TECHNOLOGICAL AND REGULATORY CHALLENGES IN INTEGRATION OF UAVS IN NON-SEGREGATED AIR SPACE

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INTRODUCTION

Unmanned Aerial Vehicles (UAVs) were initially developed for military missions. The rising capability of surveillance and armed UAVs and their successful employment in recent wars has stimulated the development of Unmanned Combat Aerial Vehicles (UCAVs) to undertake dull, dirty and dangerous combat missions in hostile territory. The global UAV market 2015-2025 report published by Strategic Defence Intelligence, a market research company, had predicted that the UCAVs segment, with a share of 34 percent, is likely to dominate the UAV market.[1] Some technology demonstrator prototypes of UCAVs have already demonstrated their ability to undertake missions which were meant exclusively for manned combat aircraft. The unique capabilities of UAVs have also made them favoured platforms for civil applications. They are ideally suited for tasks requiring long duration surveillance or operations over inaccessible areas. The industrial applications of UAVs have created business opportunities with huge economic potential.

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1. The Global UAV Market 2015-2025, January 2015, http://www.reportsnreports.com/reports/327969-the-global-uav-market-2015-2025.html. Accessed on June 6, 2016.

Proliferation and easy availability of small UAVs and the potential for their exploitation by terrorists for subversive activities have raised concerns among the security agencies.

UAVs, unlike manned aircraft, are flown either by a remote pilot or in autonomous mode and are susceptible to breaking of command and control signals, hacking of data links for feeding spurious information and clandestine exploitation of own UAVs by adversaries and/ or terrorists. Also, there are apprehensions that UAV operations in the non-segregated air space could endanger the safety of manned aircraft. UAVs have higher accident rates than manned aircraft, which adds to concerns about safety of manned aircraft and people on the ground. In addition, UAVs would also have to operate with manned military aircraft in a dynamic air environment during war. Proliferation and easy availability of small UAVs and the potential for their exploitation by terrorists for subversive activities have raised concerns among the security agencies. Military UAVs so far have been operating in the segregated air space in which they are either kept well clear of manned aircraft or made to operate in separate sectors specifically earmarked for them, which does not ensure optimum utilisation of congested air space. The military and civil UAVs now have the ability to fly at higher speeds, operate at high altitudes, have greater endurance and would be required to operate in the non-segregated air space, which is the biggest challenge.[2]

Efforts have been made by the International Civil Aviation Organisation (ICAO), European Union (EU), the United States (US) and some other countries to develop enabling technologies and formulate a favourable regulatory framework to integrate UAVs in the non-segregated air space in a step-by-step manner. Some countries have allowed small UAV operations with certain restrictions. However, they have not been able to fully integrate them in the non-segregated air space due to the uncertainty about crucial technologies. This paper, therefore, attempts to find answers to the following questions:

2. UAV operations in the non-segregated air space mean that both manned and unmanned aircraft would operate in the same air space, with a similar set of safety rules with suitable modifications for UAVs.

- What are the challenges for integration of UAVs in the non-segregated air space?
- What are the initiatives undertaken to facilitate integration?
- Why may full integration continue to be a challenge?
- What is the status of UAV integration in India?

The challenges being faced in integration of UAVs are of two types, i.e. firstly, the technological challenges, which can be overcome by developing enabling technologies; and, secondly, the regulatory challenges.

Various stakeholders have been using different terms to indicate Unmanned Aircraft (UA) and systems, i.e. UAV, Unmanned Combat Aerial Vehicle (UCAV), Unmanned Aircraft System (UAS) and Remotely Piloted Aircraft System (RPAS)[3], and these terms have been used interchangeably during the deliberations. This paper is a descriptive analysis of the challenges faced and the initiatives being taken to facilitate the integration of UAVs in the non-segregated air space. It discusses the technological and regulatory issues related to the integration of UAVs in the non-segregated air space and the initiatives taken by the ICAO, US, EU and India toward this. The paper does not address issues related to air space management in the non-segregated air space.

CHALLENGES FOR INTEGRATION

UAVs, while flying in the non-segregated air space, are likely to encounter two types of airborne traffic, i.e. cooperative and non-cooperative traffic. Cooperative traffic is capable of broadcasting its position through a transponder or by any other means, while non-cooperative traffic does

3. The term Remotely Piloted Aircraft System (RPAS) is being used by the ICAO and EU and it comprises Remotely Piloted Aircraft (RPA), Remotely Piloted System/s (RPS/s or Ground Control Station/s), Command and Control (C2) link and any other component as specified in the type design, For details, refer http://www.wyvernltd.com/wp-content/uploads/2015/05/ICAO-10019-RPAS.pdf. Accessed on June 12, 2016.

not broadcast its position.[4] UAVs, while flying through air space with dense air traffic, would have to be equipped with suitable sensing and safety equipment in order to identify non-cooperative traffic, maintain separation, and take suitable evasive measures if the traffic is found closing in dangerously. Also, regulatory provisions for licensing, certification and operations are needed to integrate UAVs with manned aircraft. Therefore, the challenges being faced in integration of UAVs are of two types, i.e. firstly, the technological challenges, which can be overcome by developing enabling technologies; and, secondly, the regulatory challenges, which can be dealt with by amending the existing rules and regulations as well as formulating new ones to facilitate operations of UAVs in the non-segregated air space.

TECHNOLOGICAL CHALLENGES

The challenges being faced in the integration of UAVs in the non-segregated air space and the technologies needed for this are discussed in the succeeding paragraphs.

Collision and Traffic Avoidance Systems

Airborne and ground-based surveillance sensors and equipment are needed to enable UAVs to take actions autonomously for de-confliction of traffic and collision avoidance. The details of the "sense and avoid" and "traffic avoidance" systems being developed are discussed below.

Sense and Avoid Systems: Sense and avoid systems are needed to provide traffic avoidance and collision avoidance capability in congested air space. The time available for identification of potential hazards from other manned, unmanned aircraft, and obstacles on the ground is very little. Human beings have the unique ability to appreciate these risks and take necessary corrective actions to ensure the safety of the aircraft. However, this task would have to be performed by on-board sensors/ equipment in UAVs.

4. Roland E. Weibel and R. John Hansman, "Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System," March 2005, http://dspace.mit.edu/bitstream/handle/1721.1/34912/Weibel%20-%20ICAT%20Report%20-%20UAV%20Safety.pdf?sequence=1. Accessed on June 3, 2016.

Therefore, these sensors/ equipment should be able to detect other manned and unmanned aircraft flying in the near vicinity, identify the threat from them as well as from obstacles on the ground and take corrective actions autonomously.[5] However, existing sensors do not seem to have this capability. The development of reliable and robust sense and avoid equipment continues to be a big challenge.

Traffic Avoidance System: The Traffic Collision Avoidance System (TCAS) is an airborne system which was designed for manned aircraft and gives warning in terms of time to go for collision by comparing velocity and direction. However, it was not meant to have high lateral fidelity for unmanned aircraft and, hence, may have to be modified for unmanned aircraft to identify collision threats and take actions autonomously.[6] Similarly, UAVs would need light weight Infra-Red (IR) sensors, optical sensors and Laser Radars (LIDAR) for detecting non-cooperative traffic.

DATA LINKS

A UAV needs secure data and voice communication links for the following:

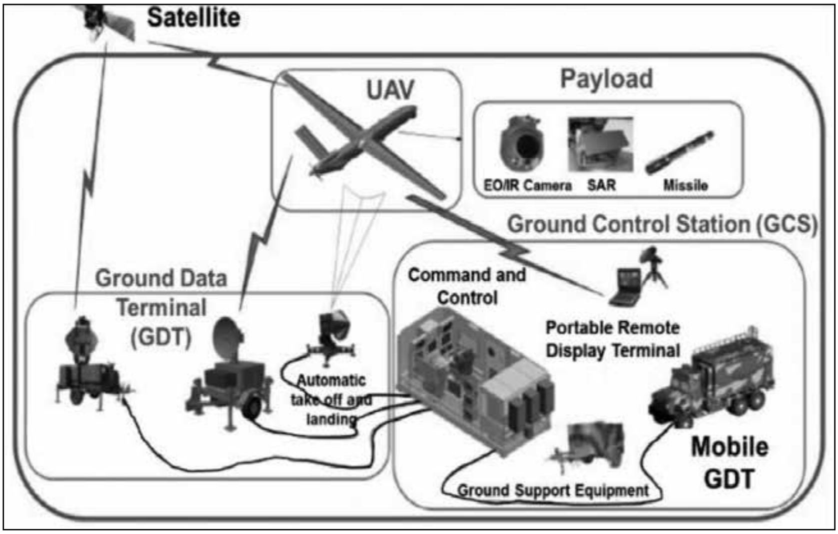
- To provide a command and control link between the UAV and its operator/pilot located in the ground control station for controlling the operation of the UAV.
- For sharing of videos and other sensors' data of the UAV with the ground control station as well as with other aircraft.
- To provide radio telephony (voice) contact between the UAV operator and air traffic control for management and de-confliction of air traffic.[7]

UAVs normally have two independent data uplink nodes for controlling the UAV and one downlink node for downloading of the payload and/or telemetry data. Two nodes are provided for the uplink to ensure that the

5. "FAA Faces Significant Barriers to Safely Integrate Unmanned Aircraft Systems into National Airspace System", https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Unmanned%20Aircraft%20Systems%5E6-26-14.pdf. Accessed on May 27, 2016.
6. n.3.
7. "Civil Air Space Invaders – The Integration of Drones in Commercial Aviation", May 2014, http://www.nortonrosefulbright.com/knowledge/publications/115638/civil-air-space-invaders-the-integration-of-drones-in-commercial-aviation. Accessed on May 25, 2016.

stand-by uplink is available to control the UAV in case of unserviceability of the main link, while only one link is provided for downloading of data since it does not impact the controllability and safety of UAVs.

Fig. 1: A Typical Data Link[8]



The data links with the UAV are either direct Line of Sight (LOS) or Beyond Line of Sight (BLOS) through satellites. The direct LOS data links normally provide command, control and data link connectivity with UAVs up to a range of 200-250 km, whereas in BLOS, the data link connectivity is maintained through satellites and it provides far greater ranges than the LOS data links.[9]

Lost Link: The command and control link between the remote pilot and the UAV could witness interruptions lasting from a few seconds to a few minutes due to unreliability of the command and control link and/ or fading of signals. This poses a serious security hazard to manned air traffic. The US Department of Transport's audit report on "Barriers to UAS Integration"

8. İsmet Çuhadar and Mahir Dursun, "Unmanned Air Vehicle System's Data Links", June 2016, http://www.joace.org/uploadfile/2015/1015/20151015021322106.pdf. Accessed on June 7, 2016.
9. Ibid.

dated June 26, 2014, had cited a few examples of data link failures, which included a UAS helicopter flying into restricted area around Washington DC in 2010 and another UAS descending from the authorised 20,000 ft to 19,000 ft without approval.[10] Therefore, apart from strengthening and improving the security of the command and control links, the need is felt for providing the auto recovery mode as a mandatory requirement for operations in the non-segregated air space.

Vulnerability of Data Links: The safety of data links is a major concern especially for UCAVs that are likely to operate in hostile enemy territory. The possibility of jamming, interference or hacking is a crucial vulnerability, which could be exploited by the adversary in a variety of ways. The adversary could carry out an electronic attack silently to disrupt downloading of sensors' data or replace original data with fake data. The adversary could also take over control of the UCAV and make it either crash or land in enemy territory or utilise it for operations against own targets. Iran's engineers had surprised the world by hacking into the control system of the highly advanced RQ-170 Sentinel Stealth UAV of the US Central Intelligence Agency (CIA) and making it land in Iran in 2011.[11]In 2012, students of the University of Texas took control of a US military UAV by hacking into its communication system in response to a challenge by the US Department of Homeland Security.[12]The possibility of a similar takeover of UAVs by terrorists cannot be ruled out and this is one of the major concerns for security agencies and air space regulators.

LEVEL OF AUTONOMY

UAVs, as of now, are not capable of fully autonomous operations, in which they could adapt to unplanned situations and take appropriate actions autonomously without the intervention/ supervision of human beings. UAVs do not yet have the capability to respond to Air Traffic Control (ATC)

10. n.5.
11. "How Iran Hacked Super-Secret CIA Stealth Drone", December 16, 2011, https://www.rt.com/usa/iran-drone-hack-stealth-943/. Accessed on June 7, 2016.
12. "Civil Air Space Invaders – The Integration of Drones in Commercial Aviation", May 2014, http://www.nortonrosefulbright.com/knowledge/publications/115638/civil-air-space-invaders-the-integration-of-drones-in-commercial-aviation. Accessed on May 25, 2016.

In future, UAVs would also be required to exchange data with other aircraft for the non-segregated operations, which would also require a certain bandwidth.

instructions autonomously, and, on the other hand, air traffic control also does not have the means to ensure that its commands are actioned by UAVs autonomously. There is a need to increase the level of autonomy of UAVs for making their operations safer in the non-segregated air space. Image processing for collision avoidance sensing, voice recognition for control and trajectory optimisation are some of the crucial technologies needed for achieving autonomy.

BANDWIDTH LIMITATION

The frequency spectrum is needed for carrying out voice communication between the UAV pilot and ATC, control of the UAV and for downloading of videos and other data from on-board sensors. In future, UAVs would also be required to exchange data with other aircraft for the non-segregated operations, which would also require a certain bandwidth. The frequency bands commonly being used for UAV operations include Ku band (12-18 GHz for high speed links), K band (18-26.5 GHz for conveying large amounts of data), S band and L band (2-4 GHz and 1-2 GHz respectively), C-band (4-8 GHz) and X band (8-12 GHz is normally earmarked for the military).[13] The frequency bandwidth required for operations of a UAV and its sensors is very high. If multiple UAVs are required to operate in the same area, the numbers that can operate would be limited due to the non-availability of the bandwidth.

ACCIDENTS/ INCIDENTS

Technology and Reliability

The high accident/incident rate of UAVs has been a cause of concern for air space regulators. The causes of UAV accidents/ incidents are

13. http://www.joace.org/uploadfile/2015/1015/20151015021322106.pdf. Accessed on June 7, 2016.

poor reliability, non-availability of separation maintenance and collision avoidance equipment, vulnerability and unreliability of the command and control link and inadequate automation in the absence of a pilot and human factors. Research is being carried out to develop/ improve essential technologies to reduce the accident/incident rate.

Human Factors

The accident rate for UAVs is much higher than for manned aircraft and a significant percentage is attributed to Human Factors (HFs) which continue to be an essential element of UAV operations despite the fact that UAVs were developed to overcome the limitations of manned aircraft. UAVs are different from manned aircraft in many ways and they have posed new challenges for the designers and regulators. The operation of UAVs is carried out from a ground control station, which had given hope that UAV operators would not be subjected to fatigue like pilots of manned aircraft. However, UAVs are being employed for missions of much longer duration than their manned counterparts, which require continuous attention under a high stress environment. The difficult working conditions have made UAV pilots susceptible to errors/ omissions, thereby adversely impacting the safety of UAVs and other aircraft. A study in 2010 observed that HFs comprised one of the major contributors in UAV accidents and accounted for 32 percent of the accidents in a sample of 56 UAV accidents.[14] The US Congressional Research Service Report (CRS) on UAS of 2012 observed that the US Air Force (USAF) alone had lost 79 UAVs due to

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14. Muhammad Asim, Dr Nadeem Ehsan and Khalid Rafique, *Probable Causal Factors In UAV Accidents Based On Human Factor Analysis and Classification System*, http://www.icas.org/ICAS_ARCHIVE/ICAS2010/PAPERS/492.PDF. Accessed on June 3, 2016.

accidents, with human error being the major contributor.[15] The human factor elements like hypo vigilance and ergonomics that contribute to accidents in UAVs are discussed below.

Hypo Vigilance: Hypo vigilance is a Post-Traumatic Stress Disorder (PSTD) in which the patient is in a hyperarousal state with constant tension and always 'on guard' symptoms causing exhaustion.[16] A study in 2014 indicated that hypo vigilance is also a significant contributor in HF accidents in UAVs since UAV operators have long working hours and their attention levels vary, depending upon the level of activity, type of mission and duty hours, which could lead to errors/omissions, thus, resulting in accidents/ incidents.[17] It is one of the human factor elements which is associated with reduction in the attention level of people and is considered to be a major contributor in car accidents.

Ergonomics: The Cambridge Dictionary defines ergonomics as the "scientific study of people and their working conditions, especially done in order to improve effectiveness."[18] The pilot has been shifted from the cockpit of a manned aircraft to the Ground Control Station (GCS) in a UAV. Ergonomically poor design of the ground control station of the UAVs could have serious flight safety implications and there are some examples in which poor ergonomics has led to UAV accidents. In one such incident, a UAV operator had erroneously put off the ignition switch (which was placed in close proximity to the landing gear switch) during landing, resulting in its crash in 2006. In another poor ergonomics related accident, strong glare on the screen had prevented the UAV operator from reading the alert while he was switching off the UAV engine erroneously.[19]

15. http://www.afsec.af.mil/shared/media/document/AFD-150116-044.pdf. Accessed on May 31, 2016.
16. "What is Hypervigilance and What is the Treatment," http://www.epainassist.com/mental-health/hypervigilance. Accessed on September 7, 2016.
17. Yerim Choi, Namyeon Kwon, Sungjun Lee, Yongwook Shin, Chuh Yeop Ryo, Jonghun Park and Dongmin Shin, "Hypovigilance Detection for UCAV Operators Based on a Hidden Markov Model," May 20, 2014, http://www.hindawi.com/journals/cmmm/2014/567645/. Accessed on June 2, 2016.
18. http://dictionary.cambridge.org/dictionary/en7glish/ergonomics. Accessed on June 5, 2016.
19. Sean Gallagher, "Pushing the Wrong Button: Bad Button Placement Leads to Drone Crashes," March 1, 2013, http://arstechnica.com/information-technology/2013/03/pushing-the-wrong-button-bad-button-placement-leads-to-drone-crashes/. Accessed on June 5, 2016.

Fig. 2: Crashed US Drone in Iraq in 2006[20]

Mode Confusion: The high performance UAVs can be programmed for take-off, climb, en-route, approach and landing mode during flying. If an operator forgets or gets confused about the mode in which the UAV is currently flying, due to fatigue or lack of situational awareness, the controller could perceive the behaviour of the UAV as unusual or unexpected, which may result in accidents. UAVs have been reported to have taken-off autonomously due to confusion of the mode.[21]

REGULATORY CHALLENGES

The successful employment of armed UAVs for anti-terror strikes has generated tremendous interest in UAVs. According to a 2011 survey, the number of UAVs being developed had increased from 195 in 2005 to 680 in 2011. The leading aerospace powers are laying special emphasis on developing more capable armed UAVs and UCAVs. Also, UAVs are being increasingly employed for industrial and agricultural applications. As a

20. Ibid.
21. "Human Factors Implications of RPA Flight in Non-Segregated Airspace," March 2014, http://reports.nlr.nl:8080/xmlui/bitstream/handle/10921/962/TP-2013-345.pdf?sequence=1. Accessed on June 27, 2016.

result, there is an increasing demand for formulating an enabling regulatory framework to facilitate their integration in the non-segregated air space.

Operations: An unmanned aircraft can fly either by Visual Flight Rules (VFR) or Instrument Flight Rules (IFR) to operate in civil air space. The IFR manned flight is flown entirely with the help of on-board instruments; however, additional sensors/ instruments would be needed for safe operations of UAVs in the IFR. The operation of UAVs in uncontrolled, non-segregated air space, where no radar cover is available, is likely to be a bigger challenge. The separation from other traffic in the VFR in the manned aircraft is maintained by the pilot visually. The flight of a UAV in the VFR, in uncontrolled air space, necessitates that it has the required instrumentation to replicate the ability of the pilot to detect and take evasive actions autonomously to maintain separation from manned/ other unmanned aircraft. It may be relatively easier for a UAV to maintain separation from cooperative traffic but the bigger challenge lies in maintaining separation and in detecting and taking collision avoidance actions from non-cooperative traffic.

Licensing and Certification: The air space regulators, on their part, have to ensure that there is no danger to manned aircraft and people on the ground. They also have to formulate/amend regulations/guidelines, etc. for licensing of operating crew, certification of UAVs and security of data links to safely integrate UAVs in the non-segregated air space.

Distributed Control: A UAV or RPA can be controlled from different locations by simply handing over of the radio control frequency to another controller situated hundreds of miles away. The distance between the controller and UAV could vary from Line of Sight (LOS) to Beyond Line of Sight (BLOS) operations for satellite controlled UAVs. This is a new development in aviation, which has raised new challenges for attribution of responsibility for control of the UAVs and would have to be factored in the regulations for the UAVs.

CERTIFICATION OF MILITARY UAVS

Euro Control, an organisation of the EU for safety of air navigation, came up with specifications for the use of military RPAs as operational air traffic outside the segregated air space in February 2012.[22] The laying down of specifications for military aircraft will help in aligning the flight safety requirements to certify them and, thus, facilitate in their integration with, civil traffic in the non-segregated air space.

INITIATIVES FOR INTEGRATION

The US, EU and ICAO have taken a lead in the formulation of regulatory mechanisms to facilitate integration of UAVs, especially in the non-segregated air space. It is being ably supported by research in developing critical technologies to facilitate safe operations of UAVs along with manned aircraft. Some of the technological, regulatory and other initiatives, which have contributed, or are likely to contribute, in integration in the non-segregated air space, are covered in the succeeding paragraphs.

Technological Initiatives

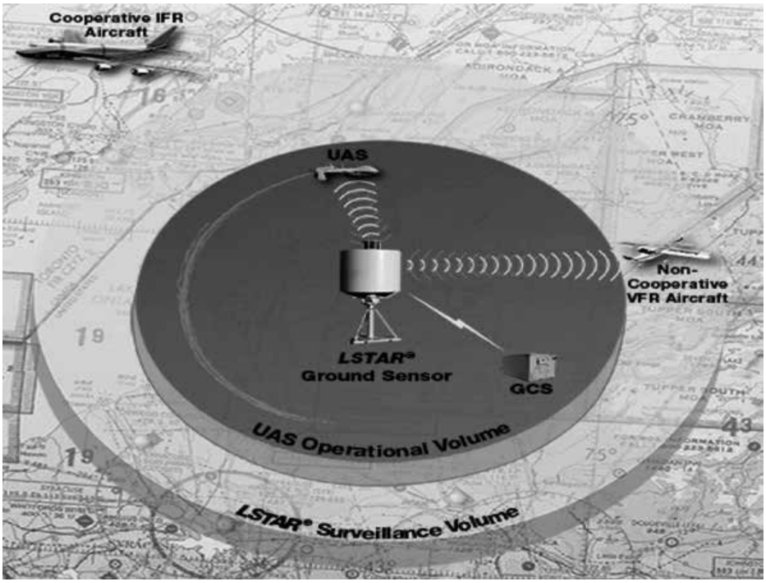
The non-availability of essential technologies is a major hurdle in integration of UAVs in the non-segregated air space. The details of some of the initiatives being undertaken to develop technologies essential for the integration of UAVs are discussed in the succeeding paragraphs.

Ground-Based Sense and Avoid (GBSAA) System

Fig. 3: GBSAA System Based on LSTAR Radars[23]

22. https://www.eurocontrol.int/sites/default/files/content/documents/single-sky/cm/civil-mil-coordination/cmac-rpa-specifications-v-2-0-20120201.pdf. Accessed on June 22, 2016.
23. http://www.srcinc.com/what-we-do/radar-and-sensors/lstar-air-surveillance-radar.html. Accessed on June 21, 2016.

Fig. 4: LSTAR Detection Range for Control of UAS



The US Army has developed a GBSAA system for providing separation between UAV and other traffic. It is based on a light weight, low cost 3-D, 360 degree surveillance radar system capable of detecting and tracking all types of aircraft, including small and slow moving drones and helicopters. The radars send their detection and track information to a central fusion processor and the data is correlated with existing traffic information to build a complete picture.[24] The GBSAA operator also monitors the UAV's deviation from the position, heading and altitude by using algorithms, and alerts the UAV operator if the separation between the UAV and other airborne aircraft reduces or poses a threat to other airborne objects. The initial system was installed at El Mirage, California, and first tested on April 27, 2011. The GBSAA operator is normally an ATC controller who is in contact with the ATC and UAS but has no contact with other aircraft. This system is also being tested by the US Navy and US Marines.[25]

24. http://www.srcinc.com/what-we-do/radar-and-sensors/lstar-air-surveillance-radar.html. Accessed on June 21, 2016.
25. Thomas P. Spriesterbach, Kelly A. Bruns, Lauren I. Baron, and Jason E. Sohlke, "Unmanned Aircraft System Airspace Integration in the National Airspace Using a Ground-Based Sense and Avoid System," http://www.jhuapl.edu/techdigest/TD/td3203/32_03-spriesterbach.pdf. Accessed on May 29, 2016.

The safety and reliability of communication and data links among the GBSAA controller, UAV operator and ATC would become crucial for ensuring safe separation and collision avoidance. The induction of such a system would add to the workload of ATC controllers and could increase their stress levels.

The non-availability of essential technologies is a major hurdle in integration of UAVs in the non-segregated air space.

Airborne Radar

The National Aeronautics Space Administration (NASA) had carried out trials of the on-board radar of a UAV in 2003 to check the detection distance of non-cooperative traffic and the UAV's ability to take evasive manoeuvres. However, the radar could pick up the target only at 4 miles, which was not adequate to take evasive measures and avoid a collision.[26] The results of the trials were not satisfactory.

Sense and Avoid System

The US Defence Advanced Research Projects Agency (DARPA) tested an integrated Sense and Avoid (SAA) system comprising an optical camera and passive ranging sensors, which identify incoming or crossing aircraft and determine the best avoidance strategy compliant with air rules as part of the Aircrew Labour In-Cockpit Automation System (ALIAS) programme. The trials of the SAA system were successful, in which a Cessna 172G aircraft was used as the target aircraft in May 2016.[27]

ADS-B

The Automatic Dependent Surveillance Broadcast (ADS-B) system will be capable of broadcasting the aircraft location in real-time in terms of altitude and velocity as well as be able to receive information about other aircraft, weather and terrain.[28] The initial reports of the system as a traffic avoidance system are encouraging. ADS-B has been included as essential

26. n.3.
27. "1st Success Seen in System Designed to Help Aircraft Automatically Avoid Mid-Air Collisions," May 04, 2016, http://www.darpa.mil/news-events/2016-04-05a. Accessed on June 15, 2016.
28. n.12.

equipment in the ICAO manual for RPAS operations. ADS-B Out, a mode of ADS-B, broadcasts Global Positioning System (GPS) information like the aircraft's location, air speed and other data to a network of ground stations, which, in turn, relay the data to air traffic control displays and to nearby aircraft equipped to receive the data via ADS-B In mode. The US has made it mandatory for all aircraft to be equipped with ADS-B equipment for operations in its controlled air space from January 1, 2020 onwards.[29]

MIDCAS

Five EU countries (Sweden, France, Germany, Italy and Spain) are funding the project to develop the Mid-Air Collision Avoidance System (MIDCAS), which integrates ADS-B with Electro-Optical (EO) and Infra-Red (IR) cameras to identify other aircraft.[30] The project was launched in 2009 and a consortium of 11 companies, led by SAAB of Sweden, is involved in the development process.

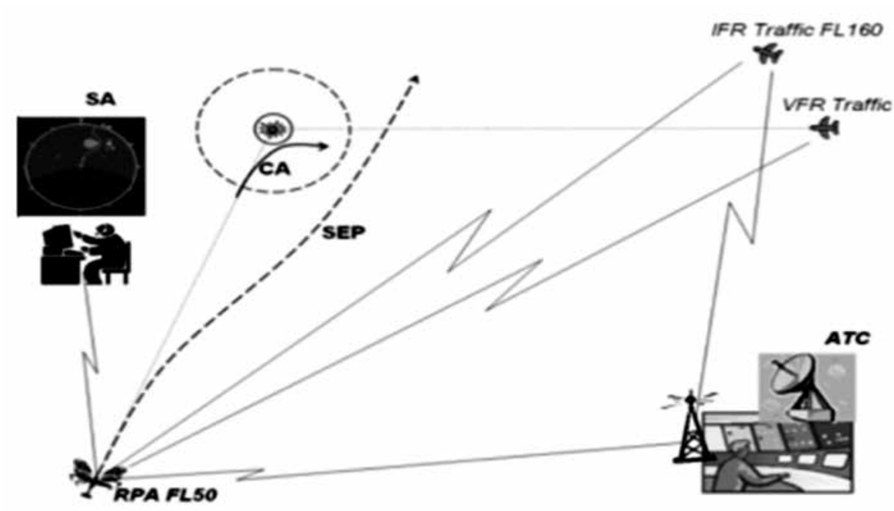
Fig. 5: MIDCAS Development Partners[31]

MIDCAS is expected to undertake the following functions:

- Improve situational awareness for the RPAS pilot.
- Help maintain separation from other traffic (or self-separation).
- Collision avoidance by anticipating traffic on collision course and taking evasive measures.[32]

29. https://www.faa.gov/nextgen/equipadsb/. Accessed on July 14, 2016.
30. n.3.
31. "MIDCAS is the European Detect and Avoid Project," http://www.midcas.org/. Accessed on August 30, 2016.
32. Ibid.

Fig. 6: Functions of MIDCAS[33]



The EU had successfully carried out MIDCAS trials in September 2015; however, there is no news since then. It appears that further testing, simulation and data collection about utilisation of the MIDCAS in a dynamic air environment is being carried out to ascertain the reliability and effectiveness of the system.[34]

Airborne Internet Protocol (AIP)

The Autonomous Systems Technology Related Airborne Evaluation and Assessment (ASTRAEA) is a UK industry-led consortium of seven companies: Airbus Defence & Space, AQS, BAE Systems, Cobham, QinetiQ, Rolls-Royce and Thales. It was allotted £62 million to develop technologies, systems, procedures and regulations that will allow autonomous vehicles to operate safely and routinely in the civil air space over the United Kingdom. ASTRAEA is developing a system

33. Ibid.
34. "Strong Interest for MIDCAS Results Advancing European RPAS Air Traffic Integration," September 11, 2015, https://www.eda.europa.eu/info-hub/press-centre/latest-news/2015/09/11/strong-interest-for-midcas-results-advancing-european-rpas-air-traffic-integration. Accessed on July 8, 2016.

The bandwidth required for command and control of UAVs, transmission of intelligence data and video imagery is huge. The capabilities of UAVs are constrained due to the limited availability of bandwidth.

which envisages using airborne Internet Protocol (IP)-based architecture[35] for sending communication signals through multiple stops for maintaining end-to-end security.[36] The Airborne Internet Protocol (AIP) was first proposed in the NASA Langley Research Centre's Small Aircraft Transportation System (SATS) planning conference in 1999. The AIP is used for providing inflight connectivity by forming a peer-to-peer (air-to-air) wireless communication network among the aircraft, thereby overcoming the limitations of satellite communication.[37] Gary Clayton, head of R&T for Cassidian UK, which is responsible for ASTRAEA's communications architecture, in an interview in 2013, had intimated that they are developing air, sea or land-based mobile IP nodes, which can create a secure territorial network between multiple air platforms.[38] AIP systems could help overcome bandwidth limitations. However, dependence on such systems without suitable back-up systems could also make them vulnerable. Any failure or disabling of a such system due to enemy actions could jeopardise the entire operation and would need to be factored in operational plans or alternative means of providing similar communication, and data transfer capability would have to be found.

Wavelet Compression

The bandwidth required for command and control of UAVs, transmission of intelligence data and video imagery is huge. The capabilities of UAVs are constrained due to the limited availability of bandwidth. Increasing the bandwidth, therefore, is not an option. A study was carried out in the

35. Steven V. Pizzi, "A Routing Architecture for the Airborne Network," May 21, 2007, https://www.mitre.org/sites/default/files/pdf/07_0746.pdf. Accessed on June 15, 2016.
36. n.12.
37. "The Airborne Internet," http://cdn.intechweb.org/pdfs/20441.pdf. Accessed on July 12, 2016.
38. https://www.theengineer.co.uk/issues/june-2013-online/your-questions-answered-astraea-autonomous-planes/. Accessed on July 8, 2016.

University of California in 2013 to find a solution to overcome the limitation of data transmission capabilities in UAVs by improving the bandwidth utilisation through wavelet compression. The study observed that reduction in size of the transmission of images by 93 percent and corresponding decrease in bandwidth demand is feasible through Enhanced Compression Wavelet (ECW) technology.[39]

ACCIDENTS/ INCIDENTS

Technological initiatives are being taken to improve the reliability of the UAV platform, develop traffic avoidance and collision avoidance systems, and improve command and control systems to curb the rate of accidents/ incidents, which are discussed separately. The initiatives being taken to reduce accidents/ incidents due to HFs are discussed below.

EEG for Hypo Vigilance Detection

The National Research Foundation (NRF) of Korea, in collaboration with the Korean government, in a study titled "Hypo Vigilance Detection for UCAV Operators Based on a Hidden Markov Model" in 2014 proposed use of Electroencephalography (EEG) signals on UAV operators for building a databank for study, and utilising these for reducing their hypo vigilance cycles.[40] The aviation medicine specialists need to analyse this study and, if found suitable, consider incorporating appropriate provisions in the annual medical schedules and/ or for the treatment of operating crew of unmanned aircraft.

Improving Ergonomics

A report by ARS Technology on the contribution of human error (ergonomics) in UAV accidents in 2013 observed that there was 98 percent overlap between inputs and output devices used by ground control workstations of UAVs and those used by general purpose computers. It observed that American National

39. Mary Elizabeth Parker, "Data Overload In Unmanned Aircraft Systems: Improving Bandwidth Utilization Through Wavelet Compression," May 2013, http://spatial.usc.edu/wp-content/uploads/2014/04/ParkerMaryThesis.pdf. Accessed on June 15, 2016.
40. n.17.

Standards Institute and Human Factors and Ergonomics Society ANSI/HFES-100-2007 standards for computing workstations could form the basis for formulating ergonomic standards of UAVs' ground control workstations.[41]

RESEARCH

The US Government Accountability Office report to the Congressional Committee on UAS dated July 2015, highlighted the technological challenges being faced in UCAV development. NASA is collaborating with the Department of Defence (DoD) to generate operations and safety data. It is also collaborating with academia to undertake research on UAS operations.[42] The Federal Aviation Administration (FAA) has collaborated with universities and DoD and had allocated a budget of $4.2 million in 2013 and $8.6 million in 2014 to undertake research in areas and technologies associated with the integration of UAVs in the National Air Space.[43]

Regulatory Initiatives

The employment of UAVs in conflicts and their increasing business potential has compelled the air space regulators to formulate an enabling regulatory framework. The International Civil Aviation Organisation (ICAO), Federal Aviation Administration (FAA) of the US and European Aviation Safety Agency (EASA) of the European Union have been at the forefront in formulating regulatory frameworks which are duly supported by technological innovations to ensure safe integration of UAVs with manned aircraft. The initiatives taken by the air space regulators are discussed in the succeeding paragraphs.

INTERNATIONAL CIVIL AVIATION ORGANISATION (ICAO)

ICAO is a specialised agency of the UN which is responsible for providing the international regulatory framework for RPAS integration into the non-

41. n.19.
42. "US GAO Report on UAS," July 2015, http://gao.gov/assets/680/671469.pdf. Accessed on May 26, 2016.
43. n.5.

segregated air space in consultation with member states. It had set up the Unmanned Aircraft Systems Study Group (UASSG) in 2007 which was the focal point for UAS related issues. This was superseded by the Remotely Piloted Aircraft System Panel (RPASP) in 2014 which aims to amend 18 out of 19 annexures (excluding Annex 5) to accommodate RPAS.[44] ICAO had published Circular 328 on UAS in the year 2011 and has so far amended Annexures 2, 7 and 13 to the Chicago Convention to accommodate RPAS for use by international civil aviation.[45]

ICAO came up with its first edition of the Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019-AN/507) in 2015.[46] The goal of ICAO is to develop Standards and Recommended Practices (SARPs) with supporting Procedures for Air Navigation Services (PANS) and guidelines to facilitate safe, secure and efficient integration of RPAS into the non-segregated air space and aerodromes.[47]

USA

Integration of UAVs in the US national air space was envisaged in the "Vision 100-Century of Aviation Reauthorisation Act" passed by the US Congress on December 12, 2003.[48] The US Department of Transportation's FAA has been actively pursuing rule making for UAS. The "FAA Modernisation and Reform Act of 2012" was a step in developing the next generation air transportation system and air traffic control modernisation by the US. Section 322 of the Act proposes a framework for integration of UAS into the US NAS.[49] The Act directed the US government to develop an integration plan by the end of Financial Year (FY) 2015 with a five-year

44. http://www.icao.int/MID/Documents/2016/RASG-MID5/PPT3%20-%20RPAS%20Elie.pdf. Accessed on June 9, 2016.
45. "Unmanned Aircraft Systems (UAS) and Remotely Piloted Aircraft Systems (RPAS)," https://www.easa.europa.eu/unmanned-aircraft-systems-uas-and-remotely-piloted-aircraft-systems-rpas. Accessed on June 10, 2016.
46. Publications:2718, February 20, 2015, http://www.icao.int/isbn/Lists/Publications/DispForm.aspx?ID=2733. Accessed on June 12, 2016.
47. http://www.icao.int/safety/RPAS/Pages/default.aspx. Accessed on June 9, 2016.
48. "Vision 100-Century of Aviation Reauthorisation Act," December 12, 2003, https://www.gpo.gov/fdsys/pkg/PLAW-108publ176/pdf/PLAW-108publ176.pdf. Accessed on August 31, 2016.
49. "FAA Modernisation and Reform Act of 2012," February 1, 2012, https://www.gpo.gov/fdsys/pkg/CRPT-112hrpt381/pdf/CRPT-112hrpt381.pdf. Accessed on May 25, 2016.

roadmap for full integration. The US government has formulated a policy for integration of small UAS; however, a comprehensive integration plan as mandated by the Act is still awaited.[50]

UAS in Arctic: The FAA released the Arctic Implementation Plan on November 1, 2012. Section 332 (d) of the UAV Modernisation and Reform Act of 2012 directs the US government to establish permanent operational areas and corridor routes in the Artic for operations of small UAS on a 24-hour basis for research and commercial purposes within six months of the Act coming into force. Two UAS companies have been granted permission to undertake operations in the Arctic, i.e. ConcoPhillips' Insitu's Scan Eagle UAV for marine mammals and ice surveys in September 2013 and BP's AeroVironment's Puma AE UAV to survey pipelines, roads, and equipment at Prudhoe Bay in Alaska in June 2014.[51]

Centre of Excellence: The FAA selected the Mississippi State University's team as the FAA's Centre of Excellence for Unmanned Aircraft Systems (COE UAS) in May 2015 after going through a rigorous competition. Mississippi State University will be supported by 22 of the world's leading research institutes to carry out cutting edge research in areas related to UAS integration in the non-segregated air space, and an initial amount of $5 million was allotted for a five-year agreement.[52]

50. https://www.faa.gov/uas/media/Sec_331_336_UAS.pdf. Accessed on June 14, 2016.
51. Ibid.
52. Press Release, "FAA Selects Mississippi State University Team as Center of Excellence for Unmanned Aircraft Systems," May 08, 2015, https://www.faa.gov/news/press_releases/news_story.cfm?newsId=18794, June 14, 2016.

Fig. 7: FAA's Centre of Excellence for UAS Research[53]

These 22 research institutes, along with more than a hundred leading industry and government agencies, formed an Alliance for System Safety of UAS through Research Excellence (ASSURE). The process of integration of UAVs is complex and ASSURE members have the expertise as well as access to infrastructure, laboratories and testing facilities. They are the core of three FAA UAS test sites, lead four FAA research centres, have seven airfields and a 340-UAS fleet. The alliance partners would undertake research in various fields related to integration of UAVs, which include air traffic control interoperability, UAS airport ground operations, control and communications, detect and avoid, human factors, UAS noise reduction, UAS wake signatures, unmanned aircraft pilot training and certification, low altitude operations safety, spectrum management and UAS traffic management. [54]

Small UAS Integration: The US had formulated a policy on July 30, 2013,[55] which allowed the FAA to grant exemption under Section 333 of the Act to deviate from certain rules if it finds that small UAV operations can be performed safely, and authorise them to operate in the NAS. The US had

53. "Alliance for System Safety of UAS through Research Excellence (ASSURE)," http://www.assureuas.org/about.php#. Accessed on August 30, 2016.
54. Ibid.
55. "Unmanned Aircraft Systems (UAS) Operational Approval," July 30, 2013, http://www.faa.gov/documentlibrary/media/notice/n_8900.227.pdf. Accessed on July 9, 2016.

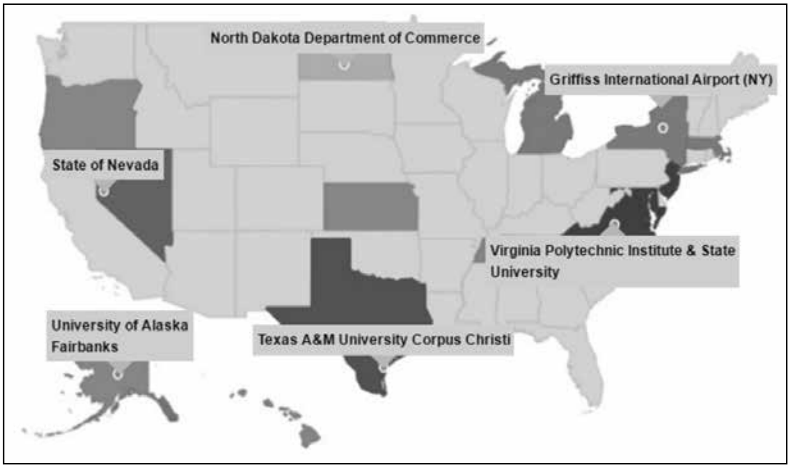
published a notice of proposed rule-making for operations of small UAS in April 2015, which was followed up by the notice for registration of small UAS in December 2015.[56] A total of 5,309 civil operators were authorised under Section 333 to operate small UAS for commercial applications from July 2013 to May 2016.[57] The final operational rules for routine commercial use of small UAS were issued under Part 107 of the regulations on June 21, 2016.[58] The small UAS Rule (Part 107) came into force with effect from August 29, 2016.[59]

Drone Advisory Committee (DAC): FAA Administrator Michael Huerta, speaking at the Association for Unmanned Vehicle System International (AUVSI) annual conference-2016 in New Orleans, had announced the setting up of a DAC consisting of a cross-section of stakeholders from the field of UAS operations, business and other related issues, which would provide inputs to the FAA and decision-makers for resolution of issues affecting the efficiency and safe integration of UAS into the NAS.[60]

Test Sites: The US had designated six test sites under the NASA to undertake research and testing of aspects related to UAS integration in civil air space in 2013.[61] The FAA had followed a rigorous selection process to select six test sites out of 25 proposals from 24 states, taking into consideration geography, climate and location of ground infrastructure, research needs, air space use, safety, aviation experience and risk.[62] These sites are at the University of Alaska Fairbanks, North Dakota Department of Commerce, State of Nevada, Griffiss International Airport, Texas A&M University, Corpus Christi, Virginia Polytechnic Institute and State University ("Virginia Tech").[63]

56. https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19856. Accessed on June 14, 2016.
57. https://www.faa.gov/uas/legislative_programs/section_333/333_authorizations/. Accessed on June 14, 2016.
58. http://www.faa.gov/uas/media/RIN_2120-AJ60_Clean_Signed.pdf. Accessed on July 8, 2016.
59. "Becoming a Pilot," https://www.faa.gov/uas/getting_started/fly_for_work_business/becoming_a_pilot/. Accessed on September 7, 2016.
60. https://www.faa.gov/uas/legislative_programs/. Accessed on June 14, 2016.
61. "US GAO Report on UAS," July 2015, http://gao.gov/assets/680/671469.pdf. Accessed on May 26, 2016.
62. https://www.faa.gov/uas/legislative_programs/. Accessed on June 14, 2016.
63. "UAS Test Sites Contacts," https://www.faa.gov/uas/legislative_programs/test_sites/contacts/. Accessed on June 14, 2016.

Fig. 8: Six UAS Test Sites in the US[64]



Focus Area Pathfinders Initiative: The FAA announced the UAS Focus Area Pathfinders Initiative in collaboration with three companies of the industry to explore UAS operations beyond the type of operations proposed in the small UAS operations. These include CNN to look at UAS operations over populated areas for news gathering, Precision Hawk to explore UAS flights outside the pilot's direct vision for crop monitoring and BNSF Railway to explore command and control challenges of using UAS to inspect the rail system infrastructure.[65]

JOINT AUTHORITIES FOR RULE-MAKING ON UNMANNED SYSTEMS (JARUS)

JARUS is a voluntary group comprising experts from the National Aviation Authorities and regional aviation safety organisations. It has 46 countries/ organisations as its members, including India. It aims to recommend technical, safety and operational requirements for the certification and safe integration of UAVs into the air space and at aerodromes, which could be used as a guideline while formulating regulations by countries/ organisations and avoid duplication of effort.[66] It has published 10 documents related to

64. http://www.faa.gov/uas/programs_partnerships/coe_test_sites/
65. "Focus Area Pathfinders," https://www.faa.gov/uas/legislative_programs/pathfinders/. Accessed on June 14, 2016.
66. http://jarus-rpas.org/. Accessed on June 12, 2016.

UAV operations and has held various conferences on issues related to UAV integration. The European Aviation Safety Agency (EASA) is working in close coordination with JARUS to formulate UAV integration regulations.[67]

EUROPEAN UNION (EU)

The EU has been formulating regulations for the integration of RPAs into the European air space. The EU Regulation (EC) No 216/2008 mandates regulation of civil unmanned aircraft with an operating mass of 150 kg or more.[68] The EU came up with a roadmap for integration of civil RPAs into the European aviation system in June 2013. The roadmap proposes a three-pronged approach involving a regulatory approach, a strategic research plan and a study on the societal impact. It envisages:

- Allowing operations of light RPAs between 2014 and 2018,
- Extending RPA operations to all the air spaces under IFR conditions and initiation of VFR operations between 2019 and 2023.
- Full integration between 2024 and 2028.[69]

The European Union came up with "Riga Declaration" on March 6, 2015, which committed to allow businesses to provide drone services in all Europe from 2016 onwards.[70] EASA published a "Technical Opinion" in December 2015 for integration of UAVs in the segregated/non-segregated air space, which is based on the degree of risks involved and does not discriminate between UAVs of different Maximum Take-off Weight (MTOW). The paper proposes a regulatory framework for performance and risk-based UAV operations in the following three categories:

- "Open Category" (low risk) permits UAV operations subject to meeting the minimum requirements.

67. "Regulations," http://jarus-rpas.org/regulations. Accessed on June 12, 2016.
68. Regulation (Ec) No 216/2008 of the European Parliament and of the Council dated February 20, 2008, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02008R0216-20130129. Accessed on June 10, 2016.
69. http://www.sesarju.eu/sites/default/files/documents/news/European-RPAS-Roadmap_130620.pdf?issuusl=ignore. Accessed on June 10, 2016.
70. "Riga Declaration on Remotely Piloted Aircraft (Drones) Framing the Future of Aviation," on March 6, 2015, http://ec.europa.eu/transport/modes/air/news/doc/2015-03-06-drones/2015-03-06-riga-declaration-drones.pdf. Accessed on June 10, 2016.

- "Specific Category" (medium risk) allows operations subject to authorisation by the National Aviation Authority (NAA).
- "Certified Category" (higher risk) UAV operations are subject to approvals by NAA and EASA.[71]

EASA aims to come up with new rules or amend existing rules during 2016 and 2017 in order to move forward towards integration of the UAVs in the European air space.[72] The EU has come up with Innovative Operational UAS Integration (INOUI) under the Single European Sky programme to facilitate UAS integration in the future air traffic management environment.[73]

INDIA

The Director General of Civil Aviation (DGCA) is India's civil aviation body which is responsible for formulation of regulations for integration of UAVs in the Indian air space. DGCA had banned launching of UAVs in the Indian air space by non-government agencies and individuals in October 2014 due to security threats and lack of regulations.[74] It subsequently came up with a draft circular titled "Guidelines for Obtaining Unique Identification Number (UIN) and Operation of Civil Unmanned Aircraft Systems (UAS)" in April 2016 for comments from the public. The final circular is awaited and the implications are discussed subsequently in the paper.[75]

WHY FULL INTEGRATION MAY TAKE LONGER

Full integration of UAVs in the non-segregated air space is the ultimate goal of UAV designers and air space regulators. In order to do that, the UAV would need to have, firstly, the capability to fly accurately and safely in IFR

71. "Introduction of a Regulatory Framework for the Operation of Unmanned Aircraft," https://www.easa.europa.eu/document-library/opinions/opinion-technical-nature. Accessed on June 10, 2016.
72. "Civil Drones (Unmanned Aircraft)," https://www.easa.europa.eu/easa-and-you/civil-drones-rpas. Accessed on June 10, 2016.
73. http://ec.europa.eu/transport/modes/air/studies/doc/ses/2010_inoui.pdf. Accessed on June 10, 2016.
74. http://dgca.nic.in/public_notice/PN_UAS.pdf. Accessed on June 12, 2016.
75. http://www.dgca.nic.in/misc/draft%20circular/AT_Circular%20-%20Civil_UAS(Draft%20April%202016).pdf. Accessed on June 12, 2016.

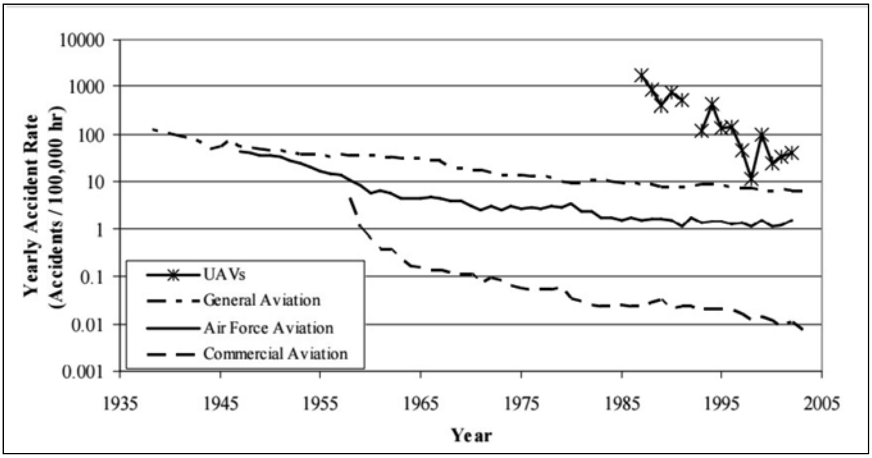
and VFR conditions in the non-segregated air space; secondly, capability to identify conflicting traffic using EO, IR sensors, radars or any other means, and take evasive measures autonomously; thirdly, to safely operate in hazardous weather or meteorological conditions; and fourthly, to protect itself from obstacles during flying. The integration of UAVs in the non-segregated civil air space is likely to be subjected to tougher certification and regulatory norms as civil regulatory bodies are extremely sensitive to accident rates, dangers of collision and possible exploitation of UAVs and sensors by hacking of data links. Therefore, it would be prudent to analyse the extent of progress made in developing the essential technologies and in regulation formulation to understand the level of integration achieved, and estimate the future of integration of UAVs.

ACCIDENT RATE: CONCERNS AND HOPE

The reliability of an airborne platform can be judged from its accident rate. The CRS report for the US Congress on "US Unmanned Aerial Vehicles" dated January 3, 2012, indicated a declining accident rate among both manned and unmanned aircraft with maturing of technology, improving reliability and better regulatory mechanisms.[76]The comparative accident rate for both manned aircraft (general aviation, air force aviation and commercial aviation) and UAVs for the time period from 1935 to 2005 is as follows:

76. Jeremiah Gertler, "US Unmanned Aerial Systems," January 3, 2012, http://www.fas.org/sgp/crs/natsec/R42136.pdf. Accessed on May 30, 2016.

Fig. 9: Comparison of Accident Rate[77]



The accident rate (per 100,000 hours) of class A mishaps of some of the unmanned and manned aircraft of the US is given below:

Fig. 10: Accident Rates of Manned and Unmanned Aircraft

Class A Accident Rate*	Unmanned					Manned	
	Predator	Hunter	Global Hawk	Pioneer	Shadow	U-2	F-16
As of 2005	20	47	88	281	191	6.8	4.1

Class A Accident Rate*	Unmanned	
	Predator	**Reaper**
As of 2009	7.5	16.4
As of 2014[78]	4.79	3.17

*The USAF defines a Class A mishap as a mishap which results in losses totalling $2,000,000 or more, or fatality/ permanent disability or destruction of aircraft.[79]

77. Roland E. Weibel and R. John Hansman, "Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System," March 2005, http://dspace.mit.edu/bitstream/handle/1721.1/34912/Weibel%20-%20ICAT%20Report%20-%20UAV%20Safety.pdf?sequence=1. Accessed on June 3, 2016.
78. Craig Whitlock,"When Drones Fall from the Sky," June 20, 2014, http://www.washingtonpost.com/sf/investigative/2014/06/20/when-drones-fall-from-the-sky/. Accessed on June 20, 2016.
79. http://www.afsec.af.mil/shared/media/document/AFD-150116-044.pdf. Accessed on May 31, 2016.

The level of automation, bandwidth limitation and security of data links are the other key areas where technology would play a key role to overcome these limitations/ challenges.

The accident rate variation of manned aircraft with time has some parallels with the UAVs. The above study indicates that the accident rate in manned aircraft was very high during the period 1935 to 1955. It dropped to below 1/1,00,000 hours in 1960. Thereafter, the accident rate continued to drop further to very low level (1 for air force aviation and 0.01 for commercial aviation) in the following five decades.

The accident rate of UAVs was also high during the initial phase and it has seen a decline with the passage of time. It reduced from over 1,000 in 1985 to about 70 in 2004. The accident rate of the Predator UAVs of the US had dropped from 20 in 2005 to 7.5 in 2009, while the accident rate of its latest UAV Reaper was 16.9 in 2009. The *Washington Post* had reported on June 20, 2014, that the accident rate of the Predator and Reaper UAVs had further reduced to 4.79 and 3.17 respectively.[80] The accident rate of UAVs is still higher than that of manned aircraft, which is a major concern. However, the silver lining lies in the fact that accident rate of UAVs is coming closer to that of manned aircraft due to improvements in designs, enhanced survivability in adverse weather and increased reliability. The reduction in the accident rate of UAVs is a good sign; however, it would have to be brought down further to facilitate smooth integration of UAVs.

TECHNOLOGY: STILL A CHALLENGE

DARPA had successfully tested the ALIAS sense and avoid equipment (which is a light weight plug and play system with single camera and passive ranging features) in May 2016, as it is considered essential to facilitate the integration of UAVs. However, this system could prove ineffective in identifying other flying objects during clouding, poor visibility, or at night. Therefore, follow-on research would be needed to develop a system which is capable of detecting aircraft below the horizon and in poor light

80. n.78.

conditions.[81] The effectiveness of the ADS-B system in the present form could be limited since its pilot cannot physically see and identify the approaching threat. The EU is developing the MIDCAS to overcome the limitations of the ADS-B by adding EO and IR sensors.

The GBSAA appears to be having relatively short range and could be used for detecting aircraft flying at low to medium altitudes since it consists of light weight portable radar/s. It would provide an alternative to meet the sense and avoid capability requirement by providing traffic information to the UAV operator for maintaining separation from other manned and unmanned aircraft. However, the GBSAA operator does not have contact with manned aircraft, which would increase the complexity of the air traffic control system. Also, there is a need to ascertain the effectiveness and reliability of the radar, data fusion and radio communication (voice) link among the GBSAA operator, UAV pilot and ATC controller.

The level of automation, bandwidth limitation and security of data links are the other key areas where technology would play a key role to overcome these limitations/ challenges. The level of automation is still low and trials are being conducted to test the efficacy and reliability of collision avoidance systems. The security of data links is still a concern and the technology being developed is not yet fool-proof. The bandwidth limits the number of UAVs that can fly in a given area of operation or data that can be exchanged and this continues to be a challenge for researchers. Efforts are on to increase encryption as well as to find hardware solutions to protect data links.

The US is making endeavours to overcome the technological challenges hampering the integration of UAVs into the NAS. The FAA's collaboration with Mississippi State University to set up a Centre of Excellence for UAVs with NASA for setting up of six test sites, and with industry for the Focus Area Pathfinder Initiative, are the best examples of collaboration among the US government, R&D agencies, industry and academia to undertake core research in developing futuristic UAV related technologies and retaining lead in the technological arena. The earmarking of test sites would facilitate in testing of critical technologies and using the experience gained and test

81. n.27.

data generated as the basis for formulation of regulations to facilitate UAV integration.

REGULATIONS: A CAUTIOUS AND SLOW INTEGRATION

ICAO has made slow progress in formulating regulations since the setting up of the Unmanned Aircraft Systems Study Group (UASSG) in 2007 and Remotely Piloted Aircraft Systems Panel (RPASP) in 2014. Publication of Circular 328 in 2011, Manual of RPAS in 2015 and amendment of three out of 18 Annexures indicates the slow pace of formulation of the regulatory framework. The setting up of working groups to address issues related to airworthiness, telecommunication for command and control and air traffic control, Detect And Avoid (DAA), personnel licensing, RPAS operations and air traffic management indicate unresolved critical areas needing further research and deliberations.[82] ICAO's plan to complete only two SARPs for air traffic management and "detect and avoid" requirements for unmanned aircraft by 2020 indicates the difficulties being faced in the finalisation of regulations.[83] All the SARPs have to be completed to facilitate integration of RPAS into the non-segregated air space.

The US was proactive in allowing limited UAV operations despite technological limitations. The FAA came up with a notice for registration of small UAS in December 2015 which was followed by the publishing of rules to allow routine civil operations of small UAS in the NAS, vide Rule 107 to Title 14 Code of Federal Regulations (14 CFR) dated June 21, 2016.[84] In the meantime, the FAA had issued a certification of waiver to over 5,300 applicants for operation of UAS in the NAS by June 2016, which indicates the willingness of the US government to allow civil UAS operations on a case by case basis. The deployment of UAS in the Arctic by the US on a 24-hour basis appears to be aimed at utilising the unique capabilities of UAS for furtherance of strategic, scientific and business interests in a common

82. http://www.icao.int/MID/Documents/2016/RASG-MID5/PPT3%20-%20RPAS%20Elie.pdf. Accessed on June 9, 2016.
83. http://www.eurocontrol.int/news/icao%E2%80%99s-rpas-manual-issued. Accessed on June 9, 2016.
84. "Operation and Certification of Small Unmanned Aircraft Systems," June 21, 2016, http://www.faa.gov/uas/media/RIN_2120-AJ60_Clean_Signed.pdf. Accessed on July 8, 2016.

international region (a global common). The abundant resources, unique climate and geographical location of the Arctic offer enormous opportunities for scientific research. The US is likely to benefit economically from the abundance of natural resources available in the Arctic. However, the US government, despite being proactive in allowing small UAS operations, was unable to make a five-year roadmap for full integration of UAS in the NAS by end 2015, which was proposed in the FAA Modernisation and Reform Act, 2012. The FAA is cautious in its approach in integrating medium and heavy UAVs in the NAS as some of the critical technologies are yet to be developed/ matured.

The EU roadmap for civil RPAS integration envisages an incremental approach with full integration of RPAS to be achieved during the time period 2024-28. The Riga Declaration on RPAS indicates efforts by the EU countries to harness the tremendous business opportunities presented by this futuristic technology. The publication of the technical opinion instead of the draft regulation and proposing risk-based operations by the RPAS is an indicator of the limitations of the existing technologies and urgency among the EU countries to facilitate integration of RPAS in the civil air space.

INTEGRATION OF UAVs IN THE INDIAN AIR SPACE

Regulations

The Director General of Civil Aviation of India publishing a draft circular titled "Guidelines for Obtaining Unique Identification Number (UIN) & Operation of Civil Unmanned Aircraft System (UAS)" on April 21, 2016, shows the willingness of the Indian government to allow UAV operations in the Indian air space. The circular had guidelines for obtaining a Unique Identification Number (UIN) for UAVs, the procedure for allotment of UA permits to UA pilots meant for operations above 200 ft above ground level (a.g.l.) and guidelines and restrictions for the operation of UAVs. The draft circular does not include guidelines for certification and operation of UAVs since SARPs in Annexure 6 (Operations) and Annexure 8 (Airworthiness) on UAS are not available.

The draft circular is likely to undergo an internal review to incorporate suggestions/ comments received from the public before DGCA comes up with a circular for the operation of civil UAVs. The requirement of safety of manned aircraft and people on the ground while facilitating the operations of UAVs is a contradictory requirement for air space regulators. The regulations should be neither too restrictive to hamper exploitation of UAVs nor too loose to become a safety and security hazard. Therefore, it would be prudent to take a closer look at the provisions of the draft circular before they become a rule. There may be a need to review some of the clauses of the draft circular or include some aspects for harnessing the unique capabilities of UAVs.

AIR SPACE MANAGEMENT

At present, the operations of UAVs belonging to the military, paramilitary, disaster management and other government agencies are allowed in the segregated air space in India. The operation of civil UAVs remains banned since October 2014. However, special permissions are granted for operation of UAVs by the respective state or government agencies for specified tasks within a specified area for a given period of time. Draft regulations for the operations of UAVs were placed in the public domain in April 2016 for comments/views. The final rules, when published by the DGCA, would, in all likelihood, make it mandatory to register small UAVs, and their operations could be permitted in segregated areas having less air traffic density, with enhanced separation from manned aircraft. The UAVs would be required to obtain air defence and security clearance from the nearest airfield and local administration respectively.

Increased reach of the civil manned aircraft and helicopters has already reduced the availability of the military air space in India. With flexible use of air space, civil aircraft are being permitted use of military air space in certain block timings or height bands. The proliferation of UAVs in the already constrained air space of India is likely to pose new challenges for air space management. The added security concerns related to ensuring physical security of military and civil UAVs' ground stations, preventing exploitation of civil UAVs by anti-national elements, monitoring the movement of small civil UAVs, preventing collision, and maintaining separation from other manned/ unmanned aircraft would further complicate the air space and security scenario in the years to come.

CIVIL-MILITARY INTEGRATION

Research and development is an essential aspect of capability development. The civil aviation authorities of the leading countries have research programmes.[85] India's research programmes are generally dedicated towards developing military aviation platforms and associated systems. The Indian civil aviation sector, which includes civil aircraft and civil air traffic management systems like air traffic surveillance and approach radars, runway aids, etc., has not been viewed as a strategic sector for 'Make in India' or for indigenisation. There is no known programme to design and develop enabling systems like ground-based collision avoidance and traffic separation systems/ ground-based radars to facilitate integration of UAVs in the non-segregated air space in India. Also, key stakeholders in civil aviation, i.e. Ministry of Civil Aviation (MoCA) and Director General of Civil Aviation (DGCA) have traditionally not been undertaking research and development of traffic separation and air traffic management systems required for the integration of UAVs in the Indian air space as research and development is not included in the functions of the Civil Aviation Ministry.[86] Also, the Research and Development Directorate of the Civil Aviation Department was renamed as Aircraft Engineering Directorate on November 3, 2009.[87]

There is a need to initiate measures, which would encourage research to support indigenous design, development and testing of UAVs and associated systems for both military and civil users in the final DGCA circular.[88] The Technology Development Board of the Ministry of Science and Technology

85. https://www.faa.gov/nextgen/equipadsb/research/. Accessed on July 14, 2016
86. "Functions Alloted to the Civil Aviation Ministry," June 23, 2014, http://civilaviation.gov.in/sites/default/files/6_0.pdf. Accessed on September 7, 2016.
87. http://dgca.nic.in/dgca/publicnotice%20R&D0-AED.pdf. Accessed on September 7, 2016.
88. "Guidelines for Obtaining Unique Identification Number (UIN) and Operation of Civil Unmanned Aircraft System (UAS)," April 21, 2016, http://www.dgca.nic.in/misc/draft%20circular/AT_Circular%20-%20Civil_UAS(Draft%20April%202016).pdf. Accessed on June 22, 2016.

(S&T) supports technology initiatives, including the ones for the defence and civil aviation and air transportation sectors. Bharat Electronics Limited (BEL) has developed Coastal Surveillance Radars, C-Band and S-Band Polarimetric doppler weather radars for civil uses and a wide variety of radars for the Indian armed forces. There is need to utilise the expertise of BEL in developing radars for use in civil airports.[89] The laboratories of the Ministry of S&T and BEL, in collaboration with MoCA, could consider developing air traffic surveillance and approach radars for providing traffic separation and collision avoidance to UAV traffic. The armed forces are the largest users of UAVs and have vast experience of operating UAVs in varied terrains. They could contribute significantly in the design and development of UAVs, associated airborne and ground control technologies and in the formulation of regulations. The potential of academia and industry could be exploited to undertake studies/ research and development of technologies necessary for the integration of UAVs. India's DRDO carries out research to develop military UAVs/UCAVs and associated technologies such as automation, airborne EO/IR sensors and for improving the security of data links. It could consider developing technologies like LIDAR, equipment similar to ADS-B/ MIDCAS, airborne radar for collision avoidance, airborne internet protocol/ peer-to-peer communication systems to facilitate integration of UAVs. The integration of UAVs in the Indian air space also needs to be included in the Civil Aviation Ministry's strategic plan.[90] The MoCA, Ministry of S&T, MoD, DGCA, HAL, DRDO, industry and academia could play important roles in the development of technologies associated with the integration of UAVs in the non-segregated air space.[91]

CONCLUSION

Unmanned Aerial Vehicles (UAVs) have enormous potential for military and civil industrial applications; however, their integration in the non-

89. "Civilian Radars," http://www.bel-india.com/Products.aspx?MId=14&LId=1&link=83. Accessed on September 7, 2016.
90. "Strategic Plan, Ministry of Civil Aviation 2010-2015," http://www.civilaviation.gov.in/sites/default/files/mocaplan_0.pdf. Accessed on July 9, 2016.
91. "Technology Development Board," http://tdb.gov.in/our-objective/#. Accessed on July 9, 2016.

segregated air space is a challenge. The push for formulating a regulatory framework for integration of UAVs in the non-segregated air space has been driven by two major factors: one, the increasing economic potential of UAVs in the civil industry as is evident from the Riga Declaration by the EU; two, enhanced capability and disproportionate advantage of UAVs/ UCAVs in certain combat/non-combat roles. However, the integration of UAVs is dependent on the development of certain enabling technologies. The safety of manned aircraft, people on the ground, and the possibility of take-over of UAVs by terrorists/ adversaries by hacking into the UAVs' data links are concerns for air space regulators and security agencies. There is a need to improve the reliability of unmanned platforms, develop airborne 'sense and avoid'/collision avoidance systems, traffic separation systems and enhance the security of data link systems.

ICAO, USA and EU have led the development of UAVs and associated technologies. The USA has published rules for operations of small civil UAVs in June 2016. It had issued over 5,300 licences to civil UAV operators during the period July 2013 to May 2016. ICAO came up with its first edition of the Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019-AN/507) in 2015, and the EU too is moving in the same direction. Similarly, many other countries – including China – have allowed operations of small civil UAVs in their national air space with certain safety restrictions. The operation of bigger UAVs in the non-segregated air space is essential to achieve full integration, which would depend on improving the reliability of UAVs and developing enabling technologies.

The US and EU have addressed the issue of full integration of UAVs at two levels: firstly, by undertaking research to develop critical enabling technologies like airborne and ground-based sense and avoid systems, security of data links, increasing automation, etc. to overcome technological challenges; and, secondly, by formulation of a regulatory framework for the integration of UAVs. The significant aspect of their technology development and regulation formulation has been collaboration among the government, Department/ Ministry of Defence, industry, academia and civil aviation regulatory authority. In the case of the EU, many countries have come together

The issue of a draft circular by the DGCA is a welcome initiative; however, development of certain technologies – and regulatory support thereof for developing UAV capability indigenously – and integration of UAVs in the non-segregated air space would need urgent attention for optimum exploitation of the potential of these unique flying machines.

to develop critical technologies and propose regulatory frameworks which are considered essential for the integration of the UAVs in the non-segregated air space.

The issue of a draft circular by the DGCA is a welcome initiative; however, development of certain technologies – and regulatory support thereof for developing UAV capability indigenously – and integration of UAVs in the non-segregated air space would need urgent attention for optimum exploitation of the potential of these unique flying machines. The Ministry of Civil Aviation needs to consider revival of the Directorate of Research and Development and pursue development of enabling technologies to facilitate integration of UAVs in the non-segregated air space. The collaboration among various stakeholders, i.e. MoCA, MoD, Ministry of S&T, Ministry of Home Affairs (MHA), DGCA, DRDO, armed forces, HAL, industry and academia is essential to address the technological and regulatory challenges being faced in the integration of UAVs in the non-segregated air space.

Some breakthroughs have been achieved in developing critical technologies; however, they are at a nascent stage and would have to mature before they can be employed for operational use. These technologies need to undergo rigorous testing, and trials and data related to their operational use would have to be generated over a period of time for verification and further improvements. The success of some of these technologies is essential for the integration of UAVs in the non-segregated air space.

The progress in the formulation of a regulatory framework has been gradual and only small civil UAVs have been granted clearance to operate on a case-by-case basis by some countries. UAVs are currently operating in the segregated air space. Some of the SARPs – including the ones for certification and operations of UAVs – have not been finalised. Therefore, full integration of UAVs in the non-segregated air space is not likely to take place in the near future till the essential enabling technologies mature. However, partial integration of UAVs in the non-segregated air space should be feasible as soon as there is reasonable confidence in at least some of the enabling technologies supported by improvements in the reliability of the UAV platform and security of command and control links. During this phase UAV flights could be allowed to operate with manned aircraft by providing greater separation between UAVs and other manned traffic and by keeping UAV traffic under positive radar surveillance and ATC control.

Full integration of UAVs in the non-segregated air space is not likely to take place in the near future till the essential enabling technologies mature.