Engineering Technology
Open Access Journal

Juniper Publishers
key to the Researchers

Review Article
Volume 4 Issue 4 - February 2023
DOI: 10.19080/ETOAJ.2023.04.555647

Eng Technol Open Acc

Unmanned Aerial Systems as a Driving Force in the Digital Information Age

Joseph Hupy*, Ryan Case, Haoruo Fu and Dylan Kloas

School of Aviation and Transportation Technology, Purdue Polytechnic Institute, Purdue University, West Lafayette, IN 47907, USA

Submission: January 17, 2023; **Published:** February 20, 2023

***Corresponding author:** Joseph Hupy, School of Aviation and Transportation Technology, Purdue Polytechnic Institute, Purdue University, West Lafayette, IN 47907, USA

Abstract

Unmanned Aerial Systems (UAS), while no longer viewed as a disruptive technology, are still in their infancy regarding how this form of technology fits within the digital information age. This commentary review examines the history of UAS technology and how the rapid growth of UAS driven primarily by hardware in the form of centralized controllers, IMUs, and GPS, getting smaller, lighter, and cheaper. While the growth of UAS demonstrates itself as an outcome of the modern digital age, we argue that it now has the potential to drive the information age forward in four primary areas: cloud-based technology, Internet of Things, Artificial Intelligence, and Big Data.

Keywords: UAS; Digital Transformation; Information Age; IoT, Edge-Based Computing; Big Data; Artificial Intelligence; Cloud Computing

Introduction

Unmanned Aerial Systems, more commonly known as drones, hereafter referred to UAS, are now at the point where the technology is longer considered disruptive. This trend can be seen in the literature to where 10 years ago, articles on UAS were few and far between, and the majority of literature was based upon the novelty of using a UAS to accomplish a goal normally performed in a traditional ground based or manual manner [1,2]. A current cursory search of literature in a vast array of STEM affiliated journals in non-exhaustive list including engineering, chemistry, remote sensing, agriculture, forestry, archaeology, geology, soils, geomorphology, and ecology attests to how much UAS has become recognized as a vital data collection tool in the research community. Such widespread implementation of UAS technologies has created an unprecedented number of drones operating in an airspace shared with manned aircraft. As UAS continues to be integrated into the Space Air Ground Integrated Networks (SAGINs), there will exist a need to tie into existing internet technologies, with abilities to communicate, detect, avoid, and deconflict with others in that airspace [3].

UAS technology is an example, among many, of how the modern world is still adjusting to the digital transformation from the industrial era to where UAS technology is both being driven and driving this digital transformation. The term "digital transformation" was popularized in a 2019 book, Digital Transformation, Survive and Thrive in an era of mass extinction [4] . In that book Siebel argues we are still very much at the beginnings of what he sees as a shift from an economy formally based on resources, manufacturing, and industrial production processes, to one that is focused on digital information age technologies. The rapid and disruptive appearance of UAS technology can be viewed as a case study in this transformation in that the technology, while no longer disruptive, still has myriad applications yet to be discovered. We argue here that UAS technology is both driving and being driven by the ongoing digital transformation. The objective of this article is not to provide a comprehensive review of literature in each component of the digital transformation. Rather, this article makes an argument on how UAS technology, while still very much in its infancy, can be directed in ways that can power the digital transformation ahead further that would make UAS both safer and a stronger economic development force. The article begins with a description of the four core disruptive components behind the digital transformation: Big Data, Internet of Things, Artificial Intelligence, and cloud-based computing [5]. This is followed by a brief history on how the explosive growth of the UAS industry was a direct outcome of the digital transformation. Finally, each component of the digital transformation is related to key UAS applications and technologies.

Components of the Digital Transformation

For us to understand how UAS technology fits within the digital transformation, we must first understand how this transformation did not just happen overnight, and that we very much do not know where it will take us. On its own, the digital transformation has gone through transitional waves just like how the industrial age went through its own transitions from wood to coal, to oil, to natural gas, with no transition being completely seamless and smooth. The digital transformation also has its phases starting with its origin in the conversion of analog to digital, followed by the onset of the internet, and now the age of big data and information [4]. In the most current phase of the digital transformation, we are faced with how to handle and process copious amounts of data and turn that into usable information [5]. These data are gathered, processed, and disseminated under the four core components of the digital transformation: Cloud Computing, Artificial Intelligence, Big Data, and Internet of Things (IoT). Each of these components has, on their own accord, gone through generations of development, and each can be defined in multiple tiers of complexity.

Cloud Computing is perhaps the best known and recognized of the four components, yet what constitutes cloud computing goes well beyond mere web-based data storage. Cloud computing can be as simple as data storage, but also complex enough to not only host data, but provide software as a service in a way that hosts both development and operations, commonly referred to as DevOps [6]. The concept of the cloud has not been fully embraced, nor utilized at this point in the digital transformation. Even now after many years, the concept of the cloud is foreign to some. Many individuals remain wary of storing valuable information in the cloud, and the concept of hosting and running software, let alone developing and operating an entire operation in the cloud; this is still not a ubiquitous concept. Such hesitation to implement cloud-based technology can be further hampered by cyber security concerns regarding online hackers and data breaches. Use of cloud-based technology continues to grow, however, and its use is spreading from large organizations equipped with the IT staff to implement the use of the cloud, to now small and medium sized organizations who realize the need for cloud-based technologies to provide efficiency and lower overhead costs [7].

Artificial Intelligence (AI) is another very familiar component of the digital transformation but is perhaps one of the most loosely defined. Associated with AI are many other terms such as algorithm, deep machine learning, and deep learning. At its most simple level, AI is developing a defined list of instructions, or algorithms for a computer to mimic human intelligence [8]. Artificial Intelligence technology is not novel, nor new, and extends back decades. In its most simple form, objects or pixels are identified in an image, and an algorithm is used to identify those pixels and objects [9]. Machine learning is a bit more advanced to where those algorithms learn from examples to refine the method. Deep learning is the most advanced form of AI, and it is a form of self-learning where the algorithms are designed to 'learn' from being fed massive amounts of data. More recent advancements in AI can be related to Digital Twin technology, where AI is utilized to virtually model a physical entity, which has many applications in the aviation and UAS realm [1].

Big Data is the currency of the digital transformation. It is arguably the fuel that drives the shift towards the information age [10]. When we think of the digital transformation in its entirety, it is big data that is being gathered, hosted, processed, and analyzed by all the other components. Big data is hosted and harvested in the cloud, and it is big data that drives the development of advanced AI [11]. For example, the aviation industry faces two major challenges of safety and performance improvement where Big Data stands to play a role. The collection and analysis of data can assist the aviation industry in conducting countermeasures to safety concerns in a "proactive" way, rather than traditional "reactive" solutions [12]. Big data can take many forms, increasingly it comes in the form of data that is gathered from an ever-expanding vast network from the Internet of Things (IoT), which is another way to refer to Edge-based computing technology [13].

The IoT network, which is in place to gather vast amounts of big data in the digital transformation, is possible through the development of Edge-based computing technologies, the internet, and cellular networks [14]. Edge-based computing technologies have adequate onboard processing capabilities that allow it to process the data and then communicate it to the internet network. With the implementation of 5G cellular technologies, an exponentially increasing number of IoT devices are feeding Big Data into the Digital age of information technology [15]. While one of the most common IoT devices out there are smart phones that gather information that the user often unwittingly sends out, other devices such as ground sensor networks, along with UAS, have the potential to feed information as fuel into the digital transformation. Each of the four components of the digital transformation as discussed above are an integral part of the UAS industry and have driven, yet have so much potential to be driven by this still arguably disruptive technology.

UAS Industry Growth as Driven and Driving Digital Transformation Technology

There exists a common consensus that the explosive growth of UAS over the past 10 years resulted as an offshoot of military UAS technology [16]. While the term "drone", and public knowledge of drone technology is very much a product of media coverage surrounding UAS over the past 20 years, the technology related to both commercial and recreational UAS platforms can arguably be linked as direct product of the digital transformation [17,18].

Prior to technological advancements in edge-based computing hardware, drones were flown for military purposes, and those who flew remotely piloted aircraft (RPA) otherwise were known as Radio Control, or RC hobbyists/enthusiasts. Learning how to fly an RPA had a steep learning curve and could be prohibitively

How to cite this article: Joseph Hupy, Ryan Case, Haoruo Fu and Dylan Kloas. Unmanned Aerial Systems as a Driving Force in the Digital Information Age. Eng Technol Open Acc. 2023; 4(4): 555647. DOI: 10.19080/ETOAJ.2023.04.555647

expensive. Most aircraft were of the fixed wing variety, and there was no 'return to home' ability if one lost track of the aircraft as it slipped out of frequency range or wandered beyond line of sight. Becoming a proficient RC pilot meant lots of crashes and repairing an aircraft with packing tape and hot glue for it to be flight worthy for more practice. Most aircraft were gasoline powered, and there was no means to engage in 'stable flight mode' through the flip of a switch – stable flight meant proficiency at the controls. An argument can also be made that hardware advancements in video card and Central Processing Units (CPUs) processing abilities also allowed for the development of highly sophisticated flight simulator technology to be developed If an aspiring UAS pilot can realistically learn how to fly a UAS platform in a simulated environment, whether it be fixed-wing, single rotor, or multi-rotor, the learning curve and repair costs become even more significantly reduced. Onboard UAS, hardware-based advancements are also allowing UAS to become cheaper, lighter, and smaller [19].

Most individuals in the UAS community would agree that what distinguishes a UAS from an RC aircraft is that a UAS is truly a system of interacting hardware components and respective collaborative software that allow it to function with a certain degree of autonomy, while RC aircraft rely on a direct interface with a remote pilot handling a radio transmitting controller. The interaction of hardware onboard a UAS is made possible with a centralized flight controller. This flight controller quite literally serves as the brain of the platform by allowing all the various forms of hardware from the Inertial Measurement Unit (IMU) to the Global Navigation Satellite System (GNSS) to the imagery sensing payload, to communicate with one another. This edge-based computing continues to advance from its analog beginnings, to where these are now predominantly digital and can perform millions of operations a second [20]. These flight controllers stabilize flight and allow the pilot to know where the aircraft is always located by communicating with the onboard IMU and GNSS.

Advancements in IMU technology are what very much flattened the learning curve for individuals interested in flying remotely piloted aircraft. These units are continuously monitoring the pitch, yaw, roll, and overall movement of the aircraft, which is then processed by the flight controller to stabilize flight and keep the aircraft level despite pilot error or winds. They allow someone to fly an aircraft and not overcompensate at the controls that leads to flipping a multirotor upside down or causing a fixed-wing aircraft to depart controlled flight. Not only does this edge-based computing lower the likelihood of pilot error induced crashes, but it also allows for autonomous flight abilities when coupled with GNSS technology. For example, miniaturization of components within the Surface Mounting Device (SMD) has eliminated the need for additional dedicated electro-mechanical interfaces and has created low-power Micro Controller Units (MCUs). With lower power consumption and weight, these devices are ideal for integration into UAS and "fields like smart farming, unmanned control, Internet of (Moving) Things, and robotics." [21].

The GNSS technology is what allows the platform to maintain geolocational abilities. The term GNSS is the same concept of Global Positioning System (GPS), but GNSS just means that the receiver is picking up more satellites than the U.S. satellite network [22]. By tapping into multiple satellite networks, a GNSS receiver can commonly detect 18-20 available satellites at any one time. Such a high number of satellites means that UAS platforms can geolocate themselves to within sub-meter precision. Advancements in edge-based computing have allowed users to equip UAS platforms in the realm of several hundred U.S. dollars with dual frequency GNSS that, when corrected by a base station, can achieve sub-centimeter precision [23]. The precise geolocational abilities onboard communicating with both the IMU and flight controller also means that platforms can engage in automated flight operations [24-26]. They can be programmed to fly to preprogrammed waypoints, engage in automated grid-based mapping missions, and return to the launch site when finished or problems arise. Such precision and automated flight abilities associated with this type of hardware has opened the door for UAS to be utilized as yet another tool for those engaging in survey quality results-oriented activities in civil engineering, mining, forestry, agriculture, etc. [27]. Hardware advancements in the realm of GNSS, IMUs, and Central Processing Technologies are important, but having an ample communication in framework of IoT to transmit that data is also important.

UAS has a massive amount of potential for being used to provide reliable and cost-effective wireless communication in the sky. While UAS have been utilized in the past to communicate gathered data, highly utilized microwave spectrum bands below 6 GHz are insufficient to transmit data and make transmission of complex spectrum data packets a crunch crisis [28]. For example, airport areas lie within areas a complex array of signal transmissions of various spectrum frequencies and bandwidth; one alternative way to efficiently operate and monitor UAS operations in these complex signal environments is the implementation of 5G mm Wave. Such a communication network is also required for transmitting large amounts of data processed with edge-based computing and IoT technologies. In the realm of UAS, current and ongoing research is using AI to assist in the identification of spot fires in wildfire events [29,30]. While such research is promising, it only carries full potential for when such identification can be done in real-time using edge-based computing, and transmitted back to ground-based users, effectively making UAS as part of an IoT network. Ongoing research using big data and AI to predict and reduce highway vehicle crashes also has great potential to be applied to UAS and will be crucial for integrating UAS into the airspace [31].

The IoT enhances connectivity from "any time, any place" for "any-one" into "any-thing". Current communication technologies are not enough to hand the incremental expansion of airports and solving the growth of passengers in air travel Using IoT's biometric analyzation can significantly decrease the time of passenger going through the checkpoint, and the implementation of IoT's space optimization significantly reduce the cost of operation and provides passengers of smooth progress transit through the airport.

How to cite this article: Joseph Hupy, Ryan Case, Haoruo Fu and Dylan Kloas. Unmanned Aerial Systems as a Driving Force in the Digital Information Age. Eng Technol Open Acc. 2023; 4(4): 555647. DOI: 10.19080/ETOAJ.2023.04.555647

Advancements in all four components of the digital transformation, particular within the realm of edge-based computing and IoT, have transformed what was a cottage RC aircraft industry that catered to a small number of hobbyists and enthusiasts into what is now a multi-billion-dollar industry that has not come close to seeing its full potential. UAS is now at the point where it not only is shaped by the digital transformation, it has the potential to feed and shape the digital transformation by contributing the information-based data that powers it [32].

Conclusion

As we move from the latter stages of the industrial age, and into what is now being coined as the information age, four components of technology are changing the current economic landscape at an unprecedented rate. Those four components, Cloud-computing, Internet of Things (IoT), Artificial Intelligence (AI), and Big Data continue to influence, and be influenced by, multiple forms of technology associated with the digital age. Each of these technologies has changed the way information is gathered, stored, and exchanged – proving disruptive in multiple economic sectors. Unmanned Aerial Systems (UAS), another disruptive technology, continues to be shaped by the digital transformation, but also is showing how the technology itself is driving growth of the current information-based digital economy. As the 5G communication network continues to expand, the information gathered and processed onboard UAS devices will continue to show the potential of how these platforms are yet another IOT device feeding Big Data into the cloud where that information can be utilized to further enhance AI in myriad applications. Future research should embrace the four components of the digital transformation and look to how all of these can be utilized to integrate UAS safely and effectively into both the airspace and the economy.

References

1. Mendi AF, Erol T, Dogan D (2022) Digital Twin in the Military Field. IEEE Internet Computing 26(5): 33-40.
2. Singh KK, Frazier AE (2018) A meta-analysis and review of unmanned aircraft system (UAS) imagery for terrestrial applications. International Journal of Remote Sensing 39(15-16): 5078-5098.
3. Zou YL, Zhu J, Wu TH, Guo HY, Wei H(2021) Cooperative Drone Communications for Space-Air-Ground Integrated Networks. IEEE Network 35(5): 100-106.
4. Siebel TM (2019) Digital Transformation: Survive and Thrive in a Time of Mass Extinction: Rosetta Books, Australia.
5. Martinelli EM, Farioli MC, Tunisini A (2021) New companies' DNA: the heritage of the past industrial revolutions in digital transformation. Journal of Management and Governance 25(4): 1079-1106.
6. (2022) What is DevOps? Gitlab. https://about.gitlab.com/topics/devops/
7. Enz C (2019) Assessment of the Economic Need for Efficient Customer Communication for Small and Medium-Sized Enterprises. Vision 2025: Education Excellence and Management of Innovations through Sustainable Economic Competitive Advantage pp. 2682-2700.
8. Arul kumaran K, Deisenroth MP, Brundage M, Bharath AA (2017) Deep Reinforcement Learning A brief survey. IEEE Signal Processing Magazine 34(6): 26-38.
9. Tong HJ, Zhao M, Li X (2009) Applications of Computational Intelligence in Remote Sensing Image Analysis. Computational Intelligence and Intelligent Systems 51: 171-179.
10. Pappas IO, Mikalef P, Giannakos MN, Krogstie J, Lekakos G (2018) Big data and business analytics ecosystems: paving the way towards digital transformation and sustainable societies. Information Systems and E-Business Management 16(3): 479-491.
11. Lim J, Gil JM, Yu H (2018) A Distributed Snapshot Protocol for Efficient Artificial Intelligence Computation in Cloud Computing Environments. Symmetry-Basel 10(1): 16.
12. Dou XS, Albert Tanb WK (2020) Big data and smart aviation information management system. Cogent Business and Management 7(1).
13. Liang F, Yu W, Liu X, Griffith D, Golmie N (2020) Toward Edge-Based Deep Learning in Industrial Internet of Things. IEEE Internet of Things Journal 7(5): 4329-4341.
14. Wu YH, Li CY, Lin YB, Wang KC, Wu MS (2022) Modeling Control Delays for Edge-Enabled UAVs in Cellular Networks. IEEE Internet of Things Journal 9(17): 16222-16233.
15. Kapassa E, Touloupou M, Stavrianos P, Kyriazis D (2018) Dynamic 5G Slices for IoT Applications with Diverse Requirements. 2018 Fifth International Conference on Internet of Things: Systems, Management and Security pp. 195-199.
16. Braun S, Friedewald M, Valkenburg G (2015) Civilizing Drones: Military Discourses Going Civil? Science and Technology Studies 28(2): 73-87.
17. Giones F, Brem A (2017) From toys to tools: The co-evolution of technological and entrepreneurial developments in the drone industry. Business Horizons 60(6): 875-884.
18. Merkert R, Bushell J (2020) Managing the drone revolution: A systematic literature review into the current use of airborne drones and future strategic directions for their effective control. Journal of Air Transport Management 89(10).
19. Camargo A, Schultz RR, Yi W, Fevig RA, Qiang H (2010) GPU-CPU implementation for super-resolution mosaicking of Unmanned Aircraft System (UAS) surveillance video, IEEE Southwest Symposium on Image Analysis & Interpretation (SSIAI), USA.
20. Wang JJ, Feng ZQ, Chen Z, George S, Bala M, Pillai P et al. (2018) Bandwidth-efficient Live Video Analytics for Drones via Edge Computing. 2018 Third IEEE/ACM Symposium on Edge Computing (Sec) pp. 159-173.
21. Crabolu M, Giuberti M, Bellusci G (2018) Electrically integrated miniature motion tracking module with multiple external GNSS receiver support. Paper presented at the DGON Inertial Sensors and Systems Conference (ISS), Braunschweig, Germany.
22. Shetty A, Gao GX (2021) Predicting State Uncertainty Bounds Using Non-Linear Stochastic Reachability Analysis for Urban GNSS-Based UAS Navigation. IEEE transactions on intelligent transportation systems 22(9): 5952-5961.
23. Li BF, Shen YZ, Zhang XF (2013) Three frequency GNSS navigation prospect demonstrated with semi-simulated data. Advances in Space Research 51(7): 1175-1185.
24. Miller ZM, Hupy J, Chandrasekaran A, Shao GF, Fei SL (2021) Application of Postprocessing Kinematic Methods with UAS Remote Sensing in Forest Ecosystems. Journal of Forestry 119(5): 454-466.

How to cite this article: Joseph Hupy, Ryan Case, Haoruo Fu and Dylan Kloas. Unmanned Aerial Systems as a Driving Force in the Digital Information Age. Eng Technol Open Acc. 2023; 4(4): 555647. DOI: 10.19080/ETOAJ.2023.04.555647

25. Tomaštík J, Mokroš M, Surový P, Grznárová A, Merganič J (2019) UAV RTK/PPK Method—An Optimal Solution for Mapping Inaccessible Forested Areas? Remote Sensing 11(6): 721.

26. Zhang H, Aldana-Jague E, Clapuyt F, Wilken F, Vanacker V, Van Oost K (2019) Evaluating the potential of post-processing kinematic (PPK) georeferencing for UAV-based structure-from-motion (SfM) photogrammetry and surface change detection. Earth Surface Dynamics 7(3): 807-827.

27. Miller Z, Hupy J, Hubbard S, Shao GF (2022) Precise Quantification of Land Cover before and after Planned Disturbance Events with UAS-Derived Imagery. Drones 6(2).

28. Zhang L, Zhao H, Hou S, Zhao Z, Xu H, et al. (2019) A Survey on 5G Millimeter Wave Communications for UAV-Assisted Wireless Networks. IEEE access 7: 117460-117504.

29. Julian KD, Kochenderfer MJ (2019) Distributed Wildfire Surveillance with Autonomous Aircraft Using Deep Reinforcement Learning. Journal of Guidance Control and Dynamics 42(8): 1768-1778.

30. Tang Z, Liu X, Chen H, Hupy J, Yang B (2020) Deep Learning Based Wildfire Event Object Detection from 4K Aerial Images Acquired by UAS. AI in Autonomous Systems 1(2): 166-179.

31. Zhang ZR, Akinci B, Qian SA (2022) Inferring the causal effect of work zones on crashes: Methodology and a case study. Analytic Methods in Accident Research 33.

32. Nayyar A, Nguyen BL, Nguyen NG (2020) The Internet of Drone Things (IoDT): Future Envision of Smart Drones. First International Conference on Sustainable Technologies for Computational Intelligence 1045: 563-580.

DOI: 10.19080/ETOAJ.2023.04.555647

How to cite this article: Joseph Hupy, Ryan Case, Haoruo Fu and Dylan Kloas. Unmanned Aerial Systems as a Driving Force in the Digital Information Age. Eng Technol Open Acc. 2023; 4(4): 555647. DOI: 10.19080/ETOAJ.2023.04.555647