International Journal of Transportation Science and Technology 5 (2016) 123–135

Contents lists available at ScienceDirect

International Journal of Transportation Science and Technology

journal homepage: www.elsevier.com/locate/ijtst

Unmanned Aircraft System traffic management: Concept of operation and system architecture

Tao Jiang, Jared Geller, Daiheng Ni *, John Collura

Department of Civil and Environmental Engineering, University of Massachusetts Amherst, 130 Natural Resource Road, Amherst, MA 01003, USA

ARTICLE INFO

Article history:
Received 13 September 2016
Received in revised form 17 January 2017
Accepted 18 January 2017
Available online 30 January 2017

Keywords:
sUAS
Unmanned aircraft system
Unmanned aircraft system traffic management

ABSTRACT

Within the past few years, civilian demand for small unmanned aircraft systems (sUAS), commonly referred to as drones, has skyrocketed. The passage of the Federal Aviation Administration (FAA) Modernization and Reform Act in 2012 acknowledged this fact, and has since prompted expedited research and development for civilian sUAS. As proposed at a recent National Aeronautics and Space Administration (NASA) Convention, central to the safe and efficient operations of sUAS will be an unmanned aircraft system traffic management (UTM) system. Such a UTM system will borrow fundamental ideas from large-scale air-traffic control, albeit with several key differences that provide for sUAS which vary in method of control, maneuverability, function, range, and operational constraints. Ultimately, an expansion of UTM infrastructure, a decentralization of governing authority over sUAS operations, and the establishment of a web-interface for pilots to submit flight plans and access crucial data will allow for sUAS operations to shift from being a science-fiction gimmick to an element of daily life. The major objectives of this paper are to: (1) define what a UTM system is; (2) review current UTM practice from industry partners; (3) describe how sUAS pilots would use a typical UTM system, and who has authority over UTM; and (4) determine what physical architecture is required in a UTM system which handles a large variety of sUAS.

Abbreviations: AACS, Automated Airspace Computer System; ADS-B, automatic dependent surveillance-broadcast; ASPs, airspace service providers; ATC, air traffic controller; ATM, air traffic management; BVLOS, beyond visual line-of-sight; CA, certificate authority; COA, certificates of waiver or authorization; DAG-TM, distributed air-ground traffic management; DOT, department of transportation; DSRC, dedicated short-range communication; EASA, European Aviation Safety Agency; FAA, Federal Aviation Administration; GPS, global position system; NAS, National Airspace System; NASA, National Aeronautics and Space Administration; NextGen ATM, next generation air traffic management; NTIA, national telecommunications and information administration; NTSB, National Transportation Safety Board; NUSTAR, national UAS standardized testing and rating; PBN, performance-based navigation; PKI, public key infrastructure; RA, registration authority; RTT, research transition team; SAA, sense-and-avoid; sUAS, small unmanned aircraft system; TCAS, traffic alert and collision avoidance system; TCLs, technical capability levels; TSAFE, Tactical Separation Assisted Flight Environment; TSS, terminal sequencing and spacing; UASIS, unmanned aircraft system information security system; UTM, unmanned aircraft system traffic management; VLOS, visual line-of-sight.

Peer review under responsibility of Tongji University and Tongji University Press.

* Corresponding author.
E-mail address: ni@ecs.umass.edu (D. Ni).

http://dx.doi.org/10.1016/j.ijtst.2017.01.004
2046-0430/

Introduction

Unmanned aircraft systems (UAS) have long been considered for a variety of tasks, including infrastructure monitoring, precision agriculture, package delivery services, search and rescue operations, photography, and more. Previously, UAS were only used for military reconnaissance and later for the U.S. military's controversial drone strike program (Spinetta, 2016). The introduction of small unmanned aircraft systems (sUAS) for civilian purposes has caused quite a stir for lawmakers and federal regulatory agencies, like the Federal Aviation Administration (FAA). Initially, there was a legal gray area for early adopters of civilian drone technology, as rules and regulations regarding the operations of these vehicles were largely nonexistent, especially on federal and state levels. The passage of the FAA Modernization and Reform Act in 2012 identified the need to prioritize drone safety and efficiency as important goals for the near-term future (West, 2015). The act requires the creation of a plan to safely integrate civil UAS into the National Airspace System (NAS) by September 30, 2015.

In 2015, the FAA published a Notice of Proposed Rulemaking (NPRM) to allow routine use of certain small UAS. The final rule, which creates a new "Part 107" in Title 14 of the United States Code of Federal regulations, was published on 28 June 2016 and took effect on 29 August 2016 (Table 1) (Federal Aviation Administration (FAA), 2016). The European Aviation Safety Agency (EASA) also published a Concept of Operations for Drones, which focused on the integration and acceptance of drones into the existing aviation system in a safe and proportionate manner (European Aviation Safety Agency (EASA), 2015a,b,c). Following this, an Introduction of a regulatory framework for the operation of drones was published on 31 July 2015, then opinion of a technical nature was published on 18 December 2015 with 27 concrete proposals for a regulatory framework and risk-control (European Aviation Safety Agency (EASA), 2015a,b,c). In the year of 2016, a "Prototype" Commission Regulation on Unmanned Aircraft Operations was published on August 22. It combined the efforts made last year and presents a formal regulation guide book with respect to the operation of UAS (European Aviation Safety Agency (EASA), 2016). Hopefully a finalized official regulation would be published by the end of 2016.

While these proposed rules are extremely limiting, they are expected to be temporary. An effective unmanned aircraft system traffic management (UTM) system must allow for both manually controlled and autonomous sUAS to be operated BVLOS, even if only in Class-G airspace (uncontrolled airspace typically below 1200 feet above ground level and a safe distance away from tower-controlled airports). Implementing sUAS activities into the NAS (beyond Class G) or into airspace with heavy manned aircraft traffic is beyond the scope of this paper. Interesting reader is encouraged to refer to the book "On Integrating Unmanned Aircraft Systems into the National Airspace Systems", which is written by K. Dalamagkidis (Konstantinos, 2012). This book presents, in a comprehensive way, current unmanned aviation regulation, airworthiness certification, operation rules, etc. This paper will focus more on what kind of UTM system should be expected by a goal of 2019.

The proposed solution for UTM agreed upon by both academia and government agencies includes elements of airspace design, corridors, dynamic geo-fencing, severe weather and wind avoidance, congestion management, terrain avoidance, route planning, re-routing, separation management, sequencing and spacing, and contingency management (NASA UTM, 2015). This solution is essentially a combination of automobile traffic management (rules of the road) and air traffic control. The challenge arises from having many more arrival and departure points than air traffic control systems as sUAS are not limited to a finite number of airports with their own air traffic control towers. The potential for significant congestion in a three-dimensional area of travel also needs to be considered. Therefore, there needs to be a national standard for UTM systems, individual zones where all sUAS operations must be approved on a case-by-case basis.

Table 1
The FAA's proposed operational constraints for sUAS.

Category	Summary of proposed requirements
Operational limitations	• Must weigh less than 55 lbs. (25 kg) • Must operate within visual line-of-sight only • May not operate above any persons not directly involved in the operation • Must only operate during the day, no nighttime operations • Maximum airspeed of 100 mph (161 km/h) • Maximum altitude of 500 feet (152 m) above ground level • Must not operate carelessly or recklessly • Establishment of a micro-manned aircraft system (UAS) category (4.4 lbs. or less) (2.0 kg or less) • Must yield right-of-way to other aircraft, manned or unmanned
Operator certification and responsibilities	• Must either hold a remote pilot airman certificate or under direct supervision of a person who does • Must pass a knowledge test initially and every 24 months • Must be vetted by the Transportation Security Administration (TSA) • Must obtain an unmanned-aircraft operator's certificate with a small UAS rating
Aircraft requirements	• FAA airworthiness certification not required, but operator must conduct a preflight check of the sUAS to ensure safe condition for operation
Model aircraft	• Would not apply to model aircraft that satisfy all of the criteria specified in Section 336 of Public Law 112-95 • Would codify the FAA's enforcement authority by prohibiting model aircraft operators from endangering the safety of the national airspace system