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DEVELOPMENT STAGES OF TRAFFIC MANAGEMENT SOLUTIONS FOR UNMANNED AIRCRAFT SYSTEMS

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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.

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.

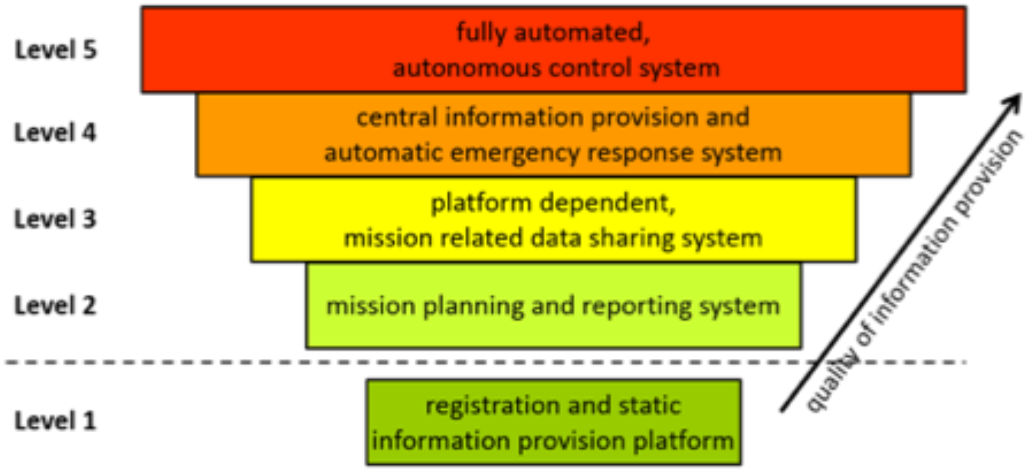

Figure 1. UTM service levels

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 AIS[3] 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 communication	Control	Responsibility for operating UAS	Affected UAS user community	Temporal support of missions
1.	no automation	static	no coverage	no communication	manual	user	all users	only preparation support
2.	no automation	semi-dynamic	no coverage	one-way (between the user and the centre)	manual	user	mixed (from the recreational activity users to the special industrial users)***	pre-flight activities
3.	partial automation of emergency avoidance	dynamic between the platforms and real-time within the same platforms	local platforms	one-way within the operation platforms	manual, automatic warning about the avoiding manoeuvre in case of emergency (platform dependent)	user	mixed (from the recreational activity users to the special industrial users)***	support of in-flight activities
4.	partial automation for multiple functions	real-time	global, platform independent	global, two-way (between the user and the centre)	mixed control	mixed (collision avoidance UTM service provider, UAV usage user)	mixed (from the recreational activity users to the special industrial users)***	support of pre-flight, in-flight and post-flight activities
5.	fully automated control	real-time	global, platform independent	global, multidirectional	autonomous control	UTM service provider	industrial users with high number of mission requests, where the active control 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*).

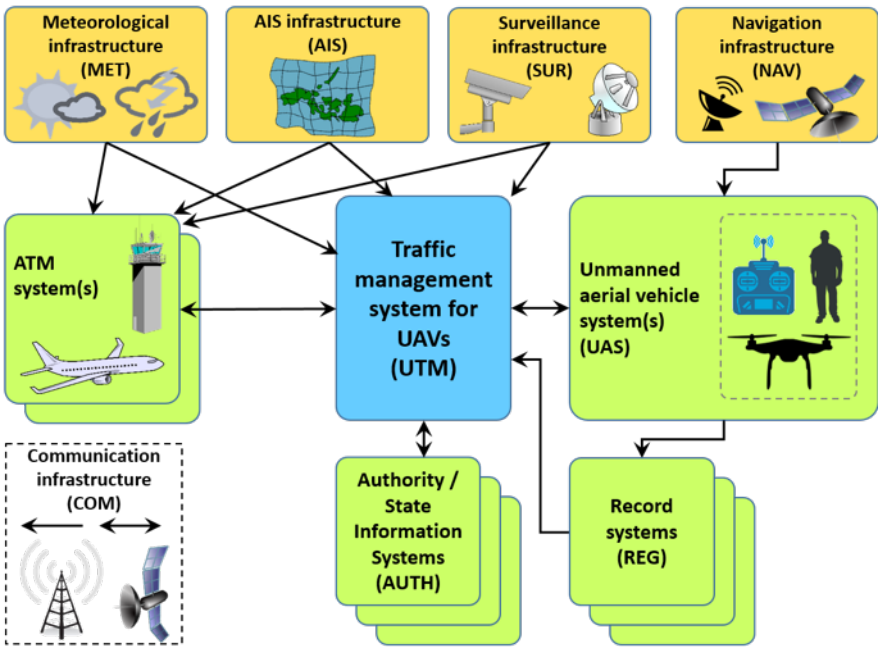

Figure 2. Simplified structure of the UTM system of systems

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.

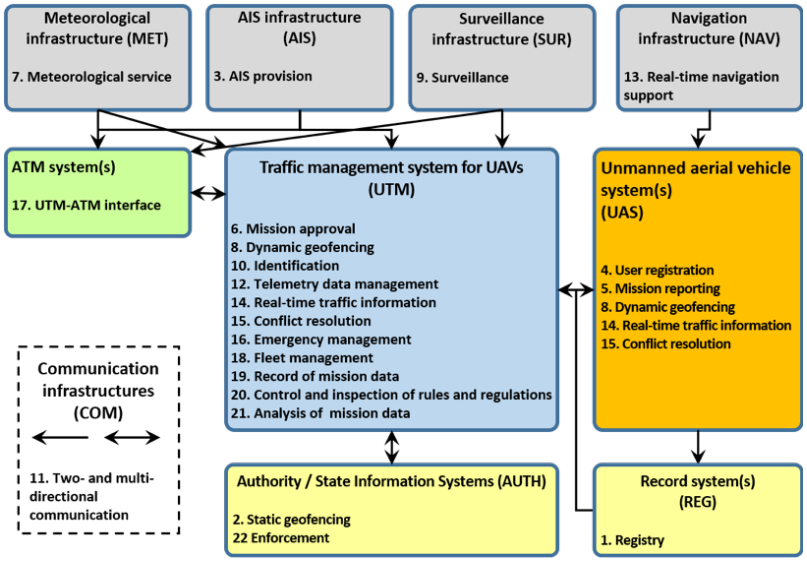

Figure 3. Simplified functional model of the UTM system of systems

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

Temp.	No	Function	Availability	Definition
Pre-flight functions	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.
	3	AIS provision*	From level 2	Collection and publishing of necessary information for the planning and execution of the mission, which are support the safe operations. Information contain all data about airspaces, terrain, obstacles, airspace usage, forecast meteorology and other regulations.
	4	User registration	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.
	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.

Temp.	No	Function	Availability	Definition
In-flight functions	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 dynamically 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.
	13	Real-time navigation support	From level 3	Display of information about the operational environment (terrain, obstacles, airspaces, etc.).
	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.
	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 emergency 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 telemetry 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
Post-flight functions	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 *value-added services*.
	22	Enforcement	From level 4	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 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.