

Autonomous Cargo Aviation

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Abstract

Advances in autopilot, auto-landing, and autonomous military drone technology have created a time in which it is time to start investing in unmanned cargo aircraft. With autonomous systems such as the RQ-4B Global Hawk, the capability for an unmanned cargo aircraft to fly the skies like freight trucks on the highway now exists. With the available systems to command, control, and communicate via a satellite connection from around the world, the cargo industry is now capable of flying multiple aircraft from one pilot. This type of operation would allow more aircraft to operate in a period of time by bypassing the human factors associated with human pilots on board, such as crew rest or environmental control systems. Utilizing this type of system would reduce the requirement to fly two pilots, plus any augmented crew from each aircraft to one operator on the ground would allow more aircraft to fly at once, reducing costs of aircrew requirements and allowing more aircraft to fly at one time. This one pilot can swap with other pilots and allow each pilot to maintain a steady work schedule and allow the pilot to monitor up to three aircraft at once. These automated onboard systems would maintain aircraft control and follow the flight plan route while also maintaining altitude. This predictability would allow Air Traffic Control (ATC) to know ahead of time what to expect from these aircraft while allowing the pilot to change headings and altitudes as if they were physically in the aircraft. Satellite communications such as Ku SATCOM and UHF SATCOM are already present on most airline aircraft that provide Wi-Fi to the passengers onboard. These types of command and control methods are easily accessible and would allow operators to fly the aircraft and communication through the radios while the aircraft is in flight.

Keywords: autonomous, cargo, unmanned, SATCOM, command and control, communication

Problem Statement

FedEx and UPS employ over 7,000 pilots to fly their fleets of cargo aircraft. (IPA, n.d.) These aircraft require a pilot and a co-pilot to fly every flight. Some of these flights require augmented crew for long duration international flights. These pilots are required to show up and fly the

entire flight from take-off to landing and either go into crew rest or prepare to fly another aircraft back to their origin airfield. This process requires crews to have at least 10 hours of interrupted rest prior to showing up for flight operations. (FAA, n.d.) After the pilots start to fly, their duty day is limited to 9-14 hours of crew duty day. (FAA, n.d.) This restricts the crew's ability to fly a long distant flight and try to return to their origin field prior to reaching their maximum crew duty day. The rules require companies that fly cargo aircraft to employ multiple aircrew to ensure they have enough people to complete their task of transporting cargo from one location to another.

Significance of the Issue

A company whose business is moving cargo can potentially lead to an organizational effect on the crews that fly the aircraft. According to Maurino et al, a link is being researched into the effects of a company's organizational mentality on the human factors of aircrews. The concern is that if the organization is more focused on the mission and not on the people that are flying the mission, it can start a slow insidious process that can lead to a major accident. A way to help ensure the safety of the crews and improve efficiency of cargo operations is to move the pilots from the aircraft to a ground stations so they fly the aircraft remotely via unmanned systems.

If the pilots were moved from the aircraft, it is possible to ensure a more predictable and stable schedule for the crews as they would simply rotate in and out of Ground Control Stations (GCS) throughout a flight. This type of shift work would ensure that the crews are maintaining a healthy schedule and lifestyle while also giving more stability for their off time and home life.

Alternative Actions

Unmanned Systems

The United States Air Force flies a large fleet of RQ-4B Global Hawk Unmanned High Altitude Long Endurance (HALE) drones. These unmanned systems can fly for up to 34 hours at one time without the need for aerial refueling. These aircraft are flown over the course of their mission by

multiple pilots. These pilots are still required to maintain the crew rest requirements that is seen by the cargo companies. The difference between the manned and unmanned systems in the unmanned system is flown by operators on the ground as seen in the figure below.



AIRBOYD 2014. RQ-4B Pilots fly from a Mission Control Element

The ground station is accessible by multiple crews throughout the duration of one flight. This capability allows the U.S. Air Force to use multiple aircrew to fly an aircraft during a single mission. Depending on the schedule, it is possible for a pilot to take an RQ-4B off from an airfield, go home and enter crew rest for 12 hours. That same pilot can return to work and fly the same aircraft that they flew 12 hours prior for their entire flight shift. During that 12 hours of crew rest, there could have been between 2-4 different pilots that flew the aircraft.

How Unmanned Systems Help with Human Factors

The ability to use multiple aircrew allows the cargo companies to focus on the human factors limitation that exist with manned aircraft by allowing more aircrew to perform the duties that would normally be limited to 2-3. With an Autonomous Unmanned Cargo System (AUCS), the concern for the well-being of passengers onboard the aircraft would be removed and the focus of the mission would be to transfer packages from one location to another without any concerns for environmental and human factor constraints such as air pressure, temperature, oxygen, crew rest, crew duty day limitations, and pilot fatigue.

The training requirements for new pilots may be lower due to the lack of requirement to manually fly the aircraft for the flight. With an autonomous system, the aircraft can fly itself while the operator watches to ensure if there are any problems or directions from ATC, they are capable of acting on anything that may occur.

Literature Review

Human Factors

According to Maurino et al, in the book titled “Beyond aviation human factors: Safety in high technology systems”, the authors look into the link between organizational effects on human factors related to aviation. The authors looked into multiple accidents and found that investigation boards were quick to blame the operators for accidents as technology grew between the 1960s and the 1990s. This boom in technology gave rise to safer aviation overall. The rise in safety led to accidents that were not caused by large blunders but small steps along the way that led to an incident.

The authors research and find that organizations that own aviation operations can have an adverse effect on the safety of an operation. If the managers of an operation were found to create a culture in which the business was more important than the people, it started a slow and insidious chain reaction that ultimately led to an incident in aviation.

This relates to unmanned cargo aviation in that an organization like UPS or FedEx are subjectively held to a different standard than commercial carriers that carry human passengers on their aircraft. It is easy for someone to accept an aircraft delay or cancel if their life was in danger due to bad weather, however it is much more difficult for someone to accept that their package is delayed in delivery due to weather that is nowhere near them and has no affect on their daily life. By creating a culture that focuses on the business and carrying cargo without delays, this can force aircrew to have ‘get there it is’, which is a common aviation term that describes the mentality of a pilot who is under pressure to fly an aircrew no matter the concerns of weather or maintenance.

By allowing the aircraft to operate remotely, the aircrew safety concern can be removed and allow the operators to focus on safety from an aircraft standpoint only. This allows for companies to allow multiple pilots fly the same aircraft from the ground and ensure its success without worrying about crew rest as they can have many pilots on staff that are always ready to fly, no matter the schedule.

RQ-4B

In the Operational Test and Evaluation Report signed by J. Michael Gilmore, the author discusses the capabilities and shortfalls of the Global Hawk system. The system was designed to allow for pre mission planning to upload what the aircrew want the aircraft to do during flight. The autonomous system onboard would fly the planned route and altitudes to include taxiing out and taking off. The author explains that the system is capable of fully autonomous flight of flight routes and mission operations.

The report indicates that the aircraft can be flown using narrowband connections or low bandwidth connection via satellite to the aircraft as well as high band or high bandwidth connections via satellite. The connection allows the operator to monitor and send commands to the aircraft in mid-flight using a satellite connection from a ground station anywhere on earth. This connection has multiple alternate and contingency connection that allow the operator to maintain a constant connection to the aircraft to monitor aircraft health and status throughout its flight.

This is one of the biggest pieces of evidence to show that an AUCS is possible. The RQ-4B is an aircraft that has a wingspan of over 133 feet, which is the size of a Boeing 737. With technology to fly large unmanned aircraft demonstrated through the RQ-4B, the possibility of an unmanned cargo system has been tested and proven. The satellite connection used by the aircraft and operator to fly the aircraft shows that it is possible to maintain a safe connection to the aircraft to ensure it is flying the route required for the cargo operation. The autonomous system also allows the pilot to modify the aircrafts heading and altitude to abide by any Air Traffic Control (ATC) requirements if needed.

The RQ-4B as a demonstrator also shows that it is possible for a pilot to monitor and fly multiple aircraft at once. With a mission planning system in place before the flight, multiple aircraft can fly from one location to another as the pilot listens to the same frequencies for all aircraft. The pilots can monitor the progress and implement changes mid-flight if needed for each aircraft as they are operating. This type of user interface would allow for the pilots to focus on human factors such as crew rest or duty day by allowing the excess copilots and augmented crews from manned pilots to swap out with the single operator at different intervals to allow for breaks as needed.

Ground Control Systems

In the paper titled “Multimodal Interface Technologies for UAV Ground Control Stations” written by Maza et al 2009, the authors discuss the requirements to create an effective ground control station with an appropriate amount of human interfaces to allow the operator to fly their

aircraft. The paper discusses the communication between the operator and the GCS and from the GCS to the operator. This connection is the normal focus of most GCS, however, the authors identify a third area of concern which is the operator's state. The operators state takes into account human factors like the operator's boredom or exhaustion depending on their rest or the activity they are working on.

The ground control station that the authors are recommending should include some components to ensure more situational awareness and should include human interface concepts that ensure the operator can more efficiently fly their aircraft. A concept that is discussed is 3D audio. By allowing the operator to heard tones or voices in a manner in which they would appear on or inside the aircraft, allows the operator to have a better mental picture of what they are hearing.

Another concept that is pushed forth by the authors is haptic feedback for the pilot. This haptic feedback would provide a response of feeling to the pilot to allow them to understand how the aircraft is responding to their commands. This would be artificial but would allow the pilot to associate a feeling to what they are doing which is very similar to how fighter pilots feel their control stick when flying. Pilots in the T-6 Texan II have a 10lb weight on their joystick. This allows the pilots to feel more weight on their joystick as the pull more G forces, which gives feedback to the pilot on how much they are pulling back on the stick.

For the operator's state, the authors discuss "The operator's state is the third information flow mentioned above. It can be defined as the set of physiological parameters that allows to estimate the state of a human operator: heartbeat, temperature, transpiration, position, orientation, etc. All this information can be used by adaptive systems to improve the operator environment or to reduce the stress/workload of the operator." (Maza et al, 2009) This type of system would allow the GCS to actually notice if the pilot is feeling fatigued or if temperatures are outside of a comfortable range. The GCS could then theoretically adjust its system settings or set up to ensure the pilot is staying active and awake to pay attention to the flight they are executing.

These types of ground control stations would allow unmanned pilots to monitor multiple aircraft as the ground control station ensures that they stay awake and active throughout the process. By using 3D audio, the pilot could monitor two aircraft at once and allow audio to come from the left side and associate that with the first aircraft while any other audio on the right side could be associated with their second aircraft. This would be ideal for Air traffic control if the pilot is listening to multiple frequencies at one time between the two aircraft.

Satellite Command and Control

In a book titled “Satellite Communications Systems Engineering: Atmospheric Effects, Satellite Link Design and System Performance” by Ippolito 2008, the author explain the advantages to using satellites for communication over long distances. The author explains that the cost to use the satellite is approximately the same regardless of the bandwidth or the distance in which communication is travelling. There is also an explanation on how there is a low error rate between the user on both ends of the satellite. The satellites are also required to have a ground station that can relay information from a ground control station to the aircraft inflight. Since satellites have a large footprint on the earth, it is safe to assume that the aircraft would fly within the footprint of the satellite, which would allow for a constant communication to the aircraft throughout its flight from its origin to its destination.

Satellites can also allow for high bandwidth and fast transfer speed between the operator and the aircraft. This is important to allow for health and status of the aircraft to continuously flow back to the operator throughout the flight to ensure safe operations. In an AUCS, the aircraft would need enough bandwidth and coverage from a satellite to ensure a constant connection to the aircraft and the operator. The system would also require a back-up connection in the event of bad weather over the ground station.

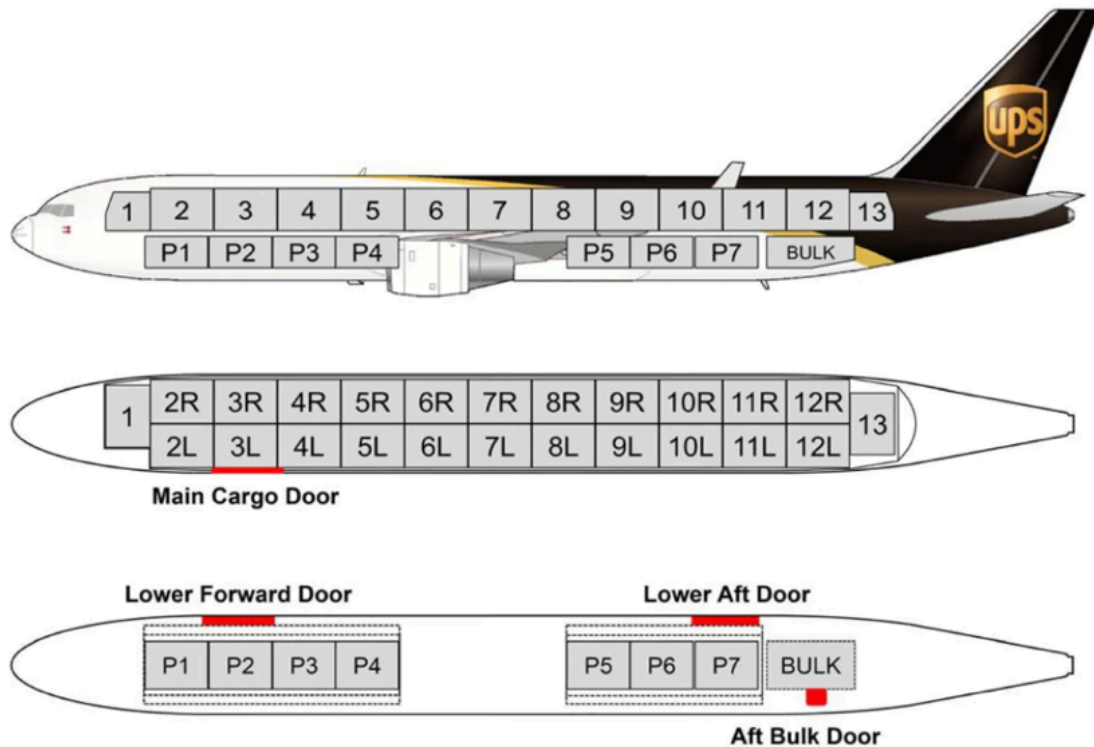
Since the satellites have a large footprint, the operator can change ground stations to a location that has better weather to ensure a better connection during the flight. Using satellites would also allow the operator to control multiple aircraft at one time. The author of the book goes on to explain multiple access techniques such as Code Division Multiple Access (CDMA) where the same signal meshes multiple codes together and transfers there as a single signal. This means that an AUCS could utilize multiple aircraft in the same footprint on the same frequency and allow the signal to use the same background architecture to send data back to the operator from the multiple aircraft.

Requirements Specifications

The requirements for an unmanned cargo aircraft will start with the platform. The platform in which the cargo will be carried must be capable of flying large quantities of cargo to ensure there is enough revenue to support the company that is utilizing the system. To ensure lower cost requirements, the answer for this would be the use of existing cargo aircraft. Currently UPS uses a Boeing 767-300 Freighter, pictured below. This aircraft can be modified to use existing

autopilot or autonomous control systems that are utilized in the RQ-4B Global Hawk. The use of an existing system would allow for easier creation of flight envelopes and computer algorithms required to ensure safe flight during each mission.

767-300 FREIGHTER



Compartment Load Capacity

Main: 24 - 88" x 125" positions
 11 - 96" x 125" positions
 Forward Belly: 4 - 88" x 125" x 64"
 96" x 125" x 64"
 Aft Belly: 3 - 88" x 125" x 64"
 96" x 125" x 64"

(224cm. X 318cm.)
 (244cm. X 318cm.)
 (224cm. X 318cm. X 163cm.)
 (244cm. X 318cm. X 163cm.)
 (224cm. X 318cm. X 163cm.)
 (244cm. X 318cm. X 163cm.)

Cargo Door Dimensions

Main Cargo Door
 Lower Forward Door
 Lower Aft Door
 Lower Bulk Door

103" x 134" (262cm. X 340cm.)
 69" x 134" (175cm. X 340cm.)
 69" x 134" (175cm. X 340cm.)
 38" x 45" (97cm. X 114cm.)

Lower Deck

7 - 88" x 125" x 64"
 or 7 - 96" x 125" x 64"
 Bulk Cargo Area

2,555 cu. ft (72.4 cu. m.)
 2998 cu. ft (84.9 cu. m.)
 766 cu. ft (21.7 cu. m.)

767-300 UPS Freighter 2020. ups.com

After the aircraft has been chosen, the next step in the requirement is a mission control system to fly the aircraft. The specifications for this would require the control system to have dual redundant back up capabilities in the event of an emergency or a failure of the system. This will allow for contingency management for the aircraft in the event of a system failure.

Command, Control, & Communication

The command, control, and communication for the aircraft would rely heavily on satellite communication from geosynchronous satellites. Geosynchronous satellites are more ideal for this system as they maintain their position relative to the Earth. This allows the aircraft to fly in a predictable footprint. In the picture below from Satbeams.com, you can see that it is possible to fly from one part of the Earth to another and maintain the same footprint.



Ku-Band SATCOM Coverage over the USA 2020. Satbeams.com

It is also possible that some of the flights will require the aircraft to change satellites throughout the flight. This can be taxing and expensive if the aircraft uses more than one antenna. In the cases for our system, we will use one antenna on the aircraft to communicate with the satellite

and we will use mission planning software to ensure the aircraft changes frequency and satellites at the appropriate time during a mission.

Ground Control Station

The Ground Control Station (GCS) for the AUCS must be capable of allowing the pilot to see exactly what is happening onboard the aircraft during the entire flight. To do this, the human interface for the system must be user friendly and must have all of the normally information available to the pilot as if they were sitting in the cockpit for the flight. In the picture below you can see a GCA designed by General Atomics. This design was created to allow the pilot to see a large field of view as if they were sitting in the cockpit on the aircraft. The controls for the systems also allow for the pilot to take control and fly the aircraft manually in the event of a failure of the onboard control system.



Ground Control Station 2020. General Atomics

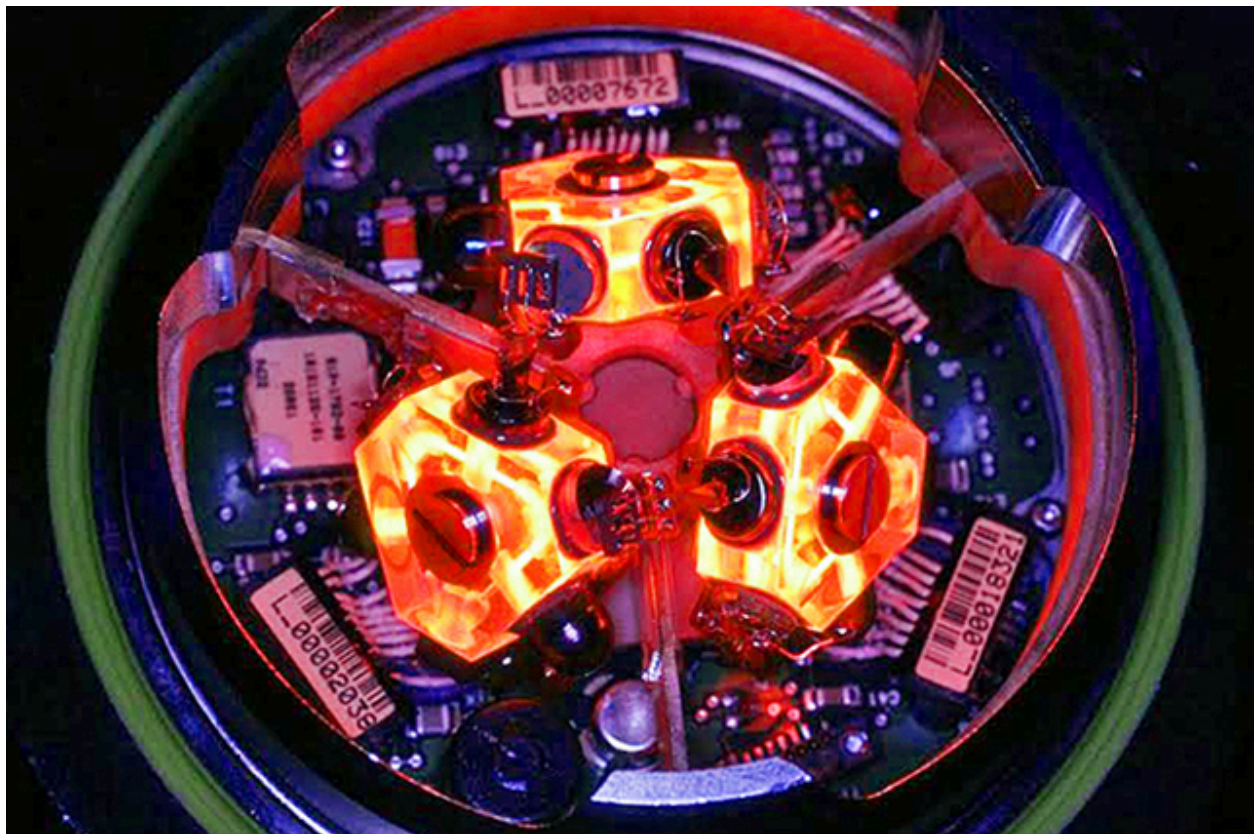
One area that would be an issue for manual flight of the AUCS is the delay of the signal from the pilot to the aircraft. With satellite communication, the pilot can expect a delay from when they input the flight controls to when the aircraft actually responds. This is important for landing and

taking off these aircraft as a pilot will be incapable of performing any terminal area procedures like taking off or landing while flying the aircraft over a satellite connection.

Taking off and landing must be done autonomously or by a pilot that is using a direct Line of Sight (LOS) link to the aircraft. A LOS link to the aircraft will have no delay and will fly as if the pilot is sitting in the cockpit of the aircraft during flight. During normal operations, the pilot that is operating the aircraft over satellite communication will require autonomous taxi, takeoff, and landing. This will ensure the aircraft does not have an incident due to the delays in the satellite signal.

Navigation System

To ensure the aircraft is capable of flying from one location to another, the AUCS must have multiple navigation system. Since we are requiring the aircraft to fly long distance with no aircrew onboard, we must ensure that the aircraft has multiple navigation systems in the event of a failure of one of the systems. This should allow it to continue its mission until it can land at its destination airport, or if there is a problem with the aircraft, land at a nearby airport before there is a catastrophic event.



Ring Laser Gyro INS 2014. Tyler Rogoway

The navigation systems should be Inertial Navigation Systems (INS) that allow for GPS corrections. This is important to ensure that if there is an interruption to GPS signals, the system will still be capable of flying its route without incident. With multiple INS navigation systems built into the aircraft, it will assist in contingency management in the event of a malfunction of one of the navigation systems onboard the aircraft.

Limitations of the Design

Crew Training

To operate the AUCS, a pilot would have to undergo additional training that is different than normal flight training. Flying an autonomous or semi-autonomous aircraft is not the same as sitting in a cockpit and learning to fly an aircraft. The U.S. Air force established an entirely separate pipeline to create Remotely Piloted Aircraft (RPA) pilots different than the standard manned pilot. The training is called the Undergraduate RPA Training (URT). The difference between URT and manned pilot training or Undergraduate Pilot Training (UPT) is time.

The students that attend URT are expected to have approximately 4 months of training for RPAs. This training consists of no actual flights and primarily focuses on flying inside a simulator for their entire duration of training. This creates a new baseline RPA pilot who will then go learn to fly an RPA like the RQ-4B or the MQ-9. Some additional months of training can vary but is on average 5 months long. The total time spent training a new USAF RPA pilot is 9 months.



URT Student Pilot inside a T-6 Simulator 2012. USAF

To compare this training timeline to a heavy cargo pilot, a UPT student will undergo 13 months of basic aviation training. This is spent in two different types of aircraft trainers. The first aircraft is the T-6 Texan II. This is a single engine propeller aircraft designed to teach basic flight training. The cargo-oriented pilot will then go fly the T-1 Jayhawk. This is a white private jet type aircraft that teaches the pilot how to fly a heavy aircraft. Once the UPT graduate finishes their 13 months of training, they move to the aircraft training for their aircraft. For the C-130 Hercules, this is 7 months. The total time to be expected from a manned pilot is 20 months.

The concern or limitation of this training expectation for the AUCS is experience. If UPS takes someone and spends 9 months teaching them how to fly, they will not have the same amount of flight experience as someone who has spent the last 20 months learning how to fly. The

difference in simulator training and manned pilot training is also very obvious when comparing the two types of pilots.

Crew training may become an issue for the AUCS and may require companies or the FAA to ensure that anyone operating any aircraft that is unmanned must possess a commercial flight certificate. This would ensure the AUCS pilots are trained in the normal flight rules that are expected of all aircrew that operate in the United States and also in other countries in which the UPS cargo carriers may operate.

Communication Delay

With a connection to the aircraft from the ground station, there will be a delay from the operator and the aircraft. The RQ-4B and the MQ-9 see an average of 3-5 seconds of delay from control input to actual aircraft action. This type of delay is not an issue if the aircraft is operated using an onboard flight computer and is operating autonomously throughout its flight. However, if the aircraft experiences some type of malfunction that inhibits its ability to navigate or use the autonomous systems, the operator might be required to “hand fly” the aircraft until it is on the ground safely.

To overcome this delay for terminal area procedures, the carriers may be required to ensure that a pilot is available to take over the aircraft using a line of sight link. This type of link normally carries no delay and can allow the pilot to send commands immediately to the aircraft and expect it to respond to the commands instantly.

Satellite Coverage

A limitation of the communication system is satellite coverage. If the AUCS is using satellites to maintain a link to the operator in the GCS, there will be areas in which a satellite may not cover the entire flight. In the event in which the aircraft flies across the Atlantic Ocean, the AUCS will

be required to change satellites. This change from one satellite to another can cause a disruption or a loss link situation for the operator and the aircraft. In the image below, the satellite seen here shows that any aircraft flying from the USA to England would lose coverage in flight.



Ku-Band SATCOM Coverage over the Atlantic Ocean 2020. Satbeams.com

With gaps in coverage like seen in the picture above, the aircraft must either carry an additional communication system to ensure constant communication, or the carrier must accept the risk of having an aircraft fly over the ocean with no one to monitor it. In the event of a loss link or a gap in coverage, it is possible that the aircraft can maintain a contingency plan to allow the aircraft to maintain its assigned and planned route of flight and altitude. This can ensure it maintains a predictable path but also ensures that ATC understands what to expect from the aircraft in the event of a loss link situation.

Research Strategy

To ensure the AUCS is a viable option for cargo carriers, they must first research the requirements, cost, manpower, and technology to ensure it is possible to move to an AUCS system from a manned aircraft fleet. To begin this research, the carriers must first convert one of

their existing aircraft into an Unmanned Aircraft test bed. This would allow the carrier to test their autonomous systems on an existing aircraft. This would drive the cost down and demonstrate the technology that is available for this program.

The carrier would then need to train crews on how to fly the system. This type of training would allow the carriers to understand if there would be any negative transfer of learning from manned aircraft to unmanned aircraft aviation. An example of a negative transfer of learning would be if the pilot made a decision to change the attitude of the aircraft, they would need to understand that the aircraft may not respond instantly as if they were sitting in the cockpit.

After the technology and training has been demonstrated, the carrier would need to establish a manning schedule. This schedule would help determine the most efficient way to man the GCS and help build a stable schedule and lifestyle for the crews. This type of schedule would be very different from a manned aircraft schedule as the pilots may show up to fly an aircraft that has been airborne for several hours prior to their arrival.

Recommendation

Current technology allows for a single operator to monitor and control multiple aircraft from a location on the ground. The technology used to fly the RQ-4B was designed in the 1990s and processing power has improved to a point in which we can start to modify current manned aircraft to allow for autonomous systems to fly the cargo missions. Replacing manned pilots with unmanned systems allows operators to have more control over the operations of their systems.

The increased efficiency and lack of human factor requirements allows for the companies to maintain a constant schedule and allow for multiple pilots to fly one aircraft over the course of a mission. The operator of the aircraft can also monitor and control multiple aircraft at once, thus allowing the cargo companies to focus on the operations of the aircraft and less on the pilots that are flying them.

The autonomous systems involved in this process would allow for the companies to ensure the aircraft is safely operated and focus on the cargo itself as the autonomous systems would ensure safe operations of the aircraft. The removal of the aircrew from the cockpit will allow the manufacturers and operators of the aircraft are focusing less on pilot ability and comfort and more on the execution of the cargo mission.

With satellite connections and GCS flight controls, there is an inherent risk to removing the pilot from the aircraft. The risk to remove the pilot to allow for more flights without concern of human factors and ensure cargo carriers are focusing on a better lifestyle for their aircrews while advancing the technology of their fleets to allow for more aircraft to fly with less people.

References

- Bestaoui Sebbane, Y. (2016;2015;). Smart autonomous aircraft: Flight control and planning for UAV. Boca Raton, Florida;New York;London, [England];: CRC Press.
- Breda, L. V. (2012). Supervisory Control of Multiple Uninhabited Systems-Methodologies and Enabling Human-Robot Interface Technologies (Commande et surveillance de multiples systemes sans pilote-Methodologies et technologies habilitantes d'interfaces homme-machine) (No. AC/323 (HFM-170) TP/451). NATO RESEARCH AND TECHNOLOGY ORGANIZATION NEUILLY-SUR-SEINE (FRANCE).
- Cummings, M. L., Bruni, S., Mercier, S., & Mitchell, P. J. (2007). Automation architecture for single operator, multiple UAV command and control. Massachusetts Inst Of Tech Cambridge.
- Donmez, B., Nehme, C., & Cummings, M. L. (2010). Modeling workload impact in multiple unmanned vehicle supervisory control. IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 40(6), 1180-1190.
- General Atomics. (n.d.). Certifiable Ground Control Station Controls First End-To-End Flight. Retrieved from <http://www.ga.com/certifiable-ground-control-station-controls-first-end-to-end-flight>
- Gilmore, M. J. (2012). RQ-4B Global Hawk Block 30 Operational Test and Evaluation Report. Department of Defense, <http://pogoarchives.org/m/ns/pentagonot-and-e-eval-rq-4b-global-hawk-20110526.pdf>, last accessed September.
- IPA. (n.d.). Independent Pilots Association. Retrieved from <http://www.ipapilot.org/>
- Ippolito, L. J. (2008). Satellite communications systems engineering : Atmospheric effects, satellite link design and system performance. Retrieved from <https://ebookcentral.proquest.com>
- FAA.Fact sheet – pilot fatigue rule comparison. Retrieved from https://www.faa.gov/news/fact_sheets/news_story.cfm?newsKey=12445
- Maza, I., Caballero, F., Molina, R., Peña, N., & Ollero, A. (2010). Multimodal interface technologies for UAV ground control stations: A comparative analysis. Journal of Intelligent & Robotic Systems, 57(1-4), 371-391. doi:<http://dx.doi.org/10.1007/s10846-009-9351-9>
- Maurino, D. E., Reason, J., Johnston, N., & Lee, R. B. (2017). Beyond aviation human factors: Safety in high technology systems. Routledge.

- Nehme, C. E., Crandall, J. W., & Cummings, M. L. (2007, June). An operator function taxonomy for unmanned aerial vehicle missions. In 12th international command and control research and technology symposium (pp. 19-21).
- Rogoway, T. (2014, August 28). This Rare Photo Shows The Most Sensitive Part Of A Combat Aircraft. Retrieved from <https://foxtrotalpha.jalopnik.com/this-rare-photo-shows-the-most-sensitive-part-of-a-comb-1627339307>
- Satbeams. (n.d.). Satbeams - World Of Satellites at your fingertips. Retrieved from <https://satbeams.com/>
- Tso, K. S., Tharp, G. K., Tai, A. T., Draper, M. H., Calhoun, G. L., & Ruff, H. A. (2003, October). A human factors testbed for command and control of unmanned air vehicles. In Digital Avionics Systems Conference, 2003. DASC'03. The 22nd (Vol. 2, pp. 8-C). IEEE.
- UPS. (n.d.). UPS Service Aircraft. Retrieved from <https://www.ups.com/aircargo/using/services/services/domestic/svc-aircraft.html>
- USAF. (2012, July 27). Innovative simulator solution enhances training, saves millions of dol. Retrieved from <https://www.aetc.af.mil/News/Article-Display/Article/261390/innovative-simulator-solution-enhances-training-saves-millions-of-dollars/>
- Yanushevsky, R. (2011). Guidance of unmanned aerial vehicles. Retrieved from <https://ebookcentral.proquest.com>
- Zhihao, C., & Ruyi, Y. (2011, August). Multi-level optimization mission planning and control methods for unmanned aerial vehicle. In Proceedings of 2011 International Conference on Fluid Power and Mechatronics (pp. 306-310). IEEE.