "capable of delivering" and fix the Plenary on "primary designed intent to deliver an *integrated* MWD-capable warhead to a designated target."⁸⁶ Likewise, as international aeronautical certification and regulatory agencies, such as the U.S. Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO), continue to mature UAS certifications, the MTCR Plenary and other policy-making entities should consider such certifications as discriminatory evidence between a missile and an unmanned aircraft.

Cultivate increased UAS collaboration and sales to develop cultural interoperability and solidify normative behaviors of use and export

U.S. foreign policy reaffirms commitment to trans-Atlantic cooperation and defense while demanding a visible increase in European self-defense capability.⁸⁷ This demand, accompanied by an apparent shift of U.S. priorities inward, could exacerbate the existing military capability gaps between the United States and Europe. Easing restrictions on UAS cooperation and sales to the United States' closest European partners reduces these gaps while improving United States-European cooperation and interoperability. Increased presence of both strike-enabled and unarmed UAS would enhance Europe's overall defense capability and help NATO "leverage the impact of new technologies," as recommended by a 2017 GLOBSEC report.⁸⁸ The integration of systems required to effectively operate UAS also creates the desired secondary effects of enhanced strategic networks, intelligence sharing, and command and control capabilities across NATO and even with near-NATO allies. With diverging security strategies, the United States and Europe must continue to actively seek such gap-closers. Parallel fighting is no longer a viable option; the collective defense of Europe, no matter the foe, would demand true interoperability.⁸⁹ NATO and the EU could and should leverage the benefits of UAS to enhance military interoperability. Relaxed U.S. UAS export and FMS policies are essential enablers.

Interoperability is more than a technical term. The interoperable [military] hardware is valuable, but the true value in [U.S.] military sales is enabling a relationship. Relationships create progress, and cultural interoperability ensures success.⁹⁰

Generally, there are three methods to establish normative behavior of individuals, groups, and even nations—incentives, persuasion, and socialization. The effectiveness of each varies by subject and scope.⁹¹ All three techniques are integral to setting international use and export norms for UAS and are most effective when layered for conditional reinforcement. The United States' top-shelf product and reliable long-term FMS support provides tremendous incentive for foreign governments to buy U.S. UAS. Demanding international buyers adhere to conditions set forth in the 2018 *U.S. Policy on the Export of UAS* and even favoring adherents of the 2016 *Joint Declaration* evoke persuasive norm setting. Together, these methods are effective in shaping use and export norms of a few of the closest partners allowed to buy U.S. UAS. It is yet uncertain as to the broader normative effects of these few cases. Until recently, the impact has been marginal with a small, U.S.-dominated international market. With greater market competition, the United States' plan to shape international norms lacks ample direct socialization. There are few assurances that those who buy Chinese or Russian UAS will use and further export in line with United States and ally practices, even if they signed the 2016 *Joint Declaration* or *MTCR*. As the list of international UAS users continues to grow, the dominate seller could quickly begin to also delineate "acceptable" practices. Selling U.S. UAS is the surest manner to ensure wider U.S. influence over international use standards, discourage unauthorized technology transfers, and deny competitor FMS opportunities

Anticipate and capitalize on the results

The United States must also anticipate the opportunities and challenges of these policy changes. Increased U.S. involvement and competition in the international UAS market will likely demand future policy adjustments. A successful whole-of-government approach to military exports will require continued emphasis and added incentives for all involved U.S. agencies, as well as consistency in language and expectations from policy down to execution. The United States should also continue to improve operational transparency to truly establish desirable normative behavior. With success, it is likely many of the negative perceptions of UAS will dissipate as dual-use UAS become more common, creating an even greater explosion of military and commercial opportunities and technological advances.

U.S. historic reliance on UAS market dominance and the veil of *MTCR* restrictions can mask challenges of the pending increased market competition. As foreign UAS sales continue to increase, policy makers must provide clear and balanced guidelines to the U.S. diplomats responsible for brokering FMS deals. Overreliance on the simplicity of the "buy American, hire American"⁹² mantra could be misleading and risk compromising other U.S. foreign policy goals. Recognizing international commercial and military UAS collaboration and progress will continue, both in parallel and intertwined, is critical to shaping policy makers' expectations and guiding future policy adjustments. Increased market inclusion will also highlight the diverging tactics of key international competitors. China, Russia, Israel, and the European Union (and each nation within) each approach military sales differently. A U.S. whole-of-government strategy that accounts for the various political actions, reactions, and counter-actions is necessary to address foreign influence in the international UAS market.

Several factors should be addressed to support a U.S. whole-of-government strategy for arms marketing. First, the general corporate culture must shift to incentivize interagency participation and priority for U.S. UAS exports and collaboration. For example, the relative newness of UAS often challenges existing host nation aviation regulations. Encouraging host nation legal reform, often best facilitated by senior U.S. State Department representatives, can then become a critical first step. End-use monitoring, also often provided by multiple U.S. agencies, is essential to establish and enforce acceptable enduring operational behaviors following UAS transfers. Second, resourcing must back policy rhetoric. Policy execution will always fall short without adequate manpower, funding, and training. Third, diplomatic divisions of labor and associated sales processes should be streamlined wherever possible. In an effort to safeguard U.S. technological advantages and comply with the multitude of United States and international export restrictions, bureaucratic processes sometimes morph to become cumbersome and ineffective and can derail even the best sales arrangements.

Increased U.S. UAS sales, and reinforcement of U.S. export policy stipulations, will continue to drive greater need for transparency in U.S. UAS operations. The "do as I say, not as I do" mentality will quickly prove insufficient, and even detrimental, to establishing international normative behavior. Partners will copy United States and allied actions rather than unquestionably comply with written international use and transfer standards. Leading open dialogue on reasonable and legal UAS use and transfer will endorse U.S. efforts to change the *MTCR*, bolster the effective-ness of the 2016 *Joint Declaration*, and reinforce appropriate U.S. national security safeguards.

Finally, general public perceptions of UAS will improve as UAS become more commonplace, governments embrace greater operational transparency, and technological advances prove the dual-purpose value to society. As this occurs, the U.S. military, UAS industry, and federal aeronautical regulating agencies should anticipate and adjust for the expectation, even demand, for further UAS integration. Specifically, to continue to offer long-term sustainment as a U.S. benchmark, the U.S. military and selected contractors must commensurately increase international operator and maintainer training capacity. Increased capacity can be generated internal to existing U.S. training operations or through aiding, advising, and assisting foreign militaries in establishing indigenous training programs. Likewise, diverging exportable hardware and software versions must be carefully managed to not overreach the efficiencies of U.S. sustainment, support, and desired international interoperability.

As innovations continue to blossom, policy must adjust to account for the added challenges of rapidly evolving dual-use UAS. Naturally, many policy makers today seem to focus on larger, traditional, airplane-sized UAS. Future policy, though, should consider all UAS sizes, from micro to macro, especially as weaponized small UAS continue to progress.⁹³ It is imperative for today's policy reforms to lay the foundation for flexible adaptation for future capabilities. Clearly establishing normal international use and transfer behaviors with today's non-autonomous UAS

through cooperative international action is imperative for the future challenges of growing UAS autonomy, artificial intelligence, swarming, manned-unmanned teaming, pilot-optional aircraft, and civil-military dual-use UAS. Fortunately, both civil and government regulatory agencies and partnerships already exist internationally to help inform smart policy of tomorrow. Now policy makers must seek their advice, follow their lead in many cases, and accept the new normal of rapid policy revisit rates to account for the pace of UAS technological evolution.

Conclusion

In 2011, the New York Times reported from the Zhuhai, China airshow on the "stark evidence that the United States' near monopoly on armed drones was coming to an end with far-reaching consequences for American security, international law, and the future of war."⁹⁴ Seven years later, the end is very near yet there are few concerted U.S. policy efforts to counteract such threats. The updates in the 2018 *Conventional Arms Transfer Policy* and *U.S. Policy on the Export of Unmanned Aerial Systems* are a great start. This reform, however, to provide positive effects for the greater UAS enterprise must be accompanied by substantial rewording of the *MTCR* and disciplined implementation from government through to industry. Close cooperation between U.S. industry, the U.S. Department of State, and Lieutenant General Hooper's DSCA will be integral to executing these changes. General Hooper already recognizes, "It is time to take a new sales approach for today's information-based, networked military capacity."⁹⁵ This is the opportunity, amidst the potential whole-of-government clamber to increase UAS exports, to restructure the supporting institutional mechanisms and lead U.S. foreign military sales into the information age. Fortunately, there is no better benchmark platform-for-change spanning hardware, software, global command and control, multi-domain effects, and multi-functional intelligence with remarkable military and commercial market opportunity and disruptive capacity than Unmanned Aircraft Systems.

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APPENDIX A - ENDNOTES

- 1 Unmanned Aircraft System: contains the unmanned aerial vehicle and the control infrastructure, which consists of the technical and human parts.
- 2 low altitude, near the ground; a few 10 meters above the ground level
- 3 Aeronautical Information Service
- 4 Data are not changed for longer periods, their validity are longer or at least equal with an AIRAC cycle.
- 5 They may contain frequently changing content, thus their validity are between and AIRAC cycle and a few hours.
- 6 Data with low temporal stability, they can change even every second.
- 7 Data which is continuously changing.
- 8 Staff, J. C. O. (2018). Department of defense dictionary of military and associated terms. Military Bookshop, 242, http://www. jcs.mil/Doctrine/DOD-Terminology/. "The DOD Dictionary of Military and Associated Terms (DOD Dictionary) sets forth standard U.S. military and associated terminology to encompass the joint activity of the Armed Forces of the United States. These military and associated terms, together with their definitions, constitute approved Department of Defense (DOD) terminology for general use by all DOD components." The plethora of terms describing unmanned aircraft (or aerial) systems (UAS) is particularly challenging when writing policy, negotiating international agreements, or shaping public opinions. U.S. policies and international agreements on the subject use numerous terms with little explanation or apparent purpose in difference. For purposes of this paper, a UAS is a "system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft." The media often prefers the term drone for ease and perhaps word count, but a drone is a flying target to many militaries and indicates an undefined degree of autonomy and expendability. Another common term, unmanned aerial vehicle (UAV), often refers specifically to the aerial platform. The U.S. Air Force prefers remotely piloted aircraft (RPA) to reinforce the essential human pilotage. Many European air forces and agencies agree but add the word, systems, to get RPAS. This paper will primarily use unmanned aircraft systems (UAS) as approved in the 2018 U.S. DOD Dictionary of Military and Associated Terms.
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PEER-REVIEWED ARTICLE

FINITE ELEMENT ANALYSIS OF BI COPTER BODY FRAME MODEL

Skanda S. Bharadwaj Graduate Student, R.V. College of Engineering

Keshavamurthy, Y. C. Assistant Professor, Department of Mechanical Engineering, RV College of Engineering

ABSTRACT

Bi copters are one of the rarely seen rotary wing vehicles in real world. Bi copters are difficult to manufacture and stabilise. Selection of proper materials and design for fabrication of a bi copter is crucial. This paper gives structural analysis of different materials using ANSYS as the software tool. Such an analysis can be done to any design model, here bi copter is under consideration. Carbon fibre and aluminium are taken as test materials for the purpose of analysis and structural analysis is done and the results are analysed and compared. It is found that carbon fibre has three times the load bearing capacity when compared to that of aluminium frame of a bi copter.

Keywords: Bi copters, rotary wing vehicles, load bearing capacity, carbon fibre, structural analysis

Introduction

Bi copter is a device in which electrical, electronic and mechanical components are integrated as a single unit to give us our desired aviation and to meet our objectives.

Bi copter is a field in which extensive research is being done, one of the major researches done recently as proposed by Gress, G. R. (2018). It incorporates the advantages of both a helicopter and a quadcopter as detailed by Bhavik Gupta, Ankit Patel, Anurag Kumar, Mohit Ujjwal (2015). Stabilised bi copter has higher payload lifting capabilities consuming lesser power since the number of rotors are less. Consumption of less power leads to higher endurance as discussed by Kanaiya Agrawal, Punit Shrivastav (2013). These features are of utmost importance in rescue operations conducted by the military whenever the need arises as described by Nataraj, Madhukumar, Karthik (2017). Unlike a quadcopter whose frame design can be done on existing literature and that which has almost reached level of saturation, bi copter is still under areas of research. Stability of a bi copter electronically alone is difficult to achieve as discussed by Qimin Zhang, Zihe Liu, Jieru Zhao, Shuguang Zhang (2016).

Bi copter body frame model is done using solidworks and analysis is done using finite element analysis with the help of ANSYS as analysed by Endrowednes Kuantama, Dan Craciun, Radu Tarca, (2016). Body frame model is done keeping in mind various pre-requisites needed such as payload carrying capacity, strength to weight ratio, centre of gravity, positioning of electrical and electronic components etc detailed by Parag Parihar, Priyanshu Bhawsar, Piyush Hargod (2016). Body frame model is designed taking various concepts from vertical take-off and landing (VTOL) and hover bike to achieve maximum structural stability as discussed by Ninad R. Patil, Ashish A. Ramugade (2017).

On completion of analysis of the model, frame can be built or 3Dimensionally (3D) printed. 3D printing is preferred owing to its advantage of having higher strength to weight ratio and its ability to craft intricate designs. The electronic components required are selected beforehand based on ideal required thrust calculations and on the objectives of bi copter to be met as discussed by Prof. Javir, A. V. Ketan Pawar, Santosh Dhudum, Nitin Patale, Sushant Patil (2015).

Objectives

The major objectives of this paper are as follows:

1. Primary objective is to analyse the load deformation (ductility) characteristics of different materials and the sequential process to do the same for a bi-copter.

2. Secondary objective is to go through the sequential steps of designing and building a structural stable bi-copter.



Methodology



Figure 1. Design process of bi-copter body frame model

Figure 1 shows the flow chart that represents the various stages in carrying out the structural analysis. Bi copter is a device in which electrical, electronic and mechanical components are integrated as a single unit. These components must work hand in hand with each other to become a homogeneous system. Each component must be compatible with all of the other components to enhance the overall performance of the copter, else the copter fails.

Electronic components are the brains behind the flight of the copter. They control the stability and manoeuvring of the copter. All low power components come under electronics. They are also responsible for enhancing the capabilities of the copter by integrating various electronic components performing different functions. Electronic components include electronic flight controller, receiver, global positioning system (GPS), sonar, gimbal, camera, first person view (FPV), power module, etc.

Electrical components are the main power supplying and distributing part of the copter. It gives sufficient power to power the copter for it to hover, accelerate, decelerate, or to perform acrobatics if needed. High power components come under electrical. Electrical components include battery, electronic speed controller (ESC), motors, power distribution board, etc.

Mechanical components are the supporting structure which holds all the other components in its appropriate or designated place. It mainly consists of body frame and landing gear designs. Other components can be added later which enhances the durability, compactness or appearance.

Electronic and electrical components cannot be placed adjacent to each other, since the high-power lines of electrical components has a probability of destroying the electronic components. Also, magnetic fields are induced due the current flowing through the electrical components which in turn induces current in electronic components in addition to the signal currents flowing through it. So, the information signals being sent are disrupted and copter loses its stability. Hence sufficient clearance must be maintained between these two components to minimize the effects as much as possible which is looked after in mechanical design of the copter.

Flight Dynamics

Bi copter is a two-rotor device. Movement in all 3 axis needs to be controlled by the two rotors present. Directional movement of the copter can be controlled in two ways. By differential increase in the speeds of the rotors or by tilting the rotors to a very small degree. Motor with a propeller spinning at its designated speed has certain thrust being produced along with inherent torque due to its rotation. Controlled speed of rotors thus leads to differential speeds and torques relative to the two rotors present which enables the movement of the copter in different directions. Bi copter movement in x and y axis are called roll and pitch respectively. Rotation of copter about its axis in x-y plane is called yaw.

Hovering and Acceleration:

Bi Copter having only two rotors is one of the most difficult ones to hover at a place but also is one of the easier ones to accelerate swiftly and make tight turns. It is ideally suited for acrobatics. But it is also imperative that it stays hovering at a place without drifting. In this regard, the flight control systems must be very well tuned and as far as possible the centre of gravity of the entire copter along with its electronic components must be below the position of motors, so that it eases the level of complications on the rotors. In order to accelerate, the two rotors are tilted in the forward or backward direction by few degrees and the copter accelerates rapidly. Care must be taken that restriction is provided on the maximum tilt of rotors, else there is a chance that copter might topple or flip.

Body frame modelling (Part-1)

In order to design the body frame model of any Copter, first we need to have a clear picture so as to the approximate weight and size of the copter we desire to build. Depending on the total weight of the copter, material needed to build our copter is decided. Sometimes multiple materials can be used in order to build our copter. In such cases, our budget restriction comes into play and we can use the material which is economical to us.

Electrical and Electronic aspects

These form the power supply and brains behind the working of a copter. Depending on the approximate weight of the copter, thrust required is calculated. Minimum of 2:1 thrust to weight ratio is preferred and can go as high as 8:1 or more for acrobatic copters. Based on individual needs, thrust is calculated and appropriate motors are chosen with its prescribed propeller length. Base on maximum current that can be drawn by the motors, electronic speed controllers (ESC's) are determined and the maximum total current drawn by all ESC's combined and the endurance of the copter desired by each individual determines the minimum milliamp hour (MAH) and 'C' rating of the battery needed. This fixes the basic power housing or the electrical components of the copter. Now depending on the level of stability, ease of operation, ease of tuning needed, and most importantly economic restrictions, flight controllers are chosen. various types of flight controllers are available in the market, from simple low cost to complicated, superior heavy budget flight controllers. Ex: KK2.0 Flight Controller, CC3D, Pixhawk, NAZA Flight Controllers etc. Finally, a receiver bound to the transmitter that is used is connected to the flight controller. This forms the basic brains and electronic components behind the operation of a copter.

Body frame modelling (Part-2)

Once the electrical and electronic components are decided, it is easier to get the exact weight of the copter and the strength of the frame required to carry the weight. Propellers are decided which gives the exact size of the copter being designed. Depending on the clearance left between the ends of propeller, size of copter is fixed from one axis of the propeller to its adjacent one. Sufficient clearance must be given between propellers so as to minimize the interference between the two rotors. Ideally, the clearance needed to be given to get the interference as zero is very high and cannot be accomplished practically. Hence some compromise is done, and an appropriate clearance is given. Exact turbulence effect between the two rotors and downwash from the rotors can be seen or calculated using computational fluid dynamics (CFD). Depending on positioning of various electrical and electronic components, the entire frame of the copter is designed. Designing is preferably done using a computer aided design (CAD) modelling software like SolidWorks, Catia Etc.

Deformation analysis of bi copter body frame model

Depending on weight of copter and maximum payload it needs to carry, different materials can be used for copter construction. Relatively few are strong but brittle, or ductile but weak or have high strength to weight ratio but expensive. Hence, while designing, a compromise needs to be done between materials by analysing properties of various materials. ANSYS is one of the software used to analyse various materials.

An analysis is done taking two materials into consideration, Aluminium 6061 alloy as shown in Figure 2 and carbon fibre epoxy composite as shown in Figure 3. A bi copter frame is designed in CAD (SolidWorks) and ANSYS deformation analysis is done on it by applying various loads taking both these materials into consideration.

Both these materials are assigned to the same frame to avoid the ambiguity of change of dimensions while analysing. Weight of frame when the frame is made by each of these materials are calculated. To avoid ambiguity, weight of electronics is considered to be zero just for the sake deformation analysis. Weight imparted by electrical and electronic components relatively vary considerably from one copter to another. This depends on the needs and ability of the individual building the copter. Weight of frame relatively remains the same for a given size and shape for similar copters. Hence, analysis is done considering just the weight of frame and weight of other components are considered as zero. Thrust given by motors are considered to be point loads acting at the centre of each rotor.



Figure 2. aluminium body frame model

Figure 3. carbon fibre body frame model

First analysis is done, taking the total thrust produced by rotors equal the weight of the frame, i.e. an ideal case when the copter just hovers. Weight of aluminium frame is 442.12 grams and weight of carbon fibre frame is 326.5 grams. Aluminium frame in Figure 4 shows maximum deformation of 3.33mm and carbon fibre frame in Figure 5 shows maximum deformation of 0.91mm respectively.



Figure 4. Aluminium Frame, Max Deformation = 3.33mm



Figure 5. Carbon fibre Frame, Max Deformation = 0.91mm

Second analysis is done, taking the total thrust produced by rotors approximately equal to that which causes one-degree deformation in both the frames independently. Aluminium frame in Figure 6 shows maximum deformation of 3.69mm and Carbon fibre frame in Figure 7 shows maximum deformation of 3.73 mm respectively.



Figure 6. Aluminium Frame, Max Deformation = 3.69mm

Thrust produced by each motor = 2.4 Newtons



Figure 7. Carbon fibre frame, Max Deformation = 3.73mm

Thrust produced by each motor = 6.5 Newtons

Third analysis is done, taking the total thrust produced by rotors approximately equal to that which causes two-degree deformation in both the frames independently. Aluminium frame in Figure 8 shows maximum deformation of 7.46mm and carbon fibre frame in Figure 9 shows maximum deformation of 7.45 mm respectively.



Figure 8. Aluminium Frame, Max Deformation = 7.46mm

Thrust produced by each motor = 4.85 Newtons



Figure 9. Carbon fibre Frame, Max Deformation = 7.45mm Thrust produced by each motor = 13 Newtons

Fourth analysis is done, taking the total thrust produced by rotors approximately equal to that which causes three-degree deformation in both the frames independently. Aluminium frame in Figure 10 shows maximum deformation of 11.13mm and carbon fibre frame in Figure 11 shows maximum deformation of 11.17 mm respectively.



Figure 10. Aluminium Frame, Max Deformation = 11.13mm

Thrust produced by each motor = 7.25 Newtons



Figure 11. Carbon fibre frame, Max Deformation = 11.17mm

Thrust produced by each motor = 19.5 Newtons

Fifth analysis is done, taking the total thrust produced by rotors approximately equal to that which causes four-degree deformation in both the frames independently. Aluminium frame in Figure 12 shows maximum deformation of 14.86 mm and carbon fibre frame in Figure 13 shows maximum deformation of 14.86 mm respectively.



Figure 12. Aluminium frame, Max Deformation = 14.86mm

Thrust produced by each motor = 9.7 Newtons



Figure 13. Carbon fibre Frame, Max Deformation = 14.86mm)

Thrust produced by each motor = 26 Newtons

Sixth analysis is done, taking the total thrust produced by rotors approximately equal to that which causes five-degree deformation in both the frames independently. Aluminium frame in Figure 14 shows maximum deformation of 18.63 mm and carbon fibre frame in Figure 15 shows maximum deformation of 18.54 mm respectively.



Figure 14. Aluminium frame, Max Deformation = 18.63mm

Thrust produced by each motor = 12.2 Newtons



Figure 15. Carbon fibre frame, Max Deformation = 18.54mm

Thrust produced by each motor = 32.5 Newtons

Results

Table 1: Deformation results of carbon fibre and aluminium frame of bi copter

Material	Weight (gram)	Lift-Off Thrust (newton)	Thrust of single motor at one-degree deformation (newton)	Thrust of single motor at Two-degree deformation (newton)	Thrust of single motor at Three- degree deformation (newton)	Thrust of single motor at Four-degree deformation (newton)	Thrust of single motor at Five-degree deformation (newton)
Aluminium Frame	442.12	4.33	2.4	4.85	7.25	9.7	12.2
Carbon Fibre Composite Frame	326.5	3.19	6.5	13	19.5	26	32.5

Conclusion

Deformation in aluminium and carbon fibre for various loads were observed. These two materials were compared based on common grounds and on ideal cases. These were Analysed for a maximum deformation of approximately 5 degrees or 2cm. Deformation of lengths greater than these are not advisable in copters as part of thrust is lost or wasted.

Similarly, analysis for different materials can be done and the best one suited for each individual can be chosen. This helps us in quantitative and qualitative view on selection of proper material for copters.



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PEER-REVIEWED ARTICLE

WHAT TYPE OF PERSON SUPPORTS 24/7 POLICE DRONES OVER NEIGHBORHOODS?

A Regression Analysis

Daniel A. Marte Human Factors Specialist, John Deere

Emily C.Anania Department of Behavioral Neurobiology and Human Factors at Embry-Riddle Aeronautical University

Dr. Stephen Rice Department of Behaviorial Neurobiology and Human Factors at Embry-Riddle Aeronautical University

Dr. Rian Mehta College of Aeronautics at the Florida Institute of Technology

Mattie N. Milner Department of Behaviorial Neurobiology and Human Factors at Embry-Riddle Aeronautical University

Dr. Scott R. Winter School of Graduate Studies at Embry-Riddle Aeronautical University

Nathan W.Walters Human Factors at Embry-Riddle Aeronautical University

John Capps Department of Behavioral Neurobiology and Human Factors at Embry-Riddle Aeronautical University

Nadine K. Ragbir Human Factors at Embry-Riddle Aeronautical University

ABSTRACT

Unmanned Aerial Systems (UAS) have significantly influenced the methods that industries use to conduct business. For example, several large city police forces have welcomed UAS, revolutionizing their surveillance capabilities. However, the influx of UAS does raise potential privacy concerns for citizens living in those areas patrolled with UAS. Therefore, the purpose of this study was to determine what variables predict participants' privacy concerns about UAS police missions above their neighborhood. There were 205 participants in stage 1 and 186 participants in stage 2, and they were presented with hypothetical scenarios involving police issued UAS patrolling near their residence. Following the scenario, they were asked to provide responses to a validated UAS privacy scale and then answer a set of questions that served as potential predictors. The data reveal that seven factors (importance of privacy, attitude towards UAS, perceptions of whether police are corrupt, feeling of safety in the neighborhood, number of children, ethnicity, and support for police activity in the neighborhood) significantly predict participants' privacy concerns about police usage of UAS in their neighborhoods. As the police employ UAS missions in public or near housing residences, it is important to consider the privacy concerns of residents and other citizens in the area. The results from this study provide information about what type of person is most concerned with UAS privacy issues.

Keywords: Privacy Concerns, Unmanned Aerial Vehicle, Police Surveillance, Public Perception

Introduction: Problem Statement

Unmanned aerial systems (UAS), more commonly referred to as drones, are operated by a remote pilot and vary in their technological capabilities and use (Clothier, Greer, Greer, & Mehta, 2015; Finn & Wright, 2012). As UAS gain popularity, more businesses and private agencies are expanding their use to fulfill new tasks and jobs previously completed by people. Business Insider reports that consumer, commercial, and government drones, combined, have the potential to increase sales from \$8.5 billion in 2016 to more than \$12 billion in 2021 (Meola, 2016). This potential increase is favorable for UAS manufacturing growth but raises potential concerns regarding citizens' privacy. The FAA currently determines the regulations for drone use, and their purpose is to protect the National Airspace System (NAS) and help prevent aircraft collisions (Matiteyahu, 2015). Though necessary to protect passengers and promote safety in the aviation industry, these regulations fail to consider citizens' privacy.

Over the past few decades, the public has grown more and more concerned over privacy rights and the intrusion of the government into their private lives, and properties, without warrants or probable cause. The ability of UAS to access areas and vantage points within properties that would otherwise remain hidden from the public has increased privacy concerns revolving around UAS usage (Villasenor, 2014). While privacy is a significant concern for citizens, it's important to understand the public's overall perception of UAS. To date, few studies have investigated citizens' perceptions of drones used by police and others. Therefore, the purpose of this study is to investigate and identify factors that may predict citizens' perceptions of UAS use by law enforcement agencies.

Privacy Issues

The issue of privacy has been strongly debated throughout American history, with shifting interpretations at different points in time. Marmor (2016) defines privacy as:

having a reasonable measure of control over ways in which we present ourselves to others, [... and securing] a reasonably predictable environment about the flow of information and the likely consequences of our conduct in the relevant types of contexts (p. 8).

Protecting citizens' privacy is a responsibility of elected Congress officials; therefore, it is important to understand the effect these regulations may have on the Fourth Amendment, which establishes "the right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures" without a warrant (U.S. Const. amend. IV, n.p.). The Fourth Amendment is crucial for citizens' privacy because it limits the government's ability to intrude in a person's life and property without due diligence or probable cause. Nonetheless, the language in the amendment and rulings by the Supreme Court of the United States (SCOTUS) limits the scope of these privacy rights and enables authorities some liberty for searches and surveillance at their discretion (Villasenor, 2014).

A reasonable expectation of privacy should not be misinterpreted as absolute privacy. The fourth amendment does not protect citizens if they are breaking the law in an open space on private property, such as their backyard, front porch, or anywhere where members of the public may feasibly see them (Blitz, 2013). For example, during routine helicopter surveillance of a residential neighborhood, police discovered illegal substances being stored outside a person's home. Despite finding the substances without a warrant on private property, SCOTUS determined the residents did not have a reasonable expectation of privacy because the illegal substance was in plain sight, and the surveilling aircraft complied with the Federal Aviation Administration's (FAA) regulations (Frazier, 2016); thus, the residents were lawfully convicted.

Currently, UAS have a wide array of capabilities, including geolocational tracking, cameras, live video streams, radar, and communication interception (Cavoukian, 2013). UAS capabilities are used to support military operations, agriculture, search and rescue, surveillance, land survey, and recreational purposes (Winter et al., 2016; Zhang & Kovacs, 2012). With so many different possibilities for UAS, concerns over Fourth Amendment violations are not unfounded. While the public widely uses UAS for a variety of purposes including surveillance and recording, it could be argued that the scope of these previous rulings was not in the context of current technology and that the software on law enforcement drones may render the UAS as a device 'not in general public use.' This is an import-

ant aspect because previous court rulings have sided with the plaintiff because the technology being used by the defendant was not considered 'general public use.' Technology outside of general public use can include sophisticated camera zoom options, live video streaming, geo-locational tracking, infrared thermal imaging, radar, etc. (Cavoukian, 2013). However, as these technologies become cheaper and more accessible, they may start to fall into the category of 'general public use,' which could negatively affect the protection of citizen's privacy.

Another concern regarding possible privacy violations is video and audio recording by civilians without consent. States laws vary in their interpretation of how recording without consent violates or fails to violate, constitutional law. For example, the Seventh Circuit in Illinois decided that audio recording is illegal without consent from all parties being recorded (Kaminski, 2012). Additionally, Texas state law bans video recording of private property without the owner's consent. The differing laws create controversy due to the conflicting nature of the Fourth and First Amendment, which protects free speech (U.S. Const. amend. I). In Fields v. Philadelphia (2017), the court stated in the opinion regarding the recording of police officers that "the First Amendment protects actual photos, videos, and recordings, [...] and for this protection to have meaning, the Amendment must also protect the act of creating that material" (n. p.) The discrepancy between these amendments may hinder the progress of new legislation or create conflicts when law enforcement uses UAS. For this reason, it is essential to explore the nature of privacy concerns regarding their use. The present study expands upon privacy perception as it relates to UAS.

Privacy Issues in UAS Missions

Prior studies have sought to determine people's willingness to accept drone use in a variety of scenarios. Vincenzi, Ison, and Liu (2013) found that privacy was the top concern regarding the domestic use of UAS, followed by safety. More than 50% of respondents were not comfortable with the use of drones outside of military airspace, but they supported their use for firefighting, weather monitoring, natural disaster management, and pipeline patrol, while applications by law enforcement, including surveillance, were rated unfavorably.

Winter, Rice, Tamilselvan, and Takorski (2016) explored participants' concerns regarding the scope of UAS employment, which consisted of police using the drones for 24/7 surveillance, or using them only during specific missions. Also, the researchers also explored whether any emotions mediated the relationship between perception of privacy concerns and whether the UAS was used 24/7 or mission-specific. Results indicated that participants experienced higher privacy concerns when the police planned to use the drones for 24/7 surveillance rather than during specific missions only. Furthermore, affect (emotion) mediated the relationship between privacy concern scores and droneuse type, with disgust and fear as significant predictors.

Heen, Lieberman, and Miethe (2018) found that public support for UAS use by police was highest when used in reactive policing contexts, such as responding to calls, search and rescue, etc. Proactive policing applications of drones received less than half the support that reactive applications did from participants. The authors propose that the results are akin to literature regarding public attitudes toward citizen-police interactions, with a possible explanation being that the intent and scope may be less clear and available to the public in proactive missions than reactive missions, where intent and scope are clear and directed.

Perry and Winter (2016) found that participants' concerns about privacy were higher when presented with a UAS scenario involving audio/video capability and almost neutral when no equipment was present. Overall, females scored higher regarding privacy concerns when the drones were equipped with the capability of audio, video, or a combination of the two. Rice and colleagues (2018) further explored this gender difference and found that the gender differences varied depending on mission type, appearing only when the mission involved unmarked UAS, real estate, online sales, and construction, with females scoring higher on privacy concerns.

The results of these studies lay the framework for a basis of the investigation, which may lead to a more insightful way to implement and use drones as part of law enforcement surveillance strategies. Once citizens' perceptions and concerns of this technology are better understood, laws and regulations can be developed that garner support from people regardless of their race, political affiliation, residential location, and other accompanying demographics that form American neighborhoods.

Current Study

The current study has two main goals. In study one, the purpose was to generate a descriptive regression model of 19 variables and their effect on the perception of privacy concerns. The 19 variables tested were: age, gender, ethnicity, political affiliation, number of children, education level, income, number of times broken the law, perceptions of whether the police protect us, perceptions of whether police are corrupt, feeling of safety in the neighborhood, importance of privacy, support for police activity in the neighborhood, trust in aviation technology, attitude towards aviation technology, attitude towards UAS, trust in technology, trust in the police, and knowledge about UAS. In study two, the purpose was to validate the model generated to measure privacy concern, and to test model fit. The following hypothesis was presented for this study:

 H_{a1} : At least one of the predictors (age, gender, ethnicity, political affiliation, number of children, education level, or income) would be a significant predictor of privacy concerns when controlling for all other variables.

Methods

Participants

In study one there were 205 (83 females) participants from the United States, while study two utilized 186 (78 females) participants from the United States. Both stages recruited participants via convenience sampling on Amazon's © Mechanical Turk © (MTurk). MTurk is a web-based platform which allows individuals to complete human intelligence tasks (HITs) in exchange for monetary compensation. Data from MTurk has been shown to have similar reliability to that of traditional data gathered in a laboratory and is arguably more generalizable than a university subject pool (Buhrmester, 2011; Germine et al., 2012; Rice et al., 2017). The mean age of participants was 36.88 (SD = 12.15) years old.

Procedure and Materials

First, participants were presented with a consent form and were then required to sign it digitally. Participants were then given instructions on completing the subsequent survey. The first section of the survey was a hypothetical scenario which read "Imagine a situation where your local police department announces plans to use unmanned aerial vehicles (UAS) to patrol the skies of your neighborhood 24/7 (day and night) every day of the year in order to assist with police activities. These UAS would fly at various altitudes and provide aerial coverage with video feedback of the entire neighborhoods at all times."

Upon reading this hypothetical scenario, participants filled out a previously validated UAS Privacy concerns scale (Mehta, Rice, Winter, Moore, & Oyman, 2015; See Appendix A). The final section of the survey required participants to answer demographic questions that were as follows: age, gender, ethnicity, political affiliation, number of children, education level, income, number of times participant has broken the law, perceptions of whether the police protect us, perceptions of whether police are corrupt, feeling of safety in the neighborhood, importance of privacy, support for police activity in the neighborhood, trust in aviation technology, attitude towards aviation technology, trust in the police, and knowledge about UAS (the last eleven factors were measured on a seven-point Likert-type scale with varying anchors). Upon completion, participants were debriefed and paid.

Results

This research was divided into two stages. The first stage used stepwise regression analysis to determine the predictors of statistical significance. The second stage tested the equation generated in stage 1 for model fit using an independent secondary sample, validating the model. Stage 1 utilized 205 participants with stage 2 containing an independent sample of 186 participants. Using G*Power, the minimum sample sizes required for the study were 187 participants with the following criterion: small effect size of .15, power (beta) of .90, an alpha level of significance .05, and the 19 predictors.

Stage I

A stepwise regression analysis was conducted to determine the statistically significant predictors of UAS Privacy in this study. The regression analysis generated seven significant predictors listed below. The regression equations generated was:

Y = -.937+.322X1 -.184X2 +.096X3 +.151X4 -.105X5 +.816X6 -.105X7

where Y was the predicted UAS privacy scores, and X1 through X7 were the importance of privacy, attitude towards UAS, perceptions of whether police are corrupt, feeling of safety in the neighborhood, number of children, ethnicity (mixed), and support for police activity in the neighborhood, respectively. The overall regression model accounted for 39.60% (37.50% adjusted) of the variance in privacy related to UAS, and was a statistically significant model with F(7,197) = 18.46, p < 0.001.

Stage 2

In stage 2, an independent set of participants was used to collect the second sample. This sample was used to test the equation created in stage 1, thus validating the predictive nature of the model. This model fit validation was conducted in three ways, using t-tests, correlations between actual and predicted scores and cross-validated R^2 . Through the application of the regression equation to the second sample, a set of predicted scores of UAS privacy were generated. These predicted scores were compared with the actual scores of the participants in the second sample.

The first test conducted in stage 2 was the t-test between the two sets of data (predicted scores calculated from the regression equation from stage 1 and the actual scores of the second sample). The test produced statistically insignificant differences between the two sets of data, where t(185) = -.230, p = .818. Based on this analysis, it can be inferred that the actual and predicted scores do not vary significantly and therefore the prediction model is valid.

The second test conducted in stage 2 was a correlation analysis between the same two sets of data of predicted and actuals scores. This analysis revealed a statistically significant correlation, where r(185) = .634, p < .0001. Based on this analysis it can be inferred that the actual and predicted scores correlate significantly and therefore the prediction model is valid.

The final analysis of stage 2 was the cross-validated R^2 test. The cross-validated $R'^2 = 1 - (1 - R^2)[(n+k)/(n-k)]$, where R^2 is overall R^2 from the initial model, n is the sample size of the stage 1 sample, and k is the degrees of freedom. The purpose of this test is to determine the application strength of the initial model onto following samples and the population. The results of this test showed $R'^2 = .353$. Since the cross-validated R^2 was very close to the overall R^2 , it can be inferred that model fit exists.

Surrounding the use of UAS in communities where they are viewed negatively, educating individuals on the types of situations UAS may be used could alleviate people's concerns. The lack of knowledge and transparency surrounding UAS programs may affect people's privacy concerns of UAS in their neighborhood. Allowing a community to become involved in creating a UAS program, similar to a neighborhood watch program, will promote buy-in to the idea. Lawmakers and law enforcement adopting a community-centric approach to legislation and use of UAS are crucial for success.

Discussion

The current research had two main goals. First, we hypothesized that at least one of the predictors (age, gender, ethnicity, political affiliation, number of children, education level, income, number of times broken the law, perceptions of whether the police protect us, perceptions of whether police are corrupt, feeling of safety in the neighborhood, importance of privacy, support for police activity in the neighborhood, trust in aviation technology, attitude towards aviation technology, attitude towards UAS, trust in technology, trust in the police, and knowledge about UAS) would be a significant predictor of privacy concerns when controlling for all other variables. Second, we wanted to test the predictive regression model on a subsequent data set, thus confirming the model fit.

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Stage 1 indicated seven significant predictors: the importance of privacy, attitude towards UAS, perceptions of whether police are corrupt, feeling of safety in the neighborhood, number of children, ethnicity, and support for police activity in the neighborhood. These predictors make intuitive sense, as individuals with negative attitudes towards UAS or police may feel that police drone surveillance threatens their privacy. Previous research has indicated that citizens feel differently about UAS usage depending on their gender, the UAS operator, and their emotions (Rice et al., 2018; Winter et al., 2016). Therefore, it is reasonable to assume that both individual differences and the situational context influence an individual's concern over privacy when a UAS is present. Also, those who place a higher importance on privacy understandably have more privacy concerns. Individuals express many concerns about their privacy around UAS, including but not limited to: recording information, stalking, and being in private places, or engaged in private activities and conversations (Wang, Xia, Yao, & Huang, 2016). Therefore, the finding that the importance of privacy and feelings of safety are two significant model predictors supports current literature. Also, individual differences such as ethnicity have been shown to influence perceptions of emergent technologies (e.g., driverless vehicles; Anania, Rice, Walters, Pierce, Winter, & Milner, 2018).

Stage 2 indicated that the model fit was strong for the equation generated by Stage 1. First, a t-test indicated that the scores were not significantly different between the two sets of data. Second, correlation analyses indicated a significant correlation. Finally, the model fit was assessed using cross-validated R^2 , attempting to indicate whether the model could be applied to other samples. Cross-validated R^2 was similar to the overall R^2 , indicating model fit.

Theoretical Contributions and Practical Applications

The current research contributes to the literature in several ways. First, it builds off previous UAS literature which indicates that individuals have differential levels of privacy concerns when considering different types of UAS (Rice et al., 2018). While previous research had identified a select few variables that influence an individual's privacy concerns, the current work expanded beyond this to consider new variables. In addition, the current research uses a regression model to help predict an individual's level of privacy concerns in regards to UAS. This adds to the body of literature regarding attitudes toward privacy, which has not focused on predictive models, but rather on the intersect between attitude and behavior (Kokolakis, 2015). However, the current results do support the previous literature in that individuals are concerned about their privacy when it comes to new technologies such as personal health records (Lafky & Horan, 2011) and new retail technologies (e.g., kiosks, mobile apps, "scan and go" technology; Inman & Nikolova, 2017).

In addition to supporting and building on the literature, the current research also has several practical applications. Using this prediction model to understand people's perceptions of UAS privacy in specific situations can provide insight to lawmakers and law enforcement who may implement, regulate, or use UAS. The researchers suggest that lawmakers and law enforcement should consider the seven significant predictors identified in the regression analysis of this study to better understand the concerns of the population which they are tasked to serve. A population's attitude towards UAS, the importance they place on privacy, their perceptions of whether the police are corrupt, their feeling of safety in their respective neighborhood, number of children, ethnicity (mixed), and support for police activity in the neighborhood (respectively) should all be considered and may be assuaged by involving the community in the creation of regulations regarding UAS use. These considerations may avoid future issues such as protesting and individual action against UAS.

In recent years, community policing has become a significant point of discussion between lawmakers, law enforcement, and many communities. Involving the community in decisions made by lawmakers and law enforcement may be an appropriate strategy in decreasing concerns surrounding the use of UAS in communities where they are viewed negatively. Allowing a community to become involved in creating a UAS program, similar to a neighborhood watch program, could promote buy-in to the idea. Lawmakers and law enforcement adopting a community-centric approach to legislation and use of UAS could be crucial.

Understanding the demographic composition of a given neighborhood, lawmakers and law enforcement may be able to understand the concerns of a community better before using a UAS in the neighborhood. This knowledge will allow them to address a community's unique concerns directly. For instance, concern in communities where residents perceive the neighborhood as safe, the police as positive, and have a large population of children would likely be

addressed differently than a community that offers little support for the police and perceives them as corrupt. In each case, the concerns of the respective communities are unique, and as such, lawmakers and law enforcement may not be able to assume blanket legislation or use of UAS. This is an example where community policing may play a role. As each community is unique, involving the community before using a UAS in their neighborhood may be the most appropriate way to address their concerns.

Limitations

One limitation of this study was the use of a convenient sample population via Amazon's ® MTurk. The use of this online survey tool limits researchers in their ability to identify if the participants were the appropriate age to participate in the survey or if the informed consent was read thoroughly. Also, the results of this study can only be generalized to the population of online users of MTurk. MTurk also limits our ability in making universal generalizations from our data due to the lack of external validity. However, prior research has suggested that data gathered using MTurk is equally reliable as data collected from a laboratory setting (Buhrmester, Kwang, & Gosling, 2011; Germine et al., 2012; Rice, Winter, Doherty & Milner, 2017).

Conclusions

The purpose of this paper was to gain a better understanding of the public's perception of police use of UAS. Previous research has shown that the public tends to have negative perceptions when it comes to the police usage of UAS in their neighborhood. However, there has not been a substantial amount of research that focuses on the specific demographics of those who do not favor police usage of UAS. The results from this study bridge this gap by revealing seven factors (importance of privacy, attitude towards UAS, perceptions of whether police are corrupt, feeling of safety in the neighborhood, number of children, ethnicity, and support for police activity in the neighborhood) that significantly predict participants' privacy concerns about police use of UAS in their neighborhoods.



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APPENDIX A - UAV PRIVACY SCALE (MEHTA ET AL., 2015).

Please respond how strongly you agree or disagree with the following statements:

1. In this situation, I believe that my privacy could be violated by the presence of this UAV.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
2. I believe that the owner/operator of this UAV could have access to too much private information about me in this situation.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
3. I believe that my control over my own privacy would be lessened in this situation.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
4. I would not be comfortable with how much information this UAV could gather about me in this situation.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
5. In this situation, the amount of private information that this UAV could gather about me makes me feel uncomfortable.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
6. This situation makes me concerned about how my privacy could be violated by the presence of this UAV.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
7. This situation generates privacy concerns with regards to the presence of this UAV.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
8. In this situation, I feel my loss of privacy is greater than what can be gained through usage of this UAV.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				
9. In this situation, the presence of this UAV poses a threat to my privacy.									
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree				

PEER-REVIEWED ARTICLE

WHO OWNS THE SKY?

Anthony G. Ison, Esq. The Ison Law Firm, Lakeland, Florida

Dr. Jon Loffi Associate Professor of Aviation and Space, Oklahoma State University

Dr. Matt Vance Professional Pilot Faculty Representative, Oklahoma State University

Dr. Ryan Wallace Assistant Professor of Aeronautical Science, Embry-Riddle Aeronautical University

ABSTRACT

The Federal Aviation Administration's 2016 release of 14 CFR parts 107 and 101 has led to substantial growth in the UAS industry. While the regulations provide stringent requirements for airspace, altitude, and other operational restrictions, they fail to address several key issues associated with property rights. The authors use a blend of doctrinal research, reform-oriented research, and theoretical research methods to assess the convergence of common law concepts, statute law, binding administrative regulations and existing case law. The purpose of this paper is to formulate a doctrinal foundation to delineate the boundary between navigable airspace and vertical real property rights.

Keywords: Drones, Navigable Airspace, Property, Privacy, Surveillance, Transportation Security, Unmanned Aerial Systems (UAS), Small UAS (sUAS)



Problem

The lack of foundational statute and case law creates a legal vacuum for determining where real property rights end and public, navigable airspace begins.

Purpose

The purpose of this study was to assess common law concepts, statute law, administrative regulations and case law to formulate a doctrinal foundation to delineate a boundary between navigable airspace and vertical real property rights. The study sought to discover answers to the following research questions:

- 1. What legal rights/concepts, and laws, exist to aid in determining an appropriate boundary between private property and navigable airspace?
- 2. What aviation regulations are applicable to defining the boundary between private property and navigable airspace?
- **3.** What factors should be considered in defining private property and navigable airspace boundaries?

Method

This study utilized a qualitative approach. The authors employed doctrinal research, reform-oriented research, and theoretical research methods considering U.S. Congressional intent for UAS integration, the concept of 'navigable airspace', both legally and from a professional pilot's perspective and the discussion of 18 distinct legal rights/concepts that could be contributory in establishing a legal boundary between private and publicly navigable airspace. As shown in Figure 1, these legal rights are grouped and discussed sequentially in five areas with the unique number of rights/concepts in the respective area shown in [brackets], as Rights of: a) Possession [3], b) Control [4], c) Exclusion [4], d) Enjoyment [5], and e) Disposition [2]. The authors assessed the potential implications of various transportation security, real property concepts and doctrines on the National Airspace System framework to assess common law concepts, statute law, aviation regulations and case law relevant to UAS law, property rights, and navigable airspace. The overall intent of the research is to catalog relevant issues for discussion and postulate a possible solution space.


Figure 1. Concept diagram of property owner legal protections from unmanned aircraft operations.

It is worth acknowledging that some of the "common law" concepts with respect to various legal elements and caveats may vary from state to state, depending on how each State's court has interpreted and worked these various concepts out; however, this manuscript reflects a more generalized/Federal review of some of the concepts (i.e. with respect to trespass, invasion of privacy, etc).

Findings & Discussion

There are many recent and authoritative writings on the general subject of UAS/sUAS privacy, and the evolving nature of case law with respect to the UAS platform's integration into the NAS and legal framework to include Carr (2013), Cash (2016), Kapnik (2012), LeighlFisher (2017), Rule (2015, 2016), and Thompson (2015); however, none offer a summary recommendation or propose a structural solution to the issue(s) – that is the potential value of this research. Prior to discussing in detail the 18 assembled legal rights/concepts associated with privacy, three background perspectives are offered to set context.

Congressional Intent for Unmanned Aircraft Integration

In 2012, Congress passed the Federal Aviation Administration Modernization and Reform Act (FMRA). Within the safety provisions contained under Title III, Congress articulated its intent for civil unmanned aircraft integration into the National Airspace System. Sections 331 through 336 charge the Secretary of Transportation with developing "a comprehensive plan to safely accelerate the *integration* [emphasis added] of civil unmanned aircraft systems into the National Airspace System" (FMRA, 2012, p. 64).

Recognizing the potential benefits of unmanned aircraft, Congress provided a provision under Section 333 to hasten approval for certain unmanned systems, contingent upon a satisfactory risk assessment executed by the Secretary of Transportation: "If the Secretary determines under this section [333] that certain unmanned aircraft systems may operate safely in the national airspace system, the Secretary shall establish requirements for the safe operation of such aircraft in the national airspace system" (FMRA, 2012, p. 67).

Congress also made under Section 333 a specific provision to protect model aircraft operations, strictly limiting curtailment of such operations. The FAA Modernization and Reform Act of 2012 clearly establishes Congressional commitment to *safely* and fully *integrate* unmanned aircraft systems into the existing national airspace system structure.

Airspace: A Public Highway Through the Sky

The sky is the domain of aircraft, balloons, rockets, kites, and all sorts of other fantastical flying machines that mankind has yet to invent. The size and scope of domestic aircraft operations in the United States is staggering. According to the FAA (2016b), at least 7,000 aircraft are airborne throughout the National Airspace System at any given time. The NAS spans 5 million square miles and includes 19,299 airports. The NAS supports an average of 23,911 commercial flights transporting nearly 2.25 million passengers every single day. General aviation accounts for a further estimated 50,000 flight hours per day. A 2016 forecast by the FAA suggests that unmanned aircraft will become a substantially larger user of the NAS in the coming years; the administration expects the 1.9 million existing unmanned aircraft will top 7 million aircraft by 2020 (FAA, 2016a).

All of these aircraft operate in a domain of the sky commonly referred to as *navigable airspace*. The Air Commerce Act (1926) identified navigable airspace in loosely defined terms as "airspace above minimum safe altitudes of flight prescribed by the Secretary of Commerce under section 3, and such navigable airspace shall be subject to a public right of freedom of interstate and foreign air navigation..." (p. 574). Today, that definition is little changed; 49 USC 40102(a)(32) defines "Navigable Airspace" as "airspace above the minimum altitudes of flight prescribed under this subpart of subpart III of this part, including airspace needed to ensure safety in the takeoff and landing of aircraft."

Codified in 49 USC 40103, the U.S. government determined that navigable airspace falls within the public domain as a medium for airborne transportation and commerce. The first criterion of navigable airspace is for aircraft to operate at a "minimal altitude to allow emergency landing in the event of an engine failure" (14 CFR 91.119(a)). With the previous (91.119(a)) caveat in mind, however, pragmatically the navigable airspace *highway* terminates at a floor of 500 or 1,000 feet AGL (Above Ground Level), depending upon the surface location congestion (14 CFR 91.119(b), (c)). Interestingly, the regulation fails to distinguish between a congested vs. uncongested area. A specific exception allows operations all the way to the surface if separated by at least 500' (laterally) from any, "person, vessel, vehicle or structure" (14 CFR 91.119(c)). One might think of airports and other aerodromes comparable to *onramps* to this public transit system, thus, by definition navigable airspace also includes the protected areas defined by 14 CFR Part 77 as dictated by 49 USC 40103. It is logical that UAS operations around airports are restricted by 14 CFR 107 and 14 CFR 101.

These definitions of navigable airspace are nuanced with unique restrictions, as defined by the specific class of airspace in which an aircraft is operating. The FAA defines these airspace classes, using the designations A-G, excluding F. Until now, manned aircraft have enjoyed unchallenged dominance in low-level airspace.

Navigable Airspace Problem: A Professional Pilot's Perspective

Beyond the definition of *Navigable Airspace* defined in 14 CFR 1.1 and the minimum altitudes prescribed in 14 CFR 91.119, the subject of who owns the sky and the corresponding floors of navigable airspace has historically not been a predominant discussion of concern in professional, commercial aviation; at least it has not been until the advent of UAS and in particular sUAS. The sanctity of the airspace surrounding air carrier airports to be free of UAS and sUAS is now of significant concern.

While possibly casually aware of 14 CFR 77, professional pilots do not need to be and are not concerned with the specificity of obstruction regulation contained there within. These regulations govern how high and how close to an airport an obstruction may be erected, thus protecting the approach corridors to airports and guaranteeing obstacle clearance. The regulations however, cannot guarantee that other aircraft including UAS or sUAS are not present in the approach corridor airspace.

Professional transport category aircraft pilots or corporate pilots do not operate low to the ground, other than that required for take-off and landing. The take-off and climb performance of jet aircraft and most turbo-prop aircraft is such that less than a minute is required to climb above 3,000 ft AGL. This altitude would be sufficient to clear almost any conceivable current civil UAS and sUAS operation. The amount of time professional transport category aircraft pilots or corporate pilots spend below 3,000 ft AGL during the landing sequence is also short, approximately 5-7 minutes depending on approach speed and associated rates of descent. All instrument approaches start at a defined point in space known as an Initial Approach Fix (IAF). IAFs are typically located at multiple points surrounding the airport of intended landing, approximately 15 NM away and at 3,000 ft AGL. From the IAF, the approaching aircraft proceeds on a prescribed descent profile to the beginning of the final glide path to the runway which formally starts at the Final Approach Fix (FAF). FAFs will consistently place an aircraft 5 NM from the airport at 1,500 ft AGL or higher and aligned with the runway.

The standard glide path in the U.S. is a 3° slope measured above the surface of the earth that starts at the FAF, from there a linear slope is followed so that 1 NM from the runway the aircraft is reliably at 300 ft AGL and in a stable position to land. Assuming a nominal approach speed of 120-140 KTAS (Knots True Airspeed), the total time spent below 3,000 ft AGL to reach the final descent slope at 1,500 ft AGL, typically does not exceed 3-5 min, with the final 2 min on the 3° glide path spent on approach to touchdown. Deviating below the prescribe descent profile or the glide path on approach is operationally unsound, judged as unprofessional, and if the aircraft's airspeed is also slow, simply unsafe. No professional pilot would consider purposefully placing their aircraft in jeopardy by taking such action.

The minimum safe altitudes prescribed in FAR 91.119 are operationally and essentially non-applicable to professional aviation. Given the objective of professional aviation is to transport passengers and goods efficiently, to do this requires the minimum time spent at low altitudes where fuel efficiency is dramatically reduced to that compared with higher, cruising altitudes. FAR 91.119 does have material, operational applicability to the General Aviation (GA) fleet, particularly the day-to-day operation of recreational, light, piston-powered aircraft that do not possess the climb/cruise performance of transport category or corporate jet aircraft.

Furthermore, virtually all scheduled commercial, for-profit passenger operations (FAR Part 121) operate in the Instrument Flight Rules (IFR) regime simply because to do so is predictable, dependable, safer and allows operations in restricted to no-visibility conditions. Every movement of the aircraft when operating IFR is charted, prescribed with a 3-D tolerance, and under the positive control of FAA Air Traffic Controllers (ATC). Additionally, the IFR system guarantees obstacle clearance and provides safe separation from other known air traffic. None of these assurances are guaranteed when operating outside of the IFR regime.

Operating IFR does not itself guarantee absolute safety; but it is significant to acknowledge the transport category fleet, which by in large operates exclusively IFR, enjoys an accident record in the developed regions of the world to include North America, Europe, and the Middle East which is exemplary. In the U.S. there has not been a loss-of-life accident from a U.S. air carrier in over eight years. There has never been in the history of aviation, in any region of the world, such a lengthy time period with no air carrier loss-of-life accidents (Aviation Safety Network, 2017; International Air Transport Association [IATA], 2016a; IATA 2016b).



Operations other than IFR are codified as Visual Flight Rules (VFR). While flight under the much less restrictive VFR can be accomplished safely, the risks are higher simply because the pilot must be able to see where they are going, their aircraft are typically much closer to the surface of the earth, closer to obstructions, closer to other aircraft, and are operating without the fore-knowledge benefit of who else is in the same airspace, or positive control from ATC. Both GPS precision and Automatic Dependent Surveillance-Broadcast (ADS-B) are significant navigation and situational awareness enhancements available for forward-fit or retro-fit to all aircraft; however, even the combination of these tools does not guarantee safe separation from other aircraft or obstacles. A small, and growing, portion of the GA fleet is equipped with both tools. A pair of ADS-B equipped aircraft can easily see each other in location and altitude but unless all aircraft, including unmanned, are nodes on the ADS-B network, the data presentation will be incomplete, thus raising the risk of in-flight collision.

The advent of UAS and especially sUAS in the airspace is of concern for two major reasons (a) the sheer proliferation potential of UAS and sUAS in the airspace—sUAS are significantly smaller, cheaper and much easier to operate autonomously, and (b) there is not yet a mechanism to formally integrate UAS (or sUAS) safely among piloted aircraft and particularly within the IFR system.

Especially at lower altitudes, below 3,000 ft AGL for UAS, and below 500 ft AGL for sUAS, the potential volume of new air vehicles competing for airspace is daunting. Simply considering the current corporate momentum and plans to commercially operate small parcel delivery with sUAS could greatly complicate safe separation between the parcel delivery sUAS and aircraft taking-off and landing at nearby airports. For these emerging UAS and sUAS reasons it is even more valuable for commercial piloted operations to transit through this lower altitude layer more quickly. The airspace immediately around airports and in the approach corridors to airports remains as the primary de-confliction concern between piloted and unpiloted aircraft.

Rights with the Potential to Determine Airspace Privacy Boundaries

This discussion presents 18 distinct legal rights/concepts that could be contributory in establishing a legal boundary between privacy and publicly navigable airspace grouped in five areas a) Possession, b) Control, c) Exclusion, d) Enjoyment, and e) Disposition.

Right of Possession. Possession is a highly ambiguous term that in practicality seems simple but given a legal lens can become enormously complex. The Lectric Law Library suggests that "a person has possession of something if the person knows of its presence and has physical control over it, or has the power and intention to control it" ("Possession," n.d., p. 1). Right of possession is conferred in title; in other words, the owner of the property has the *right* to possess it. It is important to note that the right of possession binds the owner not only to rights, but also to the obligations of the real property, such as property taxes, liabilities, ordinances, and other applicable legal considerations ("Bundle of rights," n.d.).

The concept of possession is nuanced among many distinctions.

Actual Possession. (Legal right/concept #1) Actual possession is having "physical control or custody of an object" ("Actual possession," n.d., p. 1). The owner of a house that is *actively living in the house* would be exerting actual possession of the building and its accompanying land. Comparatively, the owner of a second vacation or summer home does not exercise actual possession during the time they are not living there. This situation does not diminish the owner's *right* to possess the second owned property, as they have knowledge of its presence and ability to physically control it, upon desire.

The concept of actual possession is reasonably clear when it comes to real property. Some examples of owners demonstrating actual possession include the owner's physical presence upon the property, making property improvements, constructing structures, maintaining foliage, or making other uses out of the property's surface area. The concept of actual possession becomes much more muddied when it comes to establishing actual possession over the vertical area above the property. How does one take *possession* of the sky above a property? After all, the sky cannot be practically cordoned off with a fence like surface property.

The most obvious methods to demonstrate actual possession of the altitude above a property is to lay claim to the area by the laying of some obstacle, barrier, or structure. In some ways this concept is not unlike early explorers laying claim to territory on the American continents by planting a sovereign flag, establishing colonies, and erecting fences around plots of land. The action provides clear evidence of possession, use, and control. Perhaps more pragmatically, an owner can build a structure upon the surface of a property extending vertically. Suppose a house is built to a vertical height of 30 feet, it would seem reasonable that the most airspace or sky a person could actually possess on the property would be that space within immediate reach of the highest point of the house. To extend the argument, suppose the owner planted a row of giant sequoias trees in his yard after purchasing a plot of property. When the trees reach maturity at 200-275 feet tall, does that then imply that the owner now possesses that altitude of sky? Perhaps an owner decides to place a 50-foot flagpole in their front yard. Does this action then claim the space at that vertical level because of the object's penetration into that area? Further, does the concept of airspace possession apply equally over a horizontal span of property? If a property owner owned 100 acres and the highest structure on the property is 100 feet tall, does the owner's airspace possession apply to the farthest reaches of the property where there are no vertical impediments?

Perhaps one of the most creative methods of actual possession stems from Kansas State University, which built a 60,000-square foot outside drone enclosure, which essentially amounts to netting suspended from a series of 50-foot posts (Mayerowitz, 2015). The university built the netted area to avoid FAA restrictions to drone operations in proximity to airports, since the agency's UAS restrictions do not apply if flown within an enclosure (Mayerowitz, 2015). The creation of this aerial fence, however, seems to be one of many possible mechanisms of taking actual possession of a property's vertical space.

The concept of actual possession of airspace is best defined by the notion of *containment* or *penetration* into the auspices of the vertical space. In some ways, this concept is best represented by a quote from Sitting Bull, "They claim this mother of ours, the Earth, for their own use, and fence their neighbors away from her, and deface her with their buildings and refuse" (as cited in Hammond, Hardwick, & Lubert, 2007, p. 33). After all, a structure or navigation impediment is a certain method of keeping airborne objects clear.

Constructive Possession. Constructive possession extends the concept of possession to include lawful possession or ownership. For example, allowing someone to make use of a vacation house while the owner remains in their primary home does not cause the owner to surrender their right to later actually possess the property. Under such an example, the owner is still deemed to have knowledge of the house and the ability to exert control of it, on demand ("Constructive possession," n.d.).

To a limited extent the courts have already addressed the possession question and determined that physically occupying airspace is not necessarily a requirement, thereby establishing *constructive possession* for the surface landowner. In fact, Sen. Dianne Feinstein recently proposed language in the Drone Federalism Act of 2017 that supports this notion. If passed, this bill would grant property the ability to control airspace within 200 feet of property structures (Drone Federalism Act, 2017). Unfortunately, constructive possession of airspace does not establish an impediment to entry, like actual possession. A *keep out* sign, after all, does not necessarily have the same effect as a barrier or fence around a surface property. Nevertheless, the deterrent effects of signage can yield compliance. It is likely that the posting of signage prohibiting, or restricting drone operations around real property would likely deter some operators. Eminent Domain and Adverse Possession are both subdivisions of Constructive Possession worth presenting in more detail.

Eminent Domain. (Legal right/concept #2) The U.S. government has established mechanisms for legally seizing control over a private citizen's real property. Known as *eminent domain*, this governmental power allows the taking of private property for public use, provided the property owner receives just compensation. ("Eminent domain", n.d.). Government entities at all levels flex this power regularly, known as a *taking*, to assume legal ownership and control of private real property for all manner of public uses. Eminent domain extends beyond merely land rights, but also includes air and water rights, as well ("Eminent domain", n.d.). In some cases, eminent domain is exercised before governmental use of the property, often to legally force an unwilling owner to sell his property interest. In other cases, a taking is determined after the fact, due to court finding that



the government illegally interfered in private property. In aviation, eminent domain is sometimes used to remove obstacles to safe air navigation, as well as takeoff and landing areas near airports. Additionally, a posteriori taking result near some airports where aircraft noise impinges on proximate property owners.

The precedence established in the *Causby* and *Griggs* cases leads to several fundamental conclusions (U.S. v. Causby, 1946; Griggs v. Allegheny County, 1962). Foremost, that real property owners are not in fact entitled to an unlimited extension of airspace, as originally envisioned by the Heaven to Hell Doctrine (Abramovitch, 1962). The potential adverse impacts to aviation, commerce, and legal ramifications make the argument not only impractical but outright untenable.

While it is possible for a real property owner to establish actual possession of the airspace above a property through *containment* or *penetration* of the space, the need to physically possess it is largely irrelevant. Both cases establish a firm adherence to the concept of a property owner's inherent right to a "superadjacent space" in so far as to ensure the owner's right to the freedom of enjoyment and use over their real property, in whatever capacity that may entail.

It is possible, but extremely unlikely that the government could use the eminent domain clause to restrict the vertical rights of property owners in deference to unmanned aircraft operators. It is possible, however, that property owners may find legal relief in an a posteriori court determination that a government entity effected a taking by allowing drone operations near or over private property. This is especially true if the operation adversely affected the owner's use or enjoyment of the property.

Alternatively, such a clause *could potentially* be used to restrict a private property owner's right to fly a drone on their own property. Use of eminent domain in this fashion seems unlikely, however, as it would be fiscally impractical in most cases to compensate private property owners for restricting use of their vertical space in this fashion. Governmental entities have far more effective and less expensive legal tools to facilitate such restrictions.

Adverse Possession. (Legal right/concept #3) Adverse possession is a form of hostile takeover of real property by an individual exerting actual possession without the right of possession ("Adverse possession", n.d.). Provided that the adverse possessor exhibits exclusive, actual possession of the real property in an open and notorious manner for a duration that exceeds the statute of limitations for legal removal by the owner, the title of the real property is legally—if not unethically—passed on to the adverse possessor ("Adverse possession", n.d.). Using the vacation home example, an individual could break into the owner's vacation home and take up notorious residence there. If the vacation home owner fails to legally eject the squatter within a timeline set by the statute of limitations, and the squatter exerts adverse possession over the property's title, the original owner could lose right of possession. Perhaps a more common example is a neighbor erecting a fence that physically occupies a portion of a landowner's property. This overt action, if not addressed by the landowner could eventually result in the encroaching neighbor assuming legal ownership of the new land.

To apply this example in an aviation context, suppose that the superadjacent space entitled to property owners under the Causby and Griggs cases, is regularly overflown at low altitude by a helicopter or drone. Suppose that the landowner fails to make complaint, or take legal recourse against the offending aircraft or drone. In the same manner that surface property is assumed by a trespassing neighbor's fence, is it possible to extend the concept of adverse possession to the sky?

A rational argument can be made that low-altitude unmanned aircraft could engage in exclusive use of a property owner's superadjacent airspace in an open and notorious manner hostile to the owner's wishes for a duration that could exceed a defined statute of limitations.

The courts will likely be required to weigh in on this question, as some might argue that such an intrusion to the superadjacent space is an encroachment rather than adverse possession. Findlaw describes an encroachment as "when another person puts up a structure that intrudes on (or over) your land" ("Encroachment," n.d., p. 1). An example of an encroachment is a tree that extends over a neighbor's property line. Similarly, if a neighbor erects a structure that

impinges on a neighbor's property, like the earlier described fence, that action could also represent an encroachment. Failure to address encroachments *can* lead to adverse possession claims, but not always so. Despite the notorious invasion of the neighbor's property, the courts have found that certain encroachments, such as vegetative overgrowth, do not rise to the level of adverse possession (Jones v. Wagner, 1993).

Right of Control. The right of control is the freedom of a property owner to make use of the owned property in any *legal* manner he sees fit ("Bundle of rights," n.d.) and can be exercised through easements, covenants, zoning restrictions, or state/municipal legislation.

Easements. (Legal right/concept #4) In certain circumstances, however, use of real property is restricted through the placement of easements. Burton's Legal Thesaurus describes an easement as ("Easement," n.d.):

The right of to use the real property of another for a specific purpose. The easement is itself a real property interest, but legal title to the underlying land is retained by the original owner for all other purposes. Typical easements are for access to another property...for utility or sewer lines both under and above ground, use of spring water, entry to make repairs on a fence or slide area, drive cattle across, and other uses. (p. 1)

One unique type of easement is imposed on properties that adversely affect aviation operations, such as those that could pose an obstruction, navigation hazard, or wildlife issue (Strauss, 2012). Unlike traditional easements that generally restrict the use of property on the surface or subsurface, easements for aviation called *avigation easements*, restrict an owner's use of airspace or limits certain activities that *could* adversely affect nearby airspace. "An avigation easement is a property right acquired from a landowner which protects the use of airspace above a specified height and imposes limitations on the use of the land subject to the easement" (Strauss, 2012).

The establishment of specific avigation easements for unmanned aircraft are impractical considering the decentralized nature of such operations. As a result, the impetus from the Federal Aviation Administration would likely be to push the floor of navigable airspace lower than the existing 500-foot [uncongested]/1,000-foot [congested] levels. While not necessarily an easement in name, such an action would be an easement in deed. Reducing the defined floor of navigable airspace essentially sets a nation-wide easement for the benefit of unmanned aircraft operators and to the potential detriment of property owners.

Covenants. (Legal right/concept #5) Covenants are binding agreements that contain restrictive or beneficial stipulations related to land development or use, and are often used in the establishment of certain types of neighborhoods ("Covenant," n.d.). "Courts enforce such covenants provided they benefit and burden all property owners in a neighborhood equally" (Covenant, n.d., p. 1).

It is likely that some managed neighborhoods, such as those governed by a homeowners association, may begin enforcing policies restricting drone use. According to Sleeth (2014), homeowners associations can restrict drones operating in common areas, and establish time or use restrictions. This authority is limited to the property owner, whereon such restrictions are levied. Such restrictions would be largely unenforceable against non-property owners, unless they are agents or acting on behalf of the property owner. Consider the possibility of an insurance adjuster using a drone to survey the roof of a homeowner. It is possible that the homeowner's association may consider the adjuster as an agent, or extension of the homeowner and acting under his authority. It is possible that the association could use such an event to fine or otherwise punish the homeowner for his covenant violation.

Zoning Restrictions. (Legal right/concept #6) Zoning restrictions allow municipalities to control property development within their purview. Generally, zoning restrictions are used to separate residential, commercial and industrial areas of a municipality by structural criteria such as size, height, and property use. Zoning regulations apply to both existing structures as well as future developments ("Land Use," n.d.). While a powerful tool to control property development, zoning restrictions can sometimes run afoul of the U.S. Constitution's *Taking Clause*, codified in the Fourteenth Amendment. "Courts have held that a zoning regulation is permissible if it is reasonable and not arbitrary; if it bears a reasonable and substantial relation to the public health, safety, morals, and general welfare, and if the means employed are reasonably necessary for the accomplishment of its purpose ("Land Use," n.d., p. 1).

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"Zoning law rests upon the notion that, like a 'pig in the parlor instead of the barnyard' certain land uses may be perfectly acceptable in some locations within a city and yet be prohibitively disruptive in others" (Rule, 2016, p. 137). Rule (2016) suggests that "some municipalities might find it beneficial to adopt drone zoning ordinances that specifically restrict where, when, and under what conditions civilian drones may fly within their jurisdictions." Rule (2016) claims that state and municipal governments are more knowledgeable in the unique qualities of their jurisdictions and could implement local restrictions more effectively than the Federal Aviation Administration. A number of municipalities have implemented such drone ordinances or zoning restrictions.

State Legislation & Municipal Drone Ordinances. (Legal right/concept #7) Recognizing the potential threats drones pose to community safety, security, and privacy, some states and municipalities have adopted drone restrictions or ordinances, prohibiting, limiting, licensing, or otherwise curtailing drone and model aircraft flight within their jurisdictions.

According to the Syracuse University Institute for National Security and Counterterrorism's (n.d.) Domesticating the Drone Project, 47 states and 40 municipalities have proposed or enacted UAS legislation.

Right of Exclusion. A property owner's right of exclusion allows him to make a determination about who may or may not enter his property. With the exception of legal allowances for property entry granted under easements or warrants, property owners enjoy the right to forbid or expel individuals from their owned land ("Bundle of rights," n.d.). The right to exclusion falls under two basic doctrines, the concept of governmental *search and seizure* under the Fourth Amendment, and tort *trespass*.

Search and Seizure. Unmanned aircraft are quickly being added to the arsenals of police departments across the nation as an additional investigative and enforcement tool. According to West's Encyclopedia of American Law (n.d.), search and seizure are the investigative actions taken by law enforcement to acquire evidence or corroboration of a crime by taking possession of property for examination. Arbitrary intrusions by law enforcement are prohibited under the U.S. Constitution's Fourth Amendment (1791).

Plurality Rule. (Legal right/concept #8) Two cases overview law enforcement's authority precedent to over-fly property while conducting unwarranted investigations.

In the 1986 case of *California vs. Ciraolo*, police officers received an anonymous tip that defendant Dante Ciraolo was growing marijuana on the backyard of his premises. When officers attempted to investigate the validity of the tip from outside Ciralolo's property, they were visibly obstructed by two concentric fences surrounding the suspected weed grow (California v. Ciraolo, 1986; Falcone, 1987). To further their investigation, the officers elected to rent a private aircraft to attempt to observe the contents of the backyard enclosure from the air. Their aerial investigation validated the presence of the marijuana grow, which they documented using a camera. The sworn testimony of the officers and accompanying photo was used to secure a search warrant, leading to the arrest of Ciraolo and seizure of 73 marijuana plants. Ciraolo unsuccessfully filed a motion to suppress the evidence used to secure the warrant on the grounds the aerial investigation constituted an illegal, unwarranted search of his property under the Fourth Amendment. The California Appellate Court reversed Ciralolo's conviction, but was later overruled by the U.S. Supreme Court which reinstated the original court's conviction. In a closely contested decision, the Supreme Court iterated that the "Fourth Amendment does not require police traveling on public airways at 1,000 feet [the FAA's floor of navigable airspace over congested areas] to obtain a warrant in order to observe things visible to the naked eye" (California v. Ciraolo, 1986, p. 1365).

In a similar 1989 Florida case, Michael Riley was growing marijuana in an enclosed structure near his Pasco County home. Like in the Ciraolo case, Riley's home and the structure containing the marijuana grow was enclosed by fencing, obscuring the view of the illegal plants from the ground. A Florida sheriff's deputy received an anonymous tip of the grow and flew aboard a helicopter to gain an aerial view of Riley's property (Florida v. Riley, 1989). Flying at 400 feet AGL and using a telephoto lens, the deputy was able to observe the marijuana grow through missing roof panels of the greenhouse. The deputy secured a search warrant for the premises, based on the evidence observed during the aerial investigation. Riley moved to suppress the evidence discovered by the deputy on the notion that the greenhouse was within the curtilage of Riley's home and therefore, he had a reasonable expectation of privacy. The case elevated through the court system to the U.S. Supreme Court, which reversed the decision of the lower court,

thereby determining that even activities occurring within proximity to an individual's home are subject to aerial observation (Ebsary, 1989).

The Riley case established the *plurality rule*, which in essence permits legal, warrantless law enforcement observations of private property, provided such observations are conducted from a public vantage point (Rule, 2015).

Prohibition of Certain Sensors. (Legal right/concept #9) One case which runs contra to the Ciraolo and Riley judgments is the Kyllo v. United States. This case examined the legality of law enforcement viewing a home from a public perspective, using specialized Forward Looking Infrared (FLIR) technology. Officers viewed Kyllo's home with a FLIR device to record above normal heat loss from an area of his private home (Kyllo v. U.S., 2001). The FLIR technology revealed areas of heat emitting from Kyllo's house, and the findings were used to justify the arrest and conviction of Kyllo in a marijuana grow operation within his residence. In Kyllo v. United States, the Supreme Court ruled the use of FLIR technology to view the exterior of a private home was in fact a warrantless search and violated the Fourth Amendment. In a five-to-four decision, The Supreme Court wrote,

Where, as here, the Government uses a device that is not in general public use, to explore details of the home that would previously have been unknowable without physical intrusion, the surveillance is a search and is presumptively unreasonable without a warrant. (Kyllo v. United States, 2001, para. 22)

Most drone operators do not make use of FLIR technology, but it is readily available for the public to install and use onboard sUAS, and is typically used by thousands of manned law enforcement aircraft as well as sUAS owned by law enforcement agencies.

In consideration of the rapid expansion of sUAS technologies a burgeoning dynamic is evolving with regards to the Fourth Amendment to the Constitution. This is particularly applicable to the law enforcement community, but will most likely have implications to the general sUAS community at large.

Mosaic Theory. (Legal right/concept #10) In consideration of sUAS and surveillance of the public by individuals or law enforcement an interesting concept of what constitutes a search was decided by the U.S. Supreme Court known as the Mosaic Theory. The Mosaic Theory comes from a Supreme Court's decision on GPS surveillance, United States v. Jones when considering if a series of actions by a government entity, as a whole, constitute a search when on an individual basis or in isolated steps they would not constitute a search (Kerr, 2012). Thus, the 'mosaic' in this case is a practical application of the phrase, "the whole exceeds the sum of its parts". A unanimous opinion of the Supreme Court stated a GPS surveillance over an extended period (28 days in this case) was in fact a search under the Fourth Amendment. If one would consider the ruling by the Supreme Court in GPS monitoring it is easy to see how this conclusion may follow sUAS surveillance for extended periods of time and it would be applicable to the reasonable expectation of privacy under the Fourth Amendment.

Law enforcement capabilities have greatly increased with the addition of sUAS in concert with evidence collection and surveillance. Using applications, such as Light Detection and Ranging (LIDAR or LADAR), FLIR, and automated license plate readers have greatly enhanced law enforcement abilities to detect and prevent criminal activities. The mosaic theory may apply to extended surveillance by sUAS in law enforcement investigations and will likely be new case law in the future.

While these cases ultimately determined the legality of Fourth Amendment aerial searches, they indirectly highlight the high court's increasing deference towards public access over private ownership of low-level U.S. airspace. Rule (2015) cites Justice Brennan's dissenting opinion in the Riley case as a warning of the impingement upon property owner's rights:

Imagine a helicopter capable of hovering just above an enclosed courtyard or patio without generating any noise, wind, or dust at all—and for good measure, without posing any threat of injury. Suppose the police employed this

miraculous tool to discover not only what crops people were growing in their greenhouses, but also what books they were reading and who their dinner guests were. Suppose, finally, that the FAA regulations remain unchanged, so that the police were undeniably "where they had a right to be." Would today's plurality continue to assert that "the right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures" was not infringed by such surveillance? Yet, that is the logical consequence of the plurality's rule... (p. 173-174)

It would appear Justice Brennan's fears have come to fruition. In 2013, Florida WKMG TV released footage of a multirotor UAS that captured nearly 2 hours of footage that included coverage near an apartment window, and hovering over an unaware female sunbather (Watson, 2013). Some encounters are even more invasive. An unsuspecting Seattle apartment dweller called police after recognizing a drone peering through her 26th floor window when she was undressed (Bradwell, 2014). Yet another anecdote comes from New York Times contributor Nick Bilton, who was at first unconcerned about privacy threat posed by drones--until being startled by a buzzing noise outside his home office and coming face-to-face with an intrusive camera-equipped drone staring back. Such reports are not necessarily common, but are widespread across the country (Bilton, 2016).

Trespass. (Legal right/concept #11) A violation of an owner's right to exclusion or expulsion is known as a *trespass*. The seminal drone trespassing case involves the encounter between Kentucky residents John Boggs and William Merideth. During the encounter, Boggs had flown his drone approximately two minutes at an altitude around 200 feet AGL while operating in class G airspace. Merideth then used a shotgun to down the craft, alleging Boggs was digitally recording his daughter while hovering over his property (Boggs v. Merideth, 2016). Merideth was criminally charged with felony wanton endangerment and criminal mischief, which were later dismissed in Kentucky district court. Despite a property owner's right to exclusion, this dismissal is somewhat surprising, as the courts have generally frowned on reverting to *self-help* strategies—particularly engaging overflying drones with weapons.

In a subsequent filed lawsuit, the attorneys for plaintiff and drone owner John Boggs assert their client was operating his drone in navigable airspace and suggest the key issues arising from the case as (Boggs v. Merideth, 2016):

...the resolution to a substantial question of federal law, to wit, the boundaries of the airspace surrounding real property, the reasonable expectation of privacy as viewed from the air, and the right to damage or destroy an aircraft in-flight, in relation to the exclusive federal regulation and protection of air safety, air navigation, and control over national airspace. (p. 2)

The clear conflict between federal and state law lies at the heart of case. To his credit, Boggs was operating his drone legally within the confines of FAA rules, albeit at low altitude. Unfortunately, state and federal law are decidedly silent on the concept of aerial trespass, leaving a critical legal void in establishing clear precedent moving forward. In early 2017, Judge Thomas Russell dismissed the tort claim against Merideth, citing that federal court was not an appropriate venue for the case (Farivar, 2017).

In a similar November 2014 case, drone pilot Eric Joe was flying his custom-made hexacopter over his parent's walnut orchard in Modesto, California. The neighbor property owner, Brett McBay, allegedly had his son fire at the drone with a shotgun, causing the craft to crash on McBay's property (Archambault, 2015; Joe v. McBay, 2015). In his defense, McBay stated in court that "he only wanted peace and quiet in his neighborhood" (Archambault, 2015, p. 1).

Unfortunately, existing trespassing laws do not extend to aerial invasions, however, some relief may be granted under other laws, such as those in place to avert certain intrusive behaviors that could affect an owner's rights to the peaceful enjoyment and use of their property.

Right to Enjoyment. The right to enjoyment entitles a property owner to participate in legal, pleasurable activities while on his property ("Bundle of rights," n.d.). The right to enjoyment for real property owners is fundamental and foundational to all other property rights; moreover, legal precedent elevates the importance of this right among the bundle of rights. This supremacy was clearly reflected in the seminal *Causby* and *Griggs* cases.

Private Nuisance. (Legal right/concept #12) According to West's Encyclopedia of American Law (n.d.), a *private nuisance* is:

...an interference with a person's enjoyment and use of his land. The law recognizes that landowners, or those in rightful possession of land, have the right to the unimpaired condition of the property and to reasonable comfort and convenience in its occupation (p. 1).

Nuisances are legally distinctive from trespasses, in that a nuisances are disturbances upon the occupants of property whereas trespasses are invasions upon said property. Property occupants must generally encounter an *unreasonable, substantial interference* benchmarked by measuring the disruption, based upon "ordinary member of the community with normal sensitivity and temperament" ("Private Nuisance, n.d., p. 1).

It would likely be difficult to argue that a drone presents a private nuisance, as many unmanned aircraft platforms are virtually silent and unobtrusive when operating at altitude.

Harassment. (Legal right/concept #13) According to U.S. Legal (2016), *harassment* is defined as "a course of conduct which annoys, threatens, intimidates, alarms, or puts a person in fear of their safety" (p. 1). Harassment includes a wide variety of behaviors that causes an individual to fear for their safety or creates a hostile environment ("Harassment," 2016).

It is likely that harassment laws could be relatively easily adapted to deal with unwanted drone operations. The relatively low violation standard creates an ideal avenue for making this tort complaint.

Invasion of Privacy. An *invasion of privacy* is a tort law that protects against an intrusion on an individual's private life ("Invasion of privacy," n.d.). Under this element of law, an invasion occurs when a perpetrator infringes on the privacy of another when that individual had a reasonable expectation of privacy.

Intrusion of Solitude. (Legal right/concept #14) This subcategory of privacy invasion addresses a physical intrusion upon an individual's private life. Some examples of this behavior may include: peeping, surveilling an individual, or taking non-consensual photos of video a person ("Invasion of privacy," n.d.).

In August 2016, 65 year-old Jennifer Youngman engaged a drone flying over her property in northern Virginia. She reportedly saw two men setup a card table in proximity to her property, after which she heard a drone overhead. According to Youngman, she believed the men flying the drone were members of the paparazzi attempting to gain a glimpse of her celebrity neighbor, Robert Duvall. Youngman further admonished the drone pilots, saying, "the man [Robert Duvall] is a national treasure and they should leave him the [expletive] alone" (Farivar, 2016b, p. 1). The county sheriff's office reportedly had no record of the incident (Farivar, 2016b).

Public Disclosure of Private Facts. (Legal right/concept #15) This infraction occurs when an individual distributes offensive personal information about another and such information falls outside of the reasonable scope of public records, public concern, or public interest ("Invasion of privacy," n.d.). The California legislature passed additional privacy legislation in 2014 to curb such offenses committed by drone operators, after receiving complaints from notable celebrities such as Miley Cyrus and Kanye West (Niland, 2015).

Voyeurism. (Legal right/concept #16) Voyeurism involves the capturing of images or video of selected private areas of the human body without the individual's consent, provided that individual had a reasonable expectation of privacy ("Voyeurism," n.d.).

A Utah couple was arrested following a December 2016 incident in which a man noticed a quadcopter drone flying outside his bathroom window. The victim tracked the flying drone to a nearby parking lot. The victim was able to review the captured images and video on the device's memory card, which revealed several people in various areas of their homes (Schladebeck, 2017; Reavy, 2017).



While a number of existing laws protect a property owner's right to peaceful enjoyment, it is likely that this aspect of property rights will most heavily influence future drone policy. The prospect of unwanted aerial surveillance on the private sanctuary of one's home--especially if such intrusions breach the intimate parts of private, daily life--are likely to generate a strong public impetus for further curtailment of non-commercial drone operations.

Right of Disposition. The Right of Disposition allows property owners to transfer ownership of property to other parties, so long as the owner fulfills lien obligations ("Bundle of rights," n.d.). In many cases, the value in the transfer of real property is not only in the surface rights, but also in the vertical space those surface rights provide.

Air Rights. (Legal right/concept #17) The concept of *air rights* is a unique byproduct of aviation, whereby owners of surface property exert ownership of airspace below public, navigable airspace. In essence, this concept was initially solidified by the ruling in *U.S. v. Causby*, but has since evolved into a unique new stratum of vertical ownership. According to Schwartz (2015), "It is important to note, however, that while one may own the non-navigable airspace above one's property, local zoning and land use regulations may make it impossible or expensive to utilize such airspace in development" (p. 2).

Vertical Development Rights. (Legal right/concept #18) Vertical development rights refer to the commoditization of air rights, based on the notion that such rights are severable form the surface property and transferable to other parties (Schwartz, 2015). Usually applicable only in large cities, the concept is designed to creatively bypass municipally-established vertical zoning limitations. This allows low-story buildings that have excess air rights or more available space to build vertically, to transfer those rights to other building projects, allowing them to additively build beyond the scope of their own available air rights.

For example, if buildings in a certain area are permitted to be 10 stories, a low level 3-story building can forego adding an additional 7 floors and instead transfer its air rights to a development project allowing it to rise 7 additional floors beyond its inherent zone limits.

Such development rights allow cities to control height zoning in aggregate, while still permitting individual buildings to exceed requirements, based on their acquisition of development rights. Incidentally, allowing this practice also alleviates municipalities from most lawsuits arising from a government taking claim (Schwartz, 2015)

This concept of air rights provides credence that surface property owners do exert a level of authority of airspace above their property, regardless of whether or not it is currently used.

Conclusions

Research Question 1

What laws exist to aid in determining an appropriate boundary between private property and navigable airspace? – Researchers identified 18 distinct, existing legal rights/concepts that may be contributory in determining an appropriate boundary between private property and navigable airspace. Each of these rights/concepts, grouped in five are as, were discussed and presented in hierarchal form in Figure 1.

Research Question 2

What aviation regulations are applicable to defining the boundary between private property and navigable airspace? – The existing definition and altitude delineation between navigable and non-navigable airspace primarily stems from 14 CFR 91.119, whereas the floor of navigable airspace is pragmatically limited to 500 feet AGL over uncongested areas, and 1,000 feet AGL over congested areas. Additionally, navigable airspace is considered to be defined in proximity to airports, to include airspace needed for safe takeoff and landing of aircraft, as defined by 19 USC 40103, and established by 14 CFR Part 77.

An argument can be made that navigable airspace should also include the environment in which the FAA regulates aircraft, which would then include the space below 400 feet AGL, as identified by 14 CFR 107.51(b). While the hobbyist rules do not specifically address altitude limitations in 14 CFR 101, both 14 CFR 101.41(d) and 14 CFR 101.43 charge model aircraft operators to not interfere with manned aircraft and to not endanger the National Airspace System.

Research Question 3

What factors should be considered in defining private property and navigable airspace boundaries? – A myriad of legal factors must be weighed to determine where the legal vertical boundary between navigable airspace and private property should lie. Some considerations include:

• General usability of airspace beyond the barriers of physical structures of constructions and reasonable vertical extent of property rights.

- Monetary property interests in vertical property development.
- Potential impact to property owner safety and security.
- Property owner freedom from obtrusive private interference or government search and reasonable expectations of privacy

• Reasonability of restrictions levied upon UAS operators to avoid overly-burdensome compliance methods or stifled industry growth.

Recommendations

Policy Options

Three approaches exist to adequately address issues associated with property rights and unmanned aircraft operational freedom:

Redefine Navigable Airspace. Perhaps the most obvious option to solve the evolving legal conundrum between real property owners and UAS operators is for the Federal Aviation Administration to specifically define navigable airspace in 14 CFR 1.1 to include low-level UAS operating altitudes. A clearly defined boundary would ideally suit all stakeholders.



Define appropriate operating proximity to people and structures. In similar parlance to operating limitations codified in 14 CFR 91.119(c), the Federal Aviation Administration could define appropriate UAS operating limitations relative to proximity to persons or structures. Although this method of regulation does not wholly conclude the private property rights conflict addressed in this paper, it would likely mitigate the impetus of the original problem.

Refine Existing/Establish New Legislation & Regulations. While not a rapid solution, the application of law often evolves with technology over time. Through ongoing judicial cases, precedent becomes established to adapt the applicability and enforcement of existing laws to new technologies, such as unmanned aircraft.

Generally, it is good practice for communities to enforce existing laws rather than rush to create new ones. The predominant preference of many communities is to immediately establish new legislation and restrictions on unmanned aircraft operations. While responsive, this method may have unforeseen consequences, such as the stifling of industry growth. Communities should carefully weigh the need to protect public safety with the impacts of UAS regulation and restriction.

A Measured Approach

While it may take years for appropriate regulation, legislation, and case law to catch up with the legal challenges associated with evolving unmanned aircraft technology, several notable themes emerge. Within the scope of this research, three key stakeholders can be identified, as identified in Figure 2: property owners, UAS operators, and governmental regulators. With regard to unmanned aircraft, property owners are concerned with the maintenance of their rights, particularly their rights to private enjoyment, control, and exclusion. Conversely, UAS operators are concerned with maintaining freedom of operation, allowing maximum flexibility in which to perform commercial or recreational activities with their platforms. Finally, government—holistically at the federal, state, and local jurisdictions—has a duty to protect its citizens from harm, resulting from UAS technology, as well as maintaining the rights of both property owners and UAS operators.



Figure 2. Venn diagram of key stakeholder interests in UAS regulation and legal restriction.

The interaction between each of these respective stakeholders yields an idealistic, philosophical approach to unmanned aircraft operations. Remote pilots have a duty to operate their UAS craft in a manner that respects property owner's established rights. Similarly, property owners should accept the use of unmanned aircraft in a sensible proximity to their property, in much the same way that owners have come to accept overflying aircraft, street traffic, and other normalized activities. Governmental entities serve as the mediator between the disparate goals of property owners and UAS operators, ensuring that regulation and legislation creates accountability for UAS operators, while preserving their ability to operate in a reasonable fashion proximate to private property. In balance, these philosophical approaches lead to an idealistic goal that merges the needs of all three stakeholders known as *Responsible Operations*.

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