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RESEARCH ARTICLE

Challenges Caused by the Unmanned Aerial Vehicle in the Air Traffic Management

Zsolt Sándor[1*]

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Abstract
The increasing number of unmanned aerial vehicle poses new challenges in the aviation industry especially the air traffic control, which is responsible for the safe flight operations in the controlled airspaces. In order to protect the conventional aircraft a new operation environment has to be created, which guarantee the safe flying and the possibility of the fulfilment of the flight. In the article drone related safety and operational problems are highlighted. All issue connected to the coexistence of manned and unmanned aircrafts are critical, thus their management have significant importance.

Spread and wide use of unmanned aerial vehicle traffic management systems (UTM) can manage the critical operational issues, but is has to be defined that what is the problem, what is the scope, what is the operational environment. Services and functions related to the operation of the UTM system are defined, which are necessary for the safe flying fulfilled by the unmanned vehicles.

Keywords
unmanned aerial vehicle, traffic management, drones, aircrafts

[1] Independent transportation expert
H-1111 Budapest, Budafoki út 35. II/3., Hungary
[*] Corresponding author, e-mail: zsolt.sandor1@gmail.com

1 Introduction

The spread of small, commercially available remotely piloted aircraft systems (*RPAS*) are increasing in the last few years. Due to the technical and technological development the penetration of these aerial vehicles (commonly known as *drones*) will become even more significant in the future. The emergence of new technologies and the mass production possibilities result that the prices are decreasing and new service potentials become available, which provide the development of a new industry sector. While previously the unmanned aerial vehicles (UAVs) were primarily used by the military, till then the commercial usage of UAVs is becoming a priority in the service, agriculture and light industry segments. The satisfaction of application needs require a significantly different implementation approach both in the aircraft design, parameters and also in the control mode.

The gradual increase of civil application needs is a driving force in this area of the aviation industry, hence the development of the industry – which lasts since the Second World War – can be characterized with a totally different evolution phase. Developments are open, developers can join on any side with any development level. This resulting in the most varied solutions found in the market. User side is also attenuating due to the cheap, widespread, and easily accessible devices, thus almost anyone can enter into the aviation, which poses a serious security risk: the growing spread of RPASs could endanger the security of civil aviation and artificially built infrastructure, not to mention the human life. For these reasons, it is vital to find solutions, which can manage the emerging aviation safety and security related issues comprehensively. The final goals are that the new aerial vehicles, which use the airspace should not endanger the traditional airspace users.

The international nature of the problem is illustrated by the fact that the leading scientific research organizations in the developed countries are researching solutions, which can sufficiently manage the emerged challenges with due safety guarantee. In the USA the NASA is collaborating with FAA, in Europe the EUROCONTROL is cooperating with the leading aviation research institutes (*NATS,*[1] *DLR*[2], *DFS*[3], *Indra, Thales, etc.*) in order to find satisfactory answers.

2 Topic of unmanned aerial vehicles

In order to disambiguate the expressions used in this article, ICAO terminology is applied. Definitions of the terms can be found in the ICAO UAS publications (ICAO Cir 328, 2011; ECTL TZ, 2016; Prevot et al., 2016).

2.1 Categorization of the unmanned aircrafts

Nowadays there is no uniform standard yet, but the US Department of Defense uses a variety of criteria in order to group the existing solutions. There are several options based on different criteria (Watts et. al., 2012; GEOG, 892; DoD, 2011; Valavanis and Vachtsevanos, 2015; Gupta et al., 2013; Prevot et al., 2016):

Group by size (Table 1)
Group by performance (Table 2)
Group by structure (Table 3)
Group by mass

- below 250 gram,
- between 250 gram and 2 kg,
- between 2 kg and 25 kg
- over 25 kg (until 150 kg)

Group by function (high-level enumeration):

- State functions (including military activities):
  - law enforcement support,
  - criminal reconnaissance,
  - search and rescue,
  - disaster relief,
  - border protection,
  - aerial observation, securing priority events,
  - etc.
- Humanitarian activities (*provision of non-accessible areas*)
- Supporting agricultural activities (*spraying, counting, etc.*)
- Pipeline inspection (*gas, petrol, crude oil, power-line, etc.*)
- Environmental and natural observations
- Remote sensing, photogrammetry
- Aerial photography (*photos and movies*)
- Defence observations (*complementing or replacing security systems by aerial surveillance*)
- Scientific activities and research (*vehicle manufacturing, atmospheric physics, etc.*)
- Air freight and passenger transport
- Hobby and recreational activities

1 **N**ational **A**ir **T**raffic **S**ervices Holdings
2 **D**eutsches Zentrum für **L**uft- und **R**aumfahrt
3 **D**eutsche **F**lug**S**icherung

2.2 Industrial connections of UAVs

The usage of UAVs needs continuous cooperation between the partners within the aviation industry. Industrial partners:
Legislators: national and international organizations responsible for the regulations.

- Aviation regulatory and governmental agencies with supervisory and control roles.
- Vehicle manufacturers, developers and scientific research institutes.
- Operators and users.
- UTM[4] service providers (it can be partly of fully a global warehouse). They ensure the necessary systems which are relevant for the traffic management of the UAVs. These systems are similar to the current air traffic management systems, but they support dedicatedly the UAS solutions. They can be decomposed for further service providers:
  - radar manufacturers, surveillance / radar service providers,
  - AIS[5] providers,
  - Communication providers,
  - ATM-UTM integrator: ensures the data transmission between the different systems.
- ANSP[6] / ATM[7] providers.
- Training organizations.
- Insurance companies, who provide the mandatory liability insurance to the operators.
- Interest representation organizations.
- Conventional airspace users.
- Airports.

3 Connection between the air traffic control and the unmanned aerial vehicles

In order to identify the challenges caused by the operation of the UAVs unambiguous, it is necessary to know the base tasks of the air traffic control (ATC).

From the viewpoint of the air traffic controller responsibility controlled and uncontrolled airspace can be distinguished. Controller responsibility can only be defined in the controlled airspace, where the aircrafts are operated on the basis of the issued clearances. In these airspaces the ATC service provider is responsible for the separation between the aircrafts. Air traffic controllers (ATCO) ensure that the aircrafts do not collide with each other, with other ground based vehicles and with any natural or artificial obstacle. They maintain the order flow of traffic and inform the pilots continuously about the relevant circumstances.

In the uncontrolled airspace there is no ATC service, instead of it, there are flight information and air traffic advisory

4 **U**nmanned Aerial System **T**raffic **M**anagement System – System of systems, which provide the traffic management of UAVs.
5 **A**eronautical **I**nformation **S**ervices
6 **A**ir **N**avigation **S**ervice **P**rovider
7 **A**ir **T**raffic **M**anagement

Table 1 Classification of unmanned aerial vehicles by size (~ indicated a few / couple of)

Type	Magnitude	Load	Additional information
Extra small vehicles	~ centimetres	~ 10 grams	Nano, micro, mini UAV
Small vehicles	~ 10 centimetres	~ kilograms (e.g. camera, sensors, etc.)	In common terms they are known as drones
Medium vehicles	~ meters	~ 10 kilograms	Launch of vehicles by human power – by hand – can not be achieved. They are not relevant from air traffic control aspect, because they can be operated only in separated airspace with transponders.
Large vehicles	~ 10 meters	~ 100 kilograms military tactical equipment	They are not relevant from air traffic control aspect, because they can be operated only in separated airspace with transponders.

Table 2 Classification of unmanned aerial vehicles by performance parameters (~ indicated a few / couple of)

Performance level	Type	Operational altitude		Payload	Endurance	Range
Low performance UAV	MAV[1]	low altitude	~ 10 meters	~ gram	~ minutes	~ 100 meters
Medium performance UAV	LASE[2]		~10-100 meters	~ (1-5) kg	~ 10 minutes	~ km
High performance UAV (equipment typically used for military or public (state) use)	LALE[3]		~ 100 meters	~ (1-10) kg	~ 30 minutes	~ 10 km
	MALE[4]	medium altitude (~ 1-10 km)		~ 10 kg	~ hours	~ 100 km
	HALE[5]	high altitude (~ 10-30 km)		~ 100 kg	~ 10 hours	~ 1000 km

[1] Micro Air Vehicle
[2] Low Altitude, Short Endurance
[3] Low Altitude, Long Endurance
[4] Medium Altitude, Long Endurance
[5] High Altitude, Long Endurance

Table 3 Classification of unmanned aerial vehicles by structure

lighter-than-air aircrafts	heavier-than-air aircrafts			
• balloon • airship	• fixed wing	• hybrid (fixed wing aircraft with the capability of vertical take-off and landing, tilt-wing, tilt-rotor)	• rotorcraft (single rotor: conventional, equipped with coaxial Flettner rotor)	• rotorcraft (with multiple rotors: 3-8)

services. The aims of these services are the provision of necessary information to the pilots in order to avoid the collision and any other dangerous situations. These services are not control services, therefore they not give clearances. They use only the "*advise*" and "*recommend*" expressions. In the uncontrolled airspace the pilot in command is the person, who is responsible for the safety and security of the flight.

The major problem of the operation of the drones that they use the VLL[8] airspace (only a few 10 meters altitude above the ground), where possible conflicts between the drones and conventional airspace users can occur. These dangerous situations are imaginable where the different users are in the same altitude range, conventional traffic is significant and the traffic density is high. Some examples: in the vicinity of the airports between the arriving and departing traffic, with low level governmental or state flights (police, military, etc.), medical helicopters, inspection flights, etc.

In order to maintain the necessary separation between all (conventional and non conventional) aerial vehicles in controlled and uncontrolled airspaces the following minimum data are required for each aircraft:

- accurate position (coordinates and altitude),
- flight parameters and performance (speed, climb / descend gradient, performance and type data, etc.),
- planned route (for the three dimensional projection),
- communication possibilities with the pilot,
- special rules, which has to be applied for the operation (e.g. increased separation, etc.).

These data should be available for the ATCOs in the controlled airspace, because they are responsible for the separation through the clearances. In uncontrolled airspace the airspace users share

8 very low level

these data with each other through the radio communication. Based on the information they shape the traffic in a safe way taking the necessary separations and manoeuvres into consideration.

4 Justification of the subject

4.1 Operational aspects

The biggest challenge in the air traffic control that most of the small drones operating in low altitude are not equipped with transponders which can provide their exact localizations, so it is unknown. Small UAVs can not be detected by the conventional primary surveillance radars. Difficulty in the detection of RPASs has a huge flight safety risk. From the ATC side the intervention possibilities are limited, or in most cases they are missing. In spite of this, events can occur when the immediate intervention is needed (e.g. route modification).

From the ATC viewpoint the most significant problem is the collision of two aircrafts. This is particularly dangerous if it happens in the air and the speed or mass of the two vehicles are commensurable. In order to avoid these, a solution is needed, which integrate the operation of the UAVs into the conventional airspace users with sufficient guarantee. To achieve this, a new segment – the UTM – is emerging within the ATM industry. UTM is similar to the currently existing ATM and it covers a number of areas connected to the aviation directly or indirectly (airspace management, flight planning, etc.).

With the increase of the number of UAVs, a highly heterogeneous user community is emerging, which range from the hobby operators to the professional users. The UTM system should be prepared for the appearance of diverse user community (from low to high instrument vehicles).

4.2 Economic aspects

The RPAS market is constantly growing worldwide, which can be measured both in the number of sold aircrafts and in the industry investments. Based on the SESAR JU[9] survey, in the recent years the number of sold drones has doubled each year in Europe. At the end of 2016 at approximately 1-1.5 million drones were in use. For commercial activities app. 10.000 pieces were used, the rest were used by citizens for recreation activities (UTM Special, 2017).

According to the forecast of SESAR JU, by 2035, the annual turnover of UAVs will reach 10 billion euros, in 2050 it will reach 15 billion. Most of these amounts will be made by government and commercial orders.

In America, the FAA has conducted research and trend analysis on the subject. The 2017 forecast – based on the latest 2016 data – contains the following findings for the small UAV (*sUAV*), which mass is between 250 grams and 2.5 kg (FAA Forecast, 2017):

- From December 2015 until the end of 2016, 626,000 sUAVs were registered by individual non-commercial users, but it is estimated that the number of sUAVs is nearly the twice. Even on the basis of the conservative estimates, the number of sUAVs will increase by more than three times (3.55 million) until 2021.
- Regarding the number of commercial uses, the sector is still in the phase of the initial development. According to the forecasts these applications in the next years will increase more steeply. On the strength of the most conservative estimates, until 2021, the market could quintuple the size of 2016. But it is more likely that it will increasing tenfold or even fortyfold. The most typical commercial activities: aerial photography, real estate survey; inspections of construction sites, industrial facilities and utilities; agricultural observations.
- Number of registered UAV pilots will twenty-fold until 2021 (take part the on-line training and fill the knowledge level survey).

In 2016 there were hundreds of companies, who conducted UAS related activities. They ranged from the development of equipment, through the commercial actions to insurance. Only in America, 600 companies are manufacturing different commercially available RPA systems.

Furthermore, it should be noted that the forecasts did not deal with the parcel delivery flights, because for those activities there is no regulation yet, which enables the operations. These are typically special operations where the pilot has no visual contact with the aircraft (BVLOS[10]) and the flight is executed autonomously. When the legal and technical conditions of these kind of flights are achieved, it may increase the number of missions conducted by UAVs by millions (Prevot et al., 2016).

4.3 Legislative deficiencies and limited airspace access possibilities

Common regulation of the UAS solutions are under elaboration in several developed countries. Currently there are no rules that provide the simple, fast and efficient use of the remotely piloted aircraft systems. Due to the fact that this segment of the aviation industry is under continuous development and the application possibilities of the technologies are almost unlimited, legislators can follow the events only reactively. Operation of these devices must be integrated into the previously created environment, which has already been exceeded by RPAS technology.

The Chicago Convention provides for unmanned aerial vehicles. Due to the lack of some technical solutions and on-board equipment, the conventional rules can not be applied for these vehicles. Based on the division between the European Union and the Member States, the scope of the Member State regulation can cover the operation of UAVs, which are less than

9 **S**ingle **E**uropean **S**ky **A**TM **R**esearch **J**oint **U**ndertaking

10 **B**eyond **V**isual **L**ine **O**f **S**ight

150 kg. However, currently there is no common specific regulations, which regard to the UAVs under 150 kg.

For example, in Hungary, the drone user has to claim ad hoc segregated airspace for the drone usage, in order to not endanger any other airspace user during the operation of the UAV. This administrative act has a considerable burden both on the operative and on the service provider side. The long administration process – which may take 2-3 weeks – can make it impossible to perform the tasks if the deadline is short or the tasks require immediate work. Considering the wide range of application possibilities and the increase of the numbers of UAV movements, there is a strengthening need for the appointment of ad hoc segregated airspaces. This activity – the appointment of ad hoc segregated airspaces – decrease the possibility of the flexible use of airspace.

This barrier should be eliminated by the introduction of new rules and regulations, which provide even the immediate airspace usage. These legal obstacles are currently obstructing the large-scale spread of UAVs. With their disappearance, new development horizons will emerge in the industry.

5 Technical challenges

5.1 Surveillance

It is necessary that the air traffic control and flight information service be aware of all flying object. Primary and secondary radars can detect the conventional aircrafts because their mass, size, construction materials, instrumentation enable to provide cooperative or sensible signals.

Civil RPA systems can not be detected and identified by the secondary surveillance radars used in the air traffic control, because the size of the flying object is under the resolution of the radars and the aircraft construction materials (plastic, composite, etc.) cannot reflect the signals. This applies for small flying object with a size of a few 10 centimetres. Larger flying objects (over 20-30 kg) can be detected by the radars, because they have bigger and reflective surfaces.

Further surveillance difficulty is the lack of the mandatory transponder and the fact that these vehicles use the low level airspace (only a few 10 or maximum 200 meters altitude above the ground) where the conventional surveillance radars are not able to detect them (neither the primer nor the secondary) because the terrain shadows the spread of radar signals.

Currently there are more available solutions which can detect small flying objects, but they are totally independent from the ATM systems. Their integration is necessary into the ATM for the provision of the availability of surveillance data. Following technologies are available:

- Monitoring and analysing of RPAS control frequencies.
- Spotter RF Perimeter monitoring radars.
- Holographic radars.
- FMCW – Frequency Modulated Continuous Wave Radio Detection and Ranging – radars.
- Combined radar and imagine processing systems, which capable of the visualization of the primer target by optical sensors.
- Acoustic sensors: each UAV rotor has unique characteristic, which can be detected and the system can identify the type of the UAV based on the noise.

The identification of the RPAS requires much larger and more extended infrastructure network than the conventional aircrafts due to the limited technical solutions.

5.2 Flight reporting and flight planning

Submission of flight plans (airspace requests) connected to the flight missions made by UAVs are not compulsory. Therethrough the air traffic control service does not have any spatial and temporal information about the mission-affected areas.

Some of the currently available RPAS solutions (mission planning and reporting applications) can process the planned mission-related data and give AIS information for the users / operators, but these data are not available for the air traffic control services, because the solutions are working isolated and there is no connection with the ATM systems. Moreover the use of the applied monitoring solutions are depending on the mission controlling system used by the operator, which is influenced by the control method of the RPA system and the control platform used by the manufacturer. These kind of mission support systems are not connected with the AIS providers, thus, the reliability of the data is not guaranteed.

5.3 Aircraft identification

In case of conventional aircrafts the flight data processing system – used by the ATC provider – can unambiguously identify the vehicles in the airspace based on the assignment of the flight plan and the surveillance data. Thus the ATCOs have all the necessary data about the aircrafts and their missions.

This information provision is not possible for the UAVs, because of the limited surveillance solutions (even the primer or the secondary) and the flight plans are missing, thus the assignment is not solved. Currently applied surveillance system might identify only the type of the UAV.

5.4 Safety & Security

From the viewpoint of *aviation safety*, the most important is the avoidance of possible conflicts and collisions between other airspace users. At the current level of development, UAVs with different instrumentation may not able to detect all other vehicles and they are not equipped with anti-collision systems, which can provide against the conflicts by modifying the flight path based on the predefined resolution rules.

Another significant problem is the loss of control signal, or the applicable protocol in case of technical malfunction during the operations. Since there is no uniform solution, the applied routine is currently up to the RPAS manufacturer. Safety is also related to the strictness of airworthiness requirements for aircraft. Basic structural and operational requirements can be defined by the rules, which ensure the safe operations.

From the *security* point of view the spread of UAVs has to be investigated due to the increasing emergence of terrorism. With regard to the detection difficulties, use of UAVs might be obvious for terrorists. The following topics are still open and not solved from security aspect:

- continuous monitoring of telemetry data,
- analysis of data transfer protocols and data content,
- cyber security solutions for the inhibition of the distraction of the control,
- take-over of control of UAVs,
- prevention of the entrance of the UAVs into special airspaces (e.g. restricted or prohibited),
- identification of the freight transported by the UAVs,
- interception of UAVs: take-over the control, deactivation, elimination.

5.5 Data transmission and communication

Communication with UAVs are realized differently than with the conventional aircrafts, because the data content is variant and the data amount is larger connected to a given mission. Special communication channels should be applied, which can serve the emerging needs in real-time, without delay providing the sufficient broadband (control data have to be uploaded and telemetry has to be transmitted back to the ground station). Currently for the short range missions the WiFi and similar low performance communication ways are efficient in the vicinity of the remote station. For the longer range missions special communication methods should be applied, which are not disturbed by the signal propagation barriers. These are typically the third and fourth generation mobile data transmission solutions, which can serve the actual needs, but in the future, when the number of equipment connected to the World Wide Web (*IoT devices*) increases 4G will not be able to provide the necessary precision. The 5G communication solutions, which are now in the phase of research and development will be able to serve these high load demands. Communication between the UAVs should also be solved, for the conflict resolutions and for the capability of flying in flock.

6 System of systems for the support of traffic management of unmanned aerial vehicles

UTM systems can offer break through solutions for the above mentioned challenges. The fact that the number of UAVs is increasing justify the raison d'etre of the specific management systems. The planned solution (flight and air traffic information systems) has to have several information management operations – called them functions – which support the fulfilment of the flight related tasks in order to manage the total air traffic (conventional and UAVs together) efficiently. UTM solutions may contribute to the efficiency through the provision of new information management operations. UTM can be defined as a Systems of Systems (*SoS*) which evolves from the cooperation of the users 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.

The UTM SoS consists of the following components (Fig. 1):

- Technical infrastructure elements: components, which provide the accessibility of UTM functions
  - Communication infrastructure (COM)
  - 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/RPAS)
  - Record systems with user and aircraft data (REG)
  - Traffic management system (UTM)
  - Authority / State Information Systems (AUTH)

7 Information management operations related to the missions made by unmanned aerial vehicles (functions and data)

Table 4 illustrates the functions of the UTM systems according to the timing of the mission (pre-flight, in flight, post flight).

Taking the complex solutions into consideration, it is desirable to create a system with additional functionality, which can manage the operational (mission related) and non-operational (so called general) data integrated. Information management operations related to these functions may beyond the UTM system and the UTM service, and they might affect or redeem activities done by other state – governmental / authority – institutions.

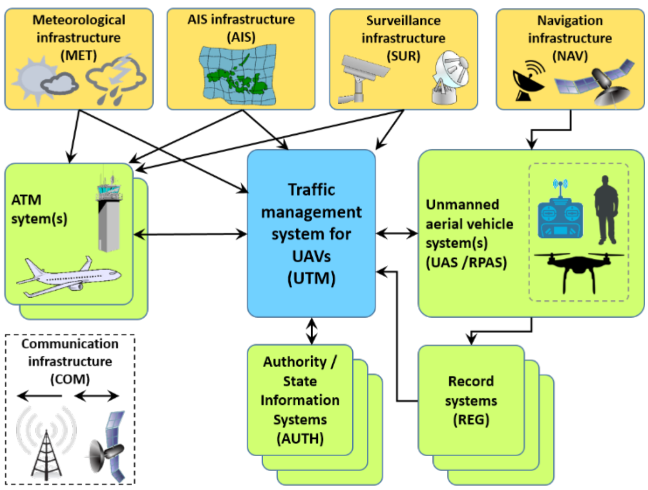

Fig. 1 Simplified structural model of the UTM System of Systems

Table 4 Functions of the UTM systems according to the timing of the mission

Additional activities	Pre-flight functions	In flight functions	Post flight functions
• regularisation • education and user awareness training	• registry • static geofencing[1] • AIS provision • user registration • flight / mission reporting • flight / mission approval	• meteorological service • dynamic geofencing • surveillance • identification • two- and multi-directional communication • telemetry data management • real-time navigation support • real-time traffic information • conflict resolution • emergency management • UTM-ATM interface • fleet management • record of flight / mission data • control and inspection of rules and regulations	• analysis of flight / mission data • enforcement

[1] Geofencing is a virtual geographic boundary, defined by GNSS technology that enable software to prevent a UAV entering a defined zone.

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,
- simultaneous control of multiple vehicles (flocks),
- conflict resolution between vehicles by the common communication (TCAS, FLARM, ADS-B, etc.).

Flight missions fulfilled by the UAVs are significantly different than the flights of conventional aircrafts, thus it is necessary to create the new regulations and to define the operation environment.

Table 5 contains the definitions of the UTM functions and the description of the data management operation. The table also indicates that the given function is a UTM service task or an additional function (non-UTM) – based on the current technological development level and the regulations. Non-UTM functions support he efficient operation of the complex UTM system, but the creation of the data connected to the given function is not the responsibility of the UTM service provider, it just uses the generated data.

It is important that the data with relevant content and temporal validity (static[11], semi-dynamic[12], dynamic[13]) are be available related to the given functions. Functions connected to the comprehensive solutions can be operated with the provision of the following data:

- **Register data**: Users and vehicles data registered into the UTM system, which is necessary for the assignment of the mission, aircraft and user.
- **Data of the aeronautical information service**: Data for the safe operation of vehicles, which can be used for the planning and the execution of the mission. Data covers actual and forecasted meteorology, traffic and airspace usage and control areas.
- **Aeronautical infrastructure (airspace management cell) data**: Data about airspaces, sectors, airports, routes, etc., which are relevant for the planning and support the execution of the mission.
- **Permission data**: Data of the authorized missions (pre-flight data).
- **Traffic data**: Data in connection with the operations, which contain the flight / mission plan and radar data. They support the operations by the correct time planning of a given mission.
- **Flight operations (telemetry) data**: Coming from different sources and contain real-time mission related generated on the UAV or even at the remote station.
- **Contact data**: Continuously updated personal information of the pilots for the immediate voice or data communication. It has paramount importance in case of adverse environmental situations.
- **Equipment data**: Ground based infrastructure data about the fixed, portable, communication, surveillance and other technical devices.

For the full availability and use of the functions it is necessary that the data coming from different sources – even from different organizations and industrial partners – should be available on a common platform, thus the data management is much simpler and fulfils the necessary data quality requirements (73/2010/EU ADQ).

11 Data are not changed for longer periods, their validity are longer or at least equal with an AIRAC cycle.

12 They may contain frequently changing content, thus their validity are between and AIRAC cycle and a few hours.

13 Data with low temporal stability, they can change even every second.

Table 5 Definitions of UTM functions

	Function	UTM / non-UTM	Definition
Additional activities	Legislation and regulation	non-UTM	Activities of state bodies which have the right to create rules and regulations in order to create legal norms. This includes legislation and regulation (national, and EU-wide operational framework for RPAS, EASA, ICAO and standardization guidelines). It is a legislative task in which an ANSP can provide professional support.
	Education and user awareness training	non-UTM	Composition of training materials and user awareness trainings, campaigns for awareness increase.
Pre-flight functions	Registry	non-UTM	State registration of UAVs after submitting all the necessary documents and providing them with unique identifier.
	Static geofencing	non-UTM	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.
	AIS provision*	UTM	Collection and publishing of necessary information for the planning and execution of the flight / mission, which are support the safe operations. Information contain all data about airspaces, terrain, obstacles, airspace usage, forecast meteorology and other regulations.
	User registration	UTM	Independent registration of users (pilots / operators) into the UTM system by entering personal and UAV related data. Assignment of users and aircrafts.
	Flight / mission reporting	UTM	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.
	Flight / mission approval	UTM	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.
In flight functions	Meteorological service	UTM	Real-time data delivery about the current and forecasted weather.
	Dynamic geofencing	non-UTM	„*No-fly zone*" around a particular airspace or aircraft, which changes dynamically in space and time. It may be over an artificial infrastructure.
	Surveillance	UTM	Detection of cooperative and non-cooperative vehicles with different technical solutions. Result is a target signal (position, speed, direction).
	Identification	UTM	Ensures availability of data and display the details of the authorized operations for each detected aircraft.
	Two- and multi-directional communication	UTM	Ensures the communication between the UTM centre and the RPAS devices (sending and receiving instructions, messages, telemetric data, etc.)
	Telemetry data management	non-UTM	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.
	Real-time navigation support	non-UTM	Display of information about the operational environment (terrain, obstacles, airspaces, etc.).
	Real-time traffic information	UTM	Display of information about other airspace users, where the mission is executed.
	Conflict resolution	UTM	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.
	Emergency management	UTM	Central information provision about events, which endangering the missions (emergency broadcast); depending on the severity of conflict, central and emergency intervention in the missions; ensuring the priority of public service RPAS vehicles, immediate appointment of ad hoc segregated airspaces.
	UTM-ATM interface	UTM	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.
	Fleet management	non-UTM	Simultaneous control of multiple vehicles and complex management of telemetry data. Not necessarily means flying in flocks.
	Record of flight / mission data	UTM	Data recording by the UTM system, where telemetry data transmitted by the aircraft is stored for further use or monitoring (like a black-box).
	Control and inspection of rules and regulations	UTM	Detection and identification of irregular user.
Post flight functions	Analysis of flight / mission data	non-UTM	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 *value-added services.*
	Enforcement	non-UTM	Registration of the against the regulations behaviour, take the necessary administrative actions (e.g. denunciation) and inflict the punishment.

* service is currently available connected to the ATM system, which is part of the ANSP tasks.

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 (see Fig. 2).

In Fig. 2, the functions are grouped according to two dimensions:

- UTM / non-UTM function,
- Grouping by the involvement of the UTM service
- Base function: task has to be covered by the UTM, because it is essential for the service provision.
- Optional function: not essential for the UTM service provision but the level of service can be increased with it.
- Supporting function: independent of the UTM, but supports the functions of the UTM and the users.

Integrated information management operations offered by the UTM SoS can be fully available only if users submit the details of the flights / missions before the operations cooperatively. Fail to do this will result in poor quality of service due to the incomplete information, which may increase safety risks.

UTM serves traffic management aims as a complex flight information system, thus issue of security are beyond the borders. UAV related security issues (like interruption, intervention, destruction, etc.) are the responsibility of the state services who are responsible for the law order. Issue of IT and cyber security is the competence of the developers, so the development of the UTM system has to warrant the protection against attacks.

8 Conclusion

Activities related to the use of UAVs are complex challenges, which have to be managed efficiently and effectively in order to provide the safety of aviation. UTM solutions are continuously evolving within the aviation industry. The expansion of this market segment is beginning nowadays through the development of connected services and technology. The development of the new technologies are much faster than the development of the legal framework, which adversely affects the spread of connected and applied services.

The technological evolution will result in a significant expansion within this industry segment in the next few years and this fact justifies that the new legal framework should be created as soon as possible. The significance of UTM is valorising, new services are continuously emerging, which initial forms can already be seen – start-ups, research collaboration, etc.

9 Summary

The UTM system is operating independently of the ATM systems, but due to the partial overlapping of information management operations (e.g. AIS, airspace usage data, etc.) the totally independent or separate operation is not possible.

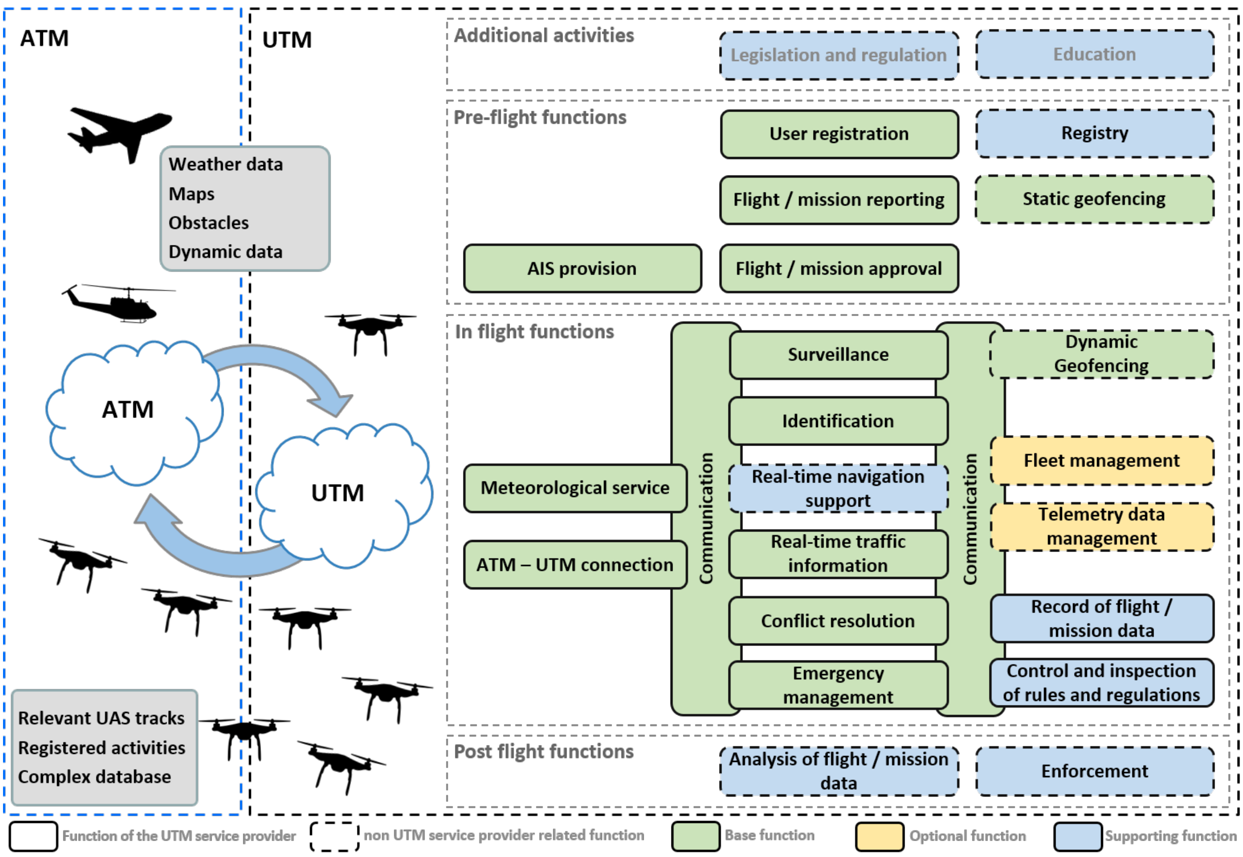

Fig. 2 The functional structure of the UTM SoS

UTM and ATM are interconnected, each system depends upon the data coming from the other system. Despite this dependency, it is feasible to operate the two systems by a different service provider, when the interoperability is provided.

Nowadays there is no UTM service provider in the world – similar to the ATM, with national coverage – the available solutions are working as pilots. Within the developers there are small and big companies. The scope is wide, it ranges from the start-ups until the market leader ATM developer companies. The future legal, business and operational environment will significantly influence the UTM services. (Global UTM Association, 2017).

The increasing spread of RPA systems results from the interaction of several closely related factors:

- Several companies are involved in the manufacture and development of UAVs, thus the competition is sharp-edged, which contribute to the wide-spread and the decreasing of prices.
- Human labour force can be replaced as a result of the new emerging functions.
- New functions can satisfy latent demands.
- Operation of UAVs has become simpler in the recent period and the control activities do not require special knowledge and qualifications.

Several industrial partners with different activities have been already cooperating in the field of common research and development in order to have more power on the market.

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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