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Correspondence and inquiries:

University Aviation Association
8092 Memphis Ave
Millington, TN 38053
(901) 563-0505
hello@uaa.aero

OBJECTIVES

The University Aviation Association publishes the Collegiate Aviation Review International throughout each calendar year. Papers published in each volume and issue are selected from submissions that were subjected to a double-blind peer review process.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education and research. Working through its officers, trustees, committees, and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aerospace industry. The University Aviation Association accomplishes its goals through a number of objectives:

- To encourage and promote the attainment of the highest standards in aviation education at the college level
- To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignment, and other professional contributions that stimulate and develop aviation education
- To furnish an international vehicle for the dissemination of knowledge relative to aviation among institutions of higher learning and governmental and industrial organizations in the aviation/aerospace field
- To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education
- To actively support aviation/aerospace oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials covering all disciplines within the aviation and aerospace field

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TABLE OF CONTENTS

Peer-Reviewed Articles

Position Papers

Literature Reviews

Collegiate Aviation Review International

Volume 39 | Issue 1 Peer-Reviewed Article #1

1-5-2021

Viability and Application of Mounting Personal PID VOC Sensors to Small Unmanned Aircraft Systems

Cheryl Lynn Marcham
Embry-Riddle Aeronautical University

James P. Solti
Embry-Riddle Aeronautical University

Scott S. Burgess
Embry-Riddle Aeronautical University

Brandon Breault
Embry-Riddle Aeronautical University

Joseph Cerreta
Embry-Riddle Aeronautical University

Joshua G. Marcham
Embry-Riddle Aeronautical University

Patti J. Clark
Embry-Riddle Aeronautical University

Using a UAS-mounted sensor to allow for a rapid response to areas that may be difficult to reach or potentially dangerous to human health can increase the situational awareness of first responders of an aircraft crash site through the remote detection, identification, and quantification of airborne hazardous materials. The primary purpose of this research was to evaluate the remote sensing viability and application of integrating existing commercial-off-the-shelf (COTS) sensors with small unmanned aircraft system (UAS) technology to detect potentially hazardous airborne contaminants in emergency leak or spill response situations. By mounting the personal photoionization detector (PID) with volatile organic compound VOC sensor technology on UAS platforms, the needed information may be obtained at an optimum range and resolution without needlessly exposing a human to possible adverse conditions.

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Marcham, C.L., Burgess, S.S., Cerreta, J., Clark, P.J., Solti, J.P., Breault, B., & Marcham, J.G. (2021). Viability and Application of Mounting Personal PID VOC Sensors to Small Unmanned Aircraft Systems. *Collegiate Aviation Review International,* 39(1), 1-24. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/8083/7440

Small Unmanned Aircraft Systems (sUAS) less than 55 pounds have demonstrated tremendous usefulness in emergency and disaster response, mapping, inspection, and other analytic functions (Nex & Remondino, 2014; Remondino, Barazzetti, Nex, Scaioni, & Sarazzi, 2011). UAS are useful because they can fly over contaminated or inaccessible areas to mitigate some risks to first responders of having to do these tasks themselves (Nex & Remondino, 2014), and they fast data acquisition and mapping during emergency response actions (Remondino et al., 2011). UAS are currently used in emergency response for search and rescue, thermal imaging locating hotspots in fires, and evaluating structural stability (Calams, 2018). For example, the Millstone Valley, New Jersey Fire Department reportedly uses four different DJI models in various techniques for search and rescue (Petrillo, 2018). Since these devices can provide a live video feed, they can also "provide a real-time overview on the spread of wildland fires and the potential harm to firefighters, the public and the surrounding communities" (Werner, 2015, para. 4). The New York Fire Department (FDNY) has been using HoverFly tethered sUAS equipped with video and infrared cameras at incident scenes since March 2017 to provide real-time situational and operational awareness, particularly in seeing where a fire may be traveling, but they can be also be used for fire surveillance, identifying hot spots, search and rescue, hazardous materials reconnaissance, and accident reconstruction (Petrillo, 2018). The Los Angeles Fire Department (LAFD) uses DJI Matrice 200 Series, Matrice 600 Series, and Phantom 4 Pro sUASs equipped with electro-optic and thermal imaging cameras to identify hot-spots, perform aerial mapping, search and rescue, and for water rescues (Lillian, 2019).

In aviation, first responder localization and recovery of aircraft crash site survivors are often challenged by induced environmental hazards, such as pending fire hot spots and potential exposures to hazardous compounds such as residual fuels and combustion byproducts, some of which are known to cause a variety of adverse cardiovascular, respiratory, and neoplastic diseases (Brandt-Rauf, Fallon, Tarantini, Idema, & Andrews, 1988). The National Transportation Safety Board (NTSB) is currently using to capture images at accident sites as well as search for aircraft components for recovery and reconstruction (Bauer, English, & Richards, 2018). Using high-quality photos and photogrammetry, orthomosaic maps and 3-D models of crash sites can be created and viewed expeditiously, providing information from hard-to-access areas and keeping investigators safe (English, 2017).

Companies are incorporating the use of sUAS to perform a plethora of dangerous jobs, including inspection of confined spaces and towers, and entering tunnels and smokestacks (Pitcher, 2019). Shell (Oil Company) is using sUAS to inspect gas flares, eliminating the need to take the system offline to make it safe enough for humans to perform the work (Pitcher, 2019). The West Memphis Fire Department proposed the use of its DJI Phantom 4 sUAS after personnel had issues trying to get close to, and gather information about, a chemical spill. The use of the sUAS would allow viewing and approaching spills without putting responders in danger (Heard, 2017).

When encountering a crash site or a chemical spill, emergency responders must consider both physical hazards and chemical hazards that may be present and must protect themselves accordingly. When potential chemical exposure is present, the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) requires that emergency responders be adequately protected from the hazards. In the absence of information regarding what chemicals are present, and/or what airborne concentrations are present, OSHA (2005) requires that maximum protection be provided to responders until the potential exposures can be characterized. This protective gear generally includes the use of a self-contained breathing apparatus and appropriate full suit protective clothing (OSHA, 2005). In addition to delaying the response, this personal protective equipment (PPE) provides a significant physiological burden for the responders (United States Department of Homeland Security/Federal Emergency Management Agency, 2004). Wearing this protective gear, workers must enter the potentially contaminated area and use direct-reading chemical sensor instruments to characterize potential chemical exposures (Kuiawa, 2003). Reassigning the task of evaluating potential exposures to a remotely operated UAS can protect workers, and reduce the cost and time associated with having and donning expensive and burdensome protective equipment.

In recent years adding sensors to sUAS for various uses has become more commonplace. Multispectral sensors currently in use on sUAS allow for the identification of problem areas, such as wilderness or urban fire hot spots and oil spills or leaks (Eismann, Stocker, & Nasrabadi, 2009; Campbell, Naik, Sowards, & Stone, 2002; Robinson, 1991). Chwaleba, Olejnik, Rapacki, and Tuśnio (2014) reviewed optical sensors that could be carried on-board an sUAS for atmospheric monitoring and determined that a Light Detecting and Ranging (LIDAR) sensor might be useful to measure ozone and nitrogen dioxide. Rossi and Brunelli (2016) evaluated the ability of metal oxide semiconductor gas sensors mounted on sUAS to determine whether containers of chemicals could be appropriately located. The researchers found that the long reaction and recovery time of these sensors caused a delay in the instrument response relative to the actual location of the chemical source. UAS have been used to measure airborne methane (Berman, Fladeland, Liem, Kolyer, & Gupta, 2012; Golston et al., 2017; Schuyler & Guzman, 2017) and carbon dioxide (Berman et al., 2012; Schuyler & Guzman, 2017). Bullock and Nath (2016) performed a proof of concept study using a UAS to carry air monitoring equipment to evaluate air quality during a fire. A hexa-copter sUAS was equipped with a monitor equipped to measure particulate matter and a four-gas monitor capable of detecting oxygen, carbon monoxide (CO), hydrogen sulfide, and lower explosive limit (LEL) concentrations and compared to readings obtained using identical hand-held real-time air monitoring devices on an elevated platform over the fire plume (Bullock & Nath, 2016). The comparison between the sUAS and elevated platform data was not broadly conclusive, especially in regards to the particulate measurements, which showed significant variability between the two monitoring methods (Bullock & Nath, 2016).

At least one fire department has placed hazmat detector kits on sUAS (in this case on the nose of a DJI Matrice 210 for the Daytona Beach, Florida Police Department) to determine the presence of contaminants in vapor or smoke from a fire. Such technology will only detect the presence or absence of chemicals, and will not provide any estimation of concentrations. At least one company has advertised that it has mounted a multi-gas detector and other sensors on an sUAS, but it appears that the sensors are mounted above the sUAS rotors (FLIR Systems, Inc., 2019). However, there is no information available on whether the placement of either of these detection devices is appropriate, given the potential interference of air movement from the sUAS. In addition, little information has been found addressing whether the use of sensors on sUAS can accurately quantify airborne concentrations of chemicals, such as fuel, from a crash or spill site.

A commonly used commercial off-the-shelf (COTS) sensing device used by emergency responders and safety and health professionals is the photoionization detector (PID). PIDs are sensing devices commonly used as an initial screening tool to monitor the ambient air for parts per million (ppm) concentrations of total hydrocarbons or volatile organic compounds (VOCs), such as those found in solvents, fuels, cleaning supplies, and paints. PIDs are used to determine both the potential hazard to, and to aid in the proper selection of PPE, for emergency responders (Kuiawa, 2003). A PID can also be used to evaluate whether a spilled fluid is a volatile organic compound, and if so, the migration pattern of airborne contaminants (Kuiawa, 2003).

The PID consists of a short-wavelength ultraviolet (UV) light that ionizes trace organic and some inorganic compounds (RAE Systems, 2013). The charged ions are collected on an electrode where the detector measures electrical current in proportion to the concentration of VOCs present (Crimmins, 2016). The amount of energy required to ionize a gas is called the ionization potential (IP), which is measured in electron volts (eV) (Crimmins, 2016). As a general rule, the PID will only detect chemicals with an IP less than the UV light's eV (Crimmins, 2016). While it does not measure all VOCs, the most commonly used lamp is a 10.6 eV lamp for general-purpose VOC screening, which will detect organic compounds such as painting and printing solvents; fuels such as gasoline, diesel, jet fuel, or kerosene; degreasers such as perchloroethylene; and refrigeration gases such as freons and ammonia (Crimmins, 2016; RAE Systems, 2013), typically in the range of 0.01 to 10,000 ppm (RAE Systems, 2013).

Purpose

The purpose of this pilot study was to evaluate the viability and application of integrating existing COTS sensors with sUAS technology to detect potentially hazardous airborne contaminants.

Research Questions

The research questions to be answered were:

1. Could sUAS-collected data compare to hand-held device collected data to establish sUAS as a future tool for remote exposure assessment?
2. Is it possible to collect airborne VOC information to characterize potential exposures for first responders using the sUAS? If so, can a 3D graphical representation of concentration surrounding the spill be created by mapping concentration to location using GPS data points?
3. Does the sUAS dispersion of air (at various altitudes) influence the VOC instrument readings?

Methodology

In order to evaluate whether sUAS-collected data would compare to data collected from hand-held devices to be able to ascertain whether sUASs may show promise in the future development of remote exposure assessment methods, the researchers simulated a spill scenario and performed subsequent monitoring using both traditional (hand-held) and sUAS-mounted direct reading PID instruments. To closely emulate conditions expected in an actual fuel contamination event, the research team utilized a static location (low ground near the top of a draw) in order to limit varying weather conditions. The goal was to maximize this first proof of concept collection by reducing as many external elements that might dilute test results, to maximize the collection of usable data.

Test equipment. To conduct this research, equipment included a DJI Inspire 1 and DJI Mavic Pro (DJI, n.d.a; DJI, n.d.b), testing equipment, flight operations support equipment, and safety gear and these are further explained below. Specifications for each aircraft are provided in Table 1.

Table 1
Descriptive Specifications for the DJI Inspire 1 and DJI Mavic Pro (DJI, 2019).

	DJI Inspire 1 with X3 camera	DJI Mavic Pro
Dimensions	438x451x301 mm.	88x83x198 mm. (folded)
Weight	6.75 lbs.	1.62 lbs.
Max Speed	49.1 mph.	40.4 mph.
Endurance	18 min.	27 min.
Range	3.1 mi.	9.3 mi.
Operating Frequency	2.4-2.483 GHz; 5.725-5.825 GHz.	2.4-2.4835 GHz; 5.150-5.25GHz.
Sensor	1/23" CMOS 12.3 Megapixels	1/23" CMOS 12.3 Megapixels
Image Size	4000 x 3000 pixels	4000 x 3000 pixels

Source: Adapted from DJI (n.d.-a) and DJI (n.d.-b)

Collection containment vessel. Potential fuel spill scenarios were staged using several gallons of either jet fuel (Jet-A) or gasoline placed in an open-top 32-inch diameter galvanized steel pan in an open field (Figure 1). The steel pan was used to prevent contamination of the fuel, and the pan was placed on a protective non-porous sheet to prevent contamination of the ground.

Figure 1. View of testing area with steel pan on a protective non-porous sheet.

Aircraft. The University's Department of Flight (DOF) performed an analysis of alternatives to select the best-fit sUAS, taking into account the payload sensor weight (2.91 ounces) and size (2.4in x 2.6in x 2.3in). Also, the analysis included a selection of sUAS that could be generalized to common systems selected by public safety agencies. The best fit sUAS included the DJI Inspire 1 and the DJI Mavic Pro (Figure 2). These aircraft performed the following tasks: test aircraft, observation platform, image collection for building orthomosaics from Pix4Dmapper photogrammetry software (Pix4D, 2019).

Figure 2. DJI Inspire 1 with the Ion Cub PID attached with a short tether (left) and DJI Mavic Pro with the Ion Cub PID attached directly below the UAS (right).

Flight operations support equipment. Weather data for wind direction and velocity, temperature, wet bulb, dew point, pressure, and relative humidity were continuously collected using a Kestrel 5500 weather meter. To protect the aircraft and PID during takeoff and landing, a 5-foot diameter helipad was used (Figure 3).

Figure 3. Helipad for takeoff and landing.

Continuous charging of the sUAS Li-Po batteries was needed, thus power was provided by a Honda EU2200i generator. The two days of data collection required enduring high temperatures and humidities, and the flight location included a 30 ftx30 ftx8 ft covered work area to house the team with work areas (bench, tables, chairs, etc.), separating humans from data collection area for safety, and protecting researchers from the elements. Fire extinguishers were also staged in the data collection site.

PID collection devices. Conducting this research required an ability to collect volatile organic compounds, and the ION Science Cub 10.6 eV PID was identified as an initial collection device (testing equipment). This particular device was selected because of its size and weight (only 2.91 ounces), compared to larger, traditional hand-held PIDs that can weigh around 30 ounces or more. The PID is equipped with a datalogger that can record total VOC readings at predefined time intervals that were being mapped to the known location and altitude of the UAS and matched to readings collected on the PID for total VOC. In this way, it was anticipated that a 3D graphical representation of VOC concentration both above and around a staged spill of the known solvent, gasoline, and jet fuel could be created. Two of these ION Science Cub PIDs were utilized for static and mobile collection.

The PIDs had been factory calibrated approximately 6-7 months prior to use, and the devices were field calibrated the day before sampling with a 100 ppm calibration gas. Both PIDs were bump tested prior to use each day to confirm that the instrument's alarms were functional (OSHA, 2013).

Flight profiles. The procedures used for collection included the use of several UAS

(DJI Inspire 1, and DJI Mavic Pro) flying various profiles. One 10.6 eV PID was hung at 24 inches directly over the pan (Figure 4).

Figure 4. PID hung 24 inches directly over pan with a second hung from a tether (close and distant views).

A second 10.6 eV PID was attached both directly to the sUAS via a Velcro™ type strap and on 15, 30, and 45-foot tethers hanging beneath the UAS so that side by side readings could be collected (Figure 4). The 45 foot length was determined through preliminary studies of the sUASs, which showed that rotorwash from the sUAS was visibly observed to disturb the surface of the Jet-A or gasoline in the pan at lower heights, and it was not until the sUAS was at 45 feet above the surface that no visible air disturbance was detected.

Additionally, one PID was directly attached to the Inspire 1 and the Mavic Pro using a Velcro™ type harness (Figure 5).

Figure 5. PID with a velcro harness to the DJI Mavic Pro (left) and the DJI Inspire 1 (right).

For each sUAS, the VOC sensor was first attached directly to the device, and then hung on a 15-, 30-, and 45-foot tether and flown over the pan such that the sensor was also at the height of 2 feet over the pan. Hovering time for each location was a minimum of 2 minutes, with actual hover times recorded in one second intervals. Data were also collected at altitudes of 3-, 5- and 10 feet in circular patterns around the fuel vessel. Data collected by each device were then compared and evaluated.

Because sUAS platforms are not completely intrinsically safe in design (Tompkinson, 2017), it was important to ensure that the sUAS were not operated in a zone in which the airborne concentration could provide an explosive atmosphere. To further explain, the lower explosive limit (LEL) of a flammable gas or vapor is the airborne concentration below which the concentrations are too lean to ignite (Asfahl & Rieske, 2010). OSHA's permit-required confined spaces regulation considers 10% or more of any LEL to be a *hazardous atmosphere* (OSHA, 2011), giving an extra protection factor for workers. An alarm was set on the PID to alert at 50 ppm, well below 1% of the LEL for either gasoline or Jet-A aviation fuel (Table 2).

Table 2

Lower Explosive Limit Concentrations

	LEL	10% LEL	1% LEL
Gasoline	1.4%	0.14% (1,400 ppm)	0.014% (140 ppm)
Jet-A Aviation Fuel	0.6%	0.06% (600 ppm)	0.006% (60 ppm)

Source: Adapted from Centers for Disease Control and Prevention National Institute for Occupational Safety and Health (2019) and Chevron Phillips Chemical Company (2019).

Results

The first phase of testing focused on RQ1 - Could sUAS-collected data compare to hand-held device collected data to establish sUAS as a future tool for remote exposure assessment? was supported as posited above. First, a static sensor mounted at 2ft over the pan containing Jet-A was allowed to collect measurements for a total of 11 minutes to establish a background concentration. Values did rise and fall, and these variations were compared to data on wind speed and direction, but no apparent connection between detectable wind speed changes and variations in the ambient concentration levels were determined from this information. The average background VOC concentration on the static sensor at 2ft above the pan for this time period was evaluated and calculated to be 0.15 ppm. Then a PID sensor was attached to the Mavic Pro and the Inspire 1, and the sUAS was flown to hover over the pan at heights of 2 ft and 3ft. Airborne concentrations detected on the sensor mounted directly onto the sUAS were then compared to the static sensor readings. As the sUAS hovered over the open pan, ripples were observed on the surface of the liquid, and this disruption was reflected in the sensor readings (Figure 6).

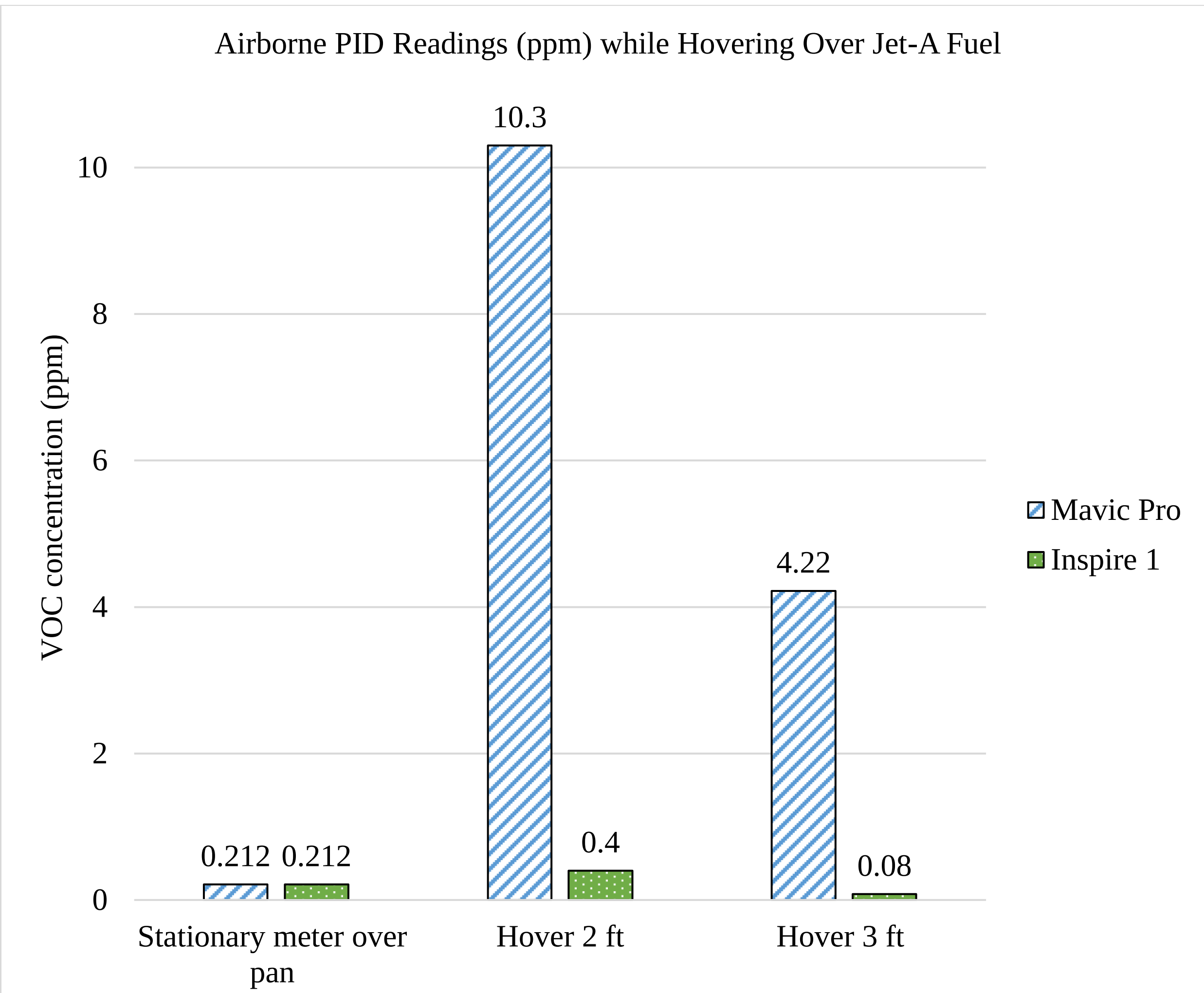

Figure 6. Average airborne VOC concentration readings with the PID sensor mounted directly on the Mavic Pro and Inspire 1 with no tether, hovering over a pan of Jet-A fuel at various heights compared to a static sensor.

Due to the increased volatility of gasoline over Jet-A fuel, similar measurements were collected using gasoline as the source of VOCs, which provided higher overall airborne concentrations. The average background VOC concentration on the static sensor at 2 ft above the pan for gasoline was evaluated and calculated to be 0.37 ppm. A PID sensor was then attached to the Mavic Pro and the Inspire 1, and the sUAS was flown to hover over the pan at heights of 3ft, 5 ft and 10 ft (see Figure 7).

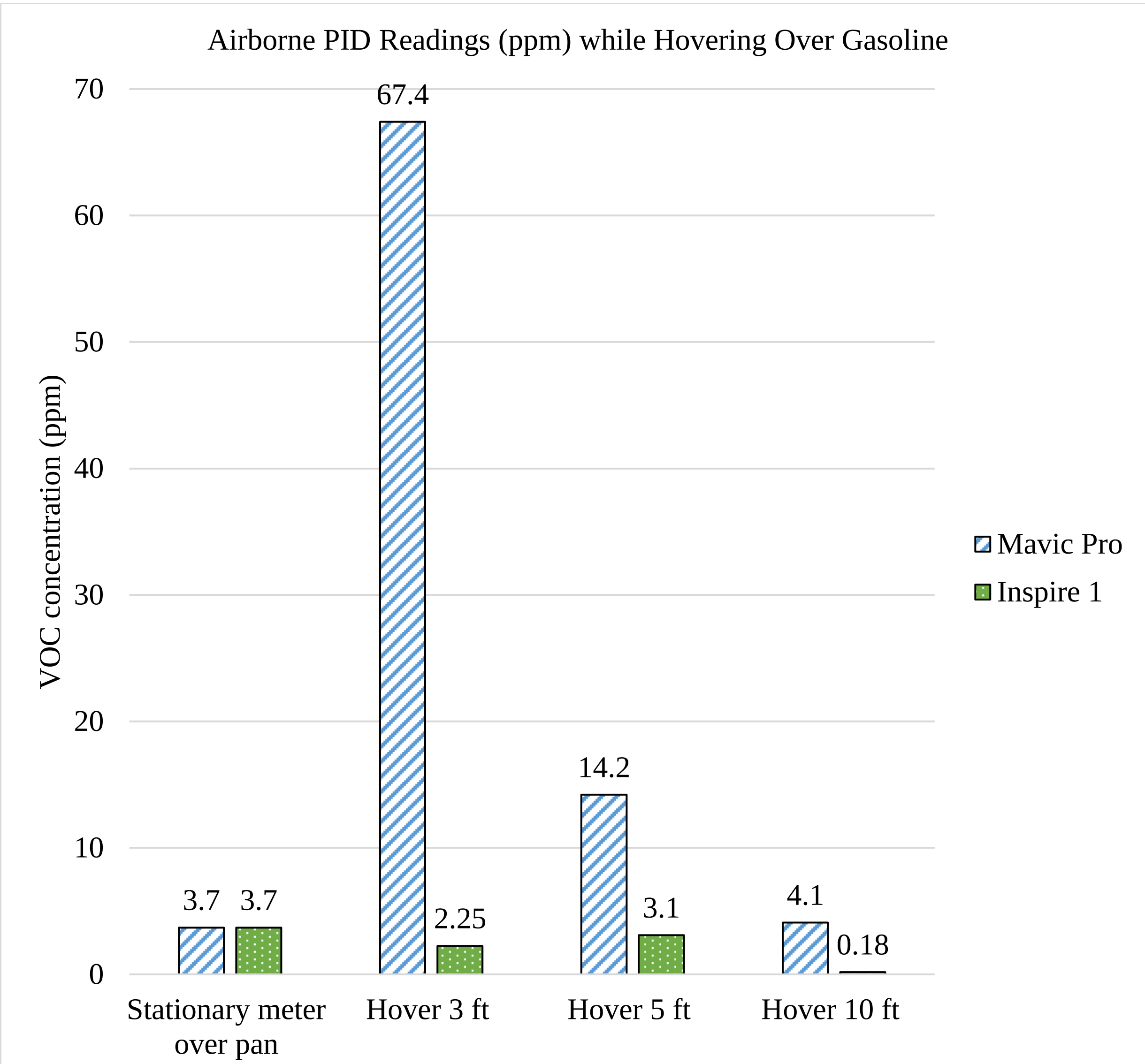

Figure 7. Airborne VOC concentration readings with the PID sensor mounted directly on the Mavic Pro and Inspire 1 with no tether, hovering over a pan of gasoline fuel at various heights compared to a static sensor.

When hovering directly over the pan, in all cases, the mean of the airborne concentration detected on the sensor attached directly to the Mavic Pro was statistically higher than both the mean of the airborne concentration above the pan without the influence of rotor wash, and higher than airborne concentrations detected with the sensor attached directly to the Inspire 1 (Figures 6 and 7). In the gasoline trials, with the sensor directly attached to the Inspire 1 hovering at 3 feet actually revealed a statistically lower average concentration (2.25 ppm) than background concentrations from the static sensor (3.7 ppm) (P = .02) (see Figure 6). One proposed basis for the differences in outcomes between the two sUAS is found in the operational aspects of the sUAS platforms. The Inspire 1 required continuous management of the hover altitude while in operation. Conversely, the Mavic Pro required very little adjustment of the vertical position of the aircraft (and sensor) while in operation. The Mavic Pro is also a smaller system and produces less thrust overall, resulting in less rotorwash than the Inspire 1, which is actually counterintuitive to the results. With higher concentrations detected with less rotor wash, one theory is that with greater rotor wash from the Inspire 1, the vapors may be pushed away from the sensor rather than drawing the vapors to the platform-mounted PID sensor.

The findings from the following phase of the research addressed RQ3: Does the sUAS dispersion of air (at various altitudes) influence the VOC instrument readings? Distancing the sensor from the rotor wash generated by the sUAS with a tether was then studied. Sensors mounted at various lengths on a tether hanging beneath the sUAS demonstrated a high similarity to the static sensor measurements, as depicted in Figure 8 and 9.

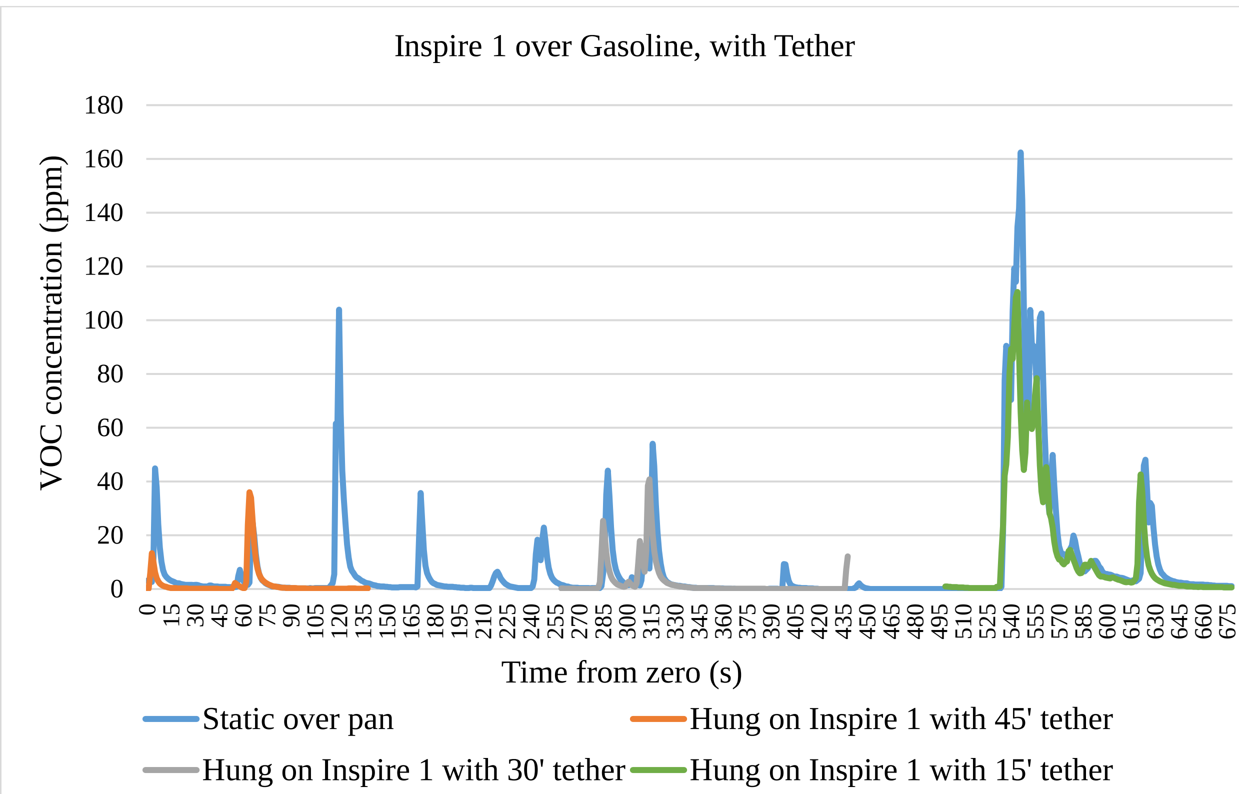

Figure 8. Static sensor over the pan compared to sensor hung by a tether at various lengths from the Inspire 1, gasoline.

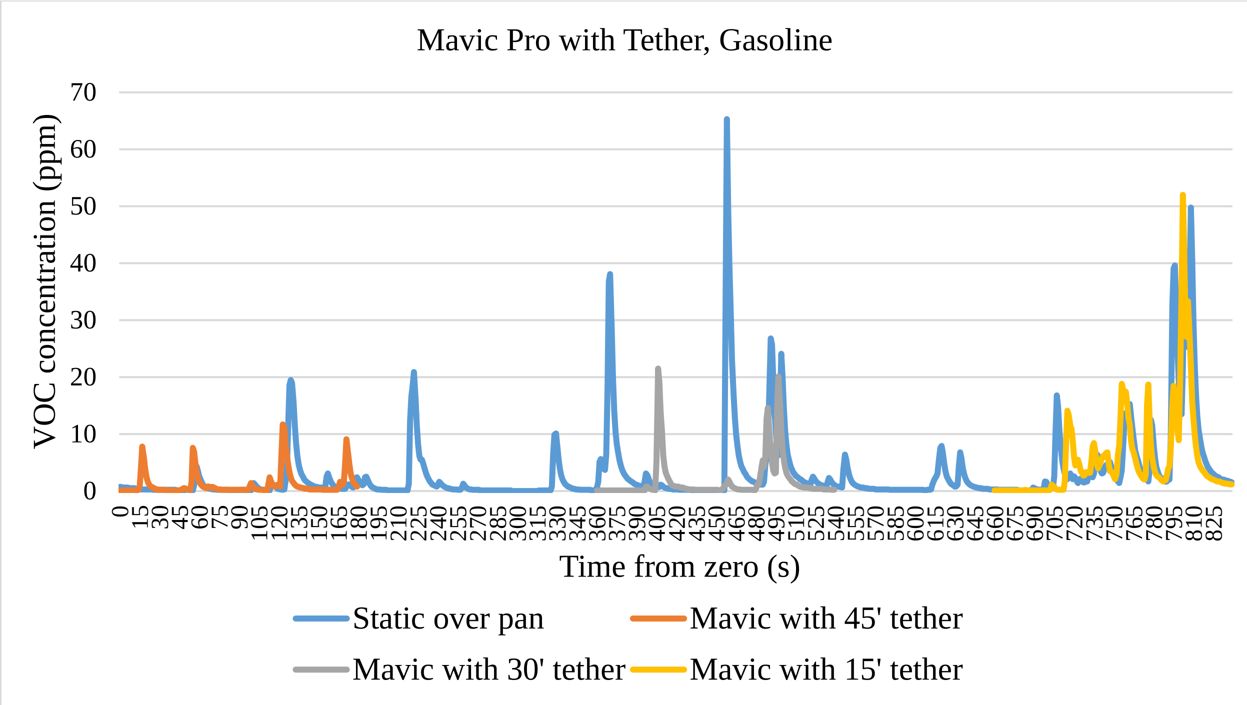

Figure 9. Static sensor over the pan compared to sensor hung by a tether at various lengths from the Mavic Pro, gasoline.

The collective results demonstrate that the side-by-side sensors appear to provide similar results, however, the overall airborne concentration increased as the tether length decreased (see Figures 10 and 11). The higher concentration with shorter tether length was likely due to the rotorwash, increasing the evaporation rate of the solvent and causing more vapor to become airborne.

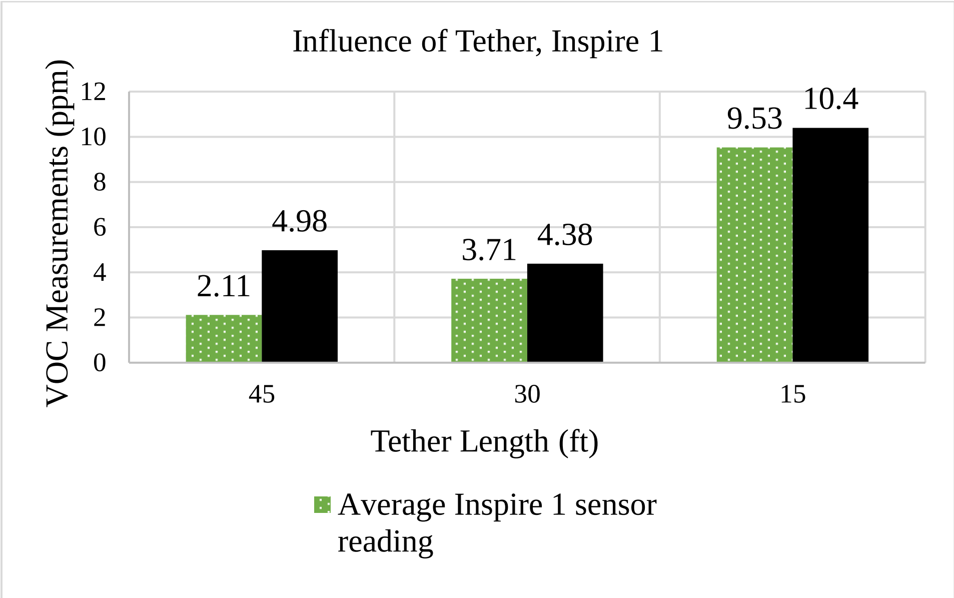

Figure 10. Average readings for static sensor over the pan compared to sensor hung by a tether at various lengths from the Inspire 1, gasoline.

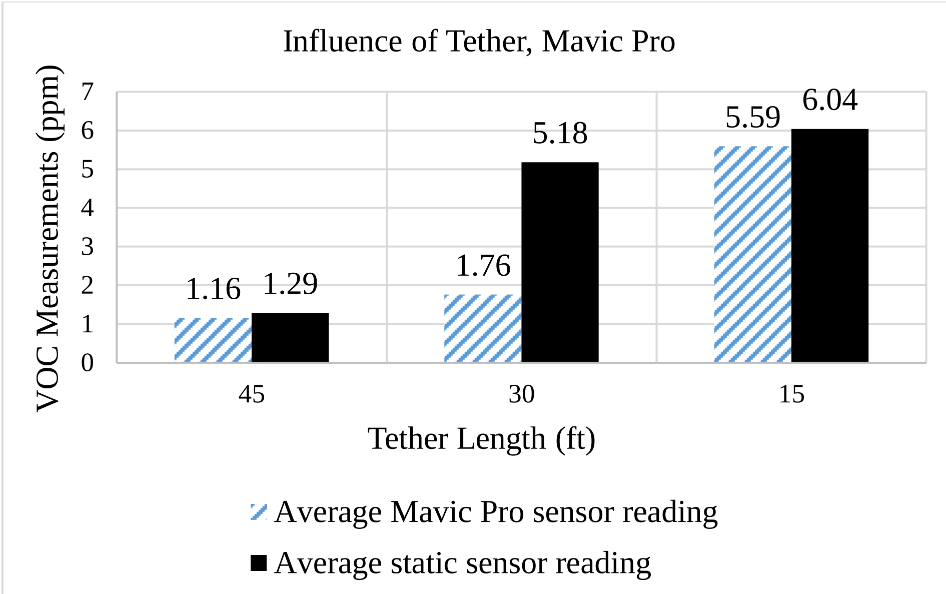

Figure 11. Average readings for static sensor over the pan compared to sensor hung by a tether at various lengths from the Mavic Pro, gasoline.

Additional testing was conducted determine whether the second research question (RQ2) could be supported that theorized: Is it possible to collect meaningful airborne VOC information to characterize potential exposures for first responders using the sUAS? To gather the needed data, the sUAS was flown in a circular pattern surrounding the pan at 3-, 5- and 10 feet altitude and at 5-foot radius and 10-foot radius in order to determine whether a measurable plume of vapor could be detected over the pan of evaporating fuel. The researchers discovered that while airborne vapor concentrations were detected directly above the pan on the static sensor, the sensor mounted on the sUAS did not consistently detect airborne VOC concentrations when not directly over the pan, even when measured as close as to within a 5-foot radius of the center of the pan and only 3 feet off the ground. Figure 12 displays examples of those results for the Inspire 1 and Figure 13 displays results for the Mavic Pro, in both cases using gasoline as the source of VOCs.

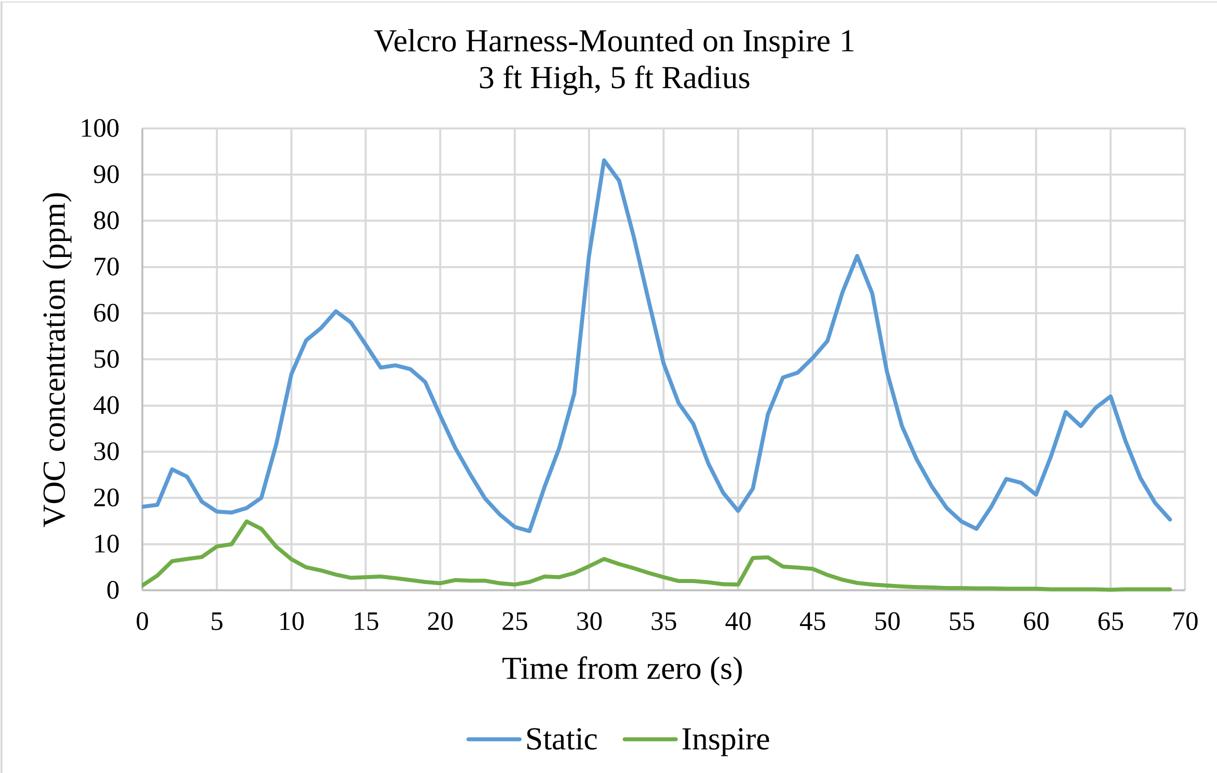

Figure 12. Static sensor over the pan compared to velcro harness-mounted on the Inspire 1, gasoline.

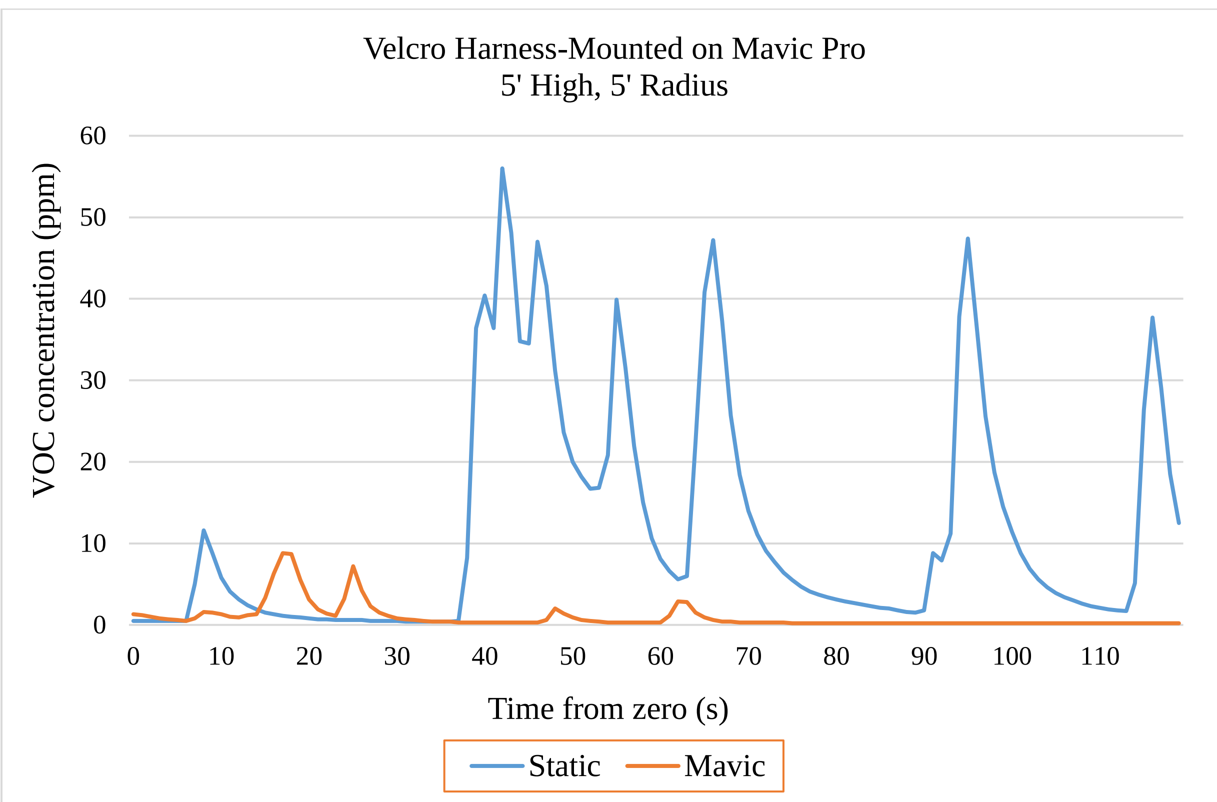

Figure 13. Static sensor over the pan compared to velcro harness-mounted on the Mavic Pro, gasoline.

The second part of RQ 2 theorized: If so, can a 3D graphical representation of concentration surrounding the spill be created by mapping concentration to location using GPS data points? The outcome of the collection and evaluation of the data demonstrated promise in the capability to develop a 3D image of mapping of airborne concentrations around the open container by applying GPS coordinates to the recorded sensor readings. By combining the time points of the PID data with concentrations, and the time points with GPS location on the sUAS, and considering that according to an Ion Science representative that there is no delay between exposure and sensor readings (B. Piritz, personal communication, December 6, 2019), the concentration and GPS data points (accounting for tether length) were plotted. An example of such a 3D plot is presented in Figure 14, using the Inspire 1 data with a 15-foot tether over gasoline.

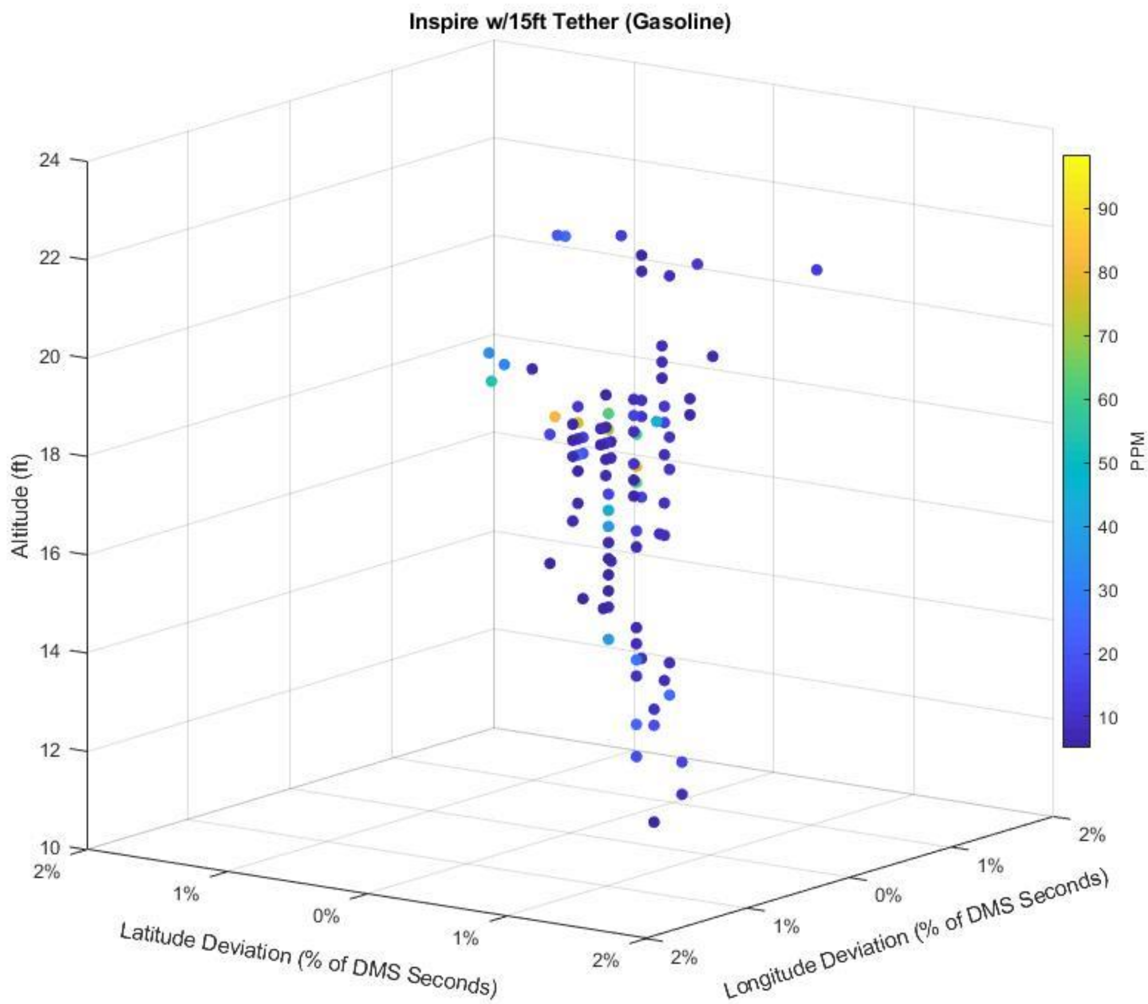

Figure 14. Airborne concentrations of VOCs (ppm) surrounding open pan of gasoline detected with the Inspire 1 using a 15-foot tether.

However, because the airborne concentration detected dropped significantly when the sensors were not directly over the pan (e.g., Figures 12 and 13), it is unclear whether this process can serve as a useful tool for emergency responders.

Discussion

Integrating a tether system impacted the operational aspects of the sUAS as launching and recovering the sUAS required a great deal of caution. The use of a tether also caused the system to be more susceptible to wind variances. During the research, the sensor locations were monitored and manually stabilized if needed. If this system were to be used in the field, manual stabilization would not be a viable option.

Data collected from a sensor hanging below the UAS produced a similarity with the static sensor data gathered for both the Inspire 1 and the Mavic Pro. What is noteworthy is that when using the 15-foot tether, rotorwash visibly agitated the fuel, whereas such observable disturbance was not detected with the 30- or 45-foot tether. This rotorwash may be helpful in stirring up and generating higher airborne concentrations so that a spill may be detected, but this outside or induced influence may also impact the accuracy that is needed to quantify potential occupational exposure for first responders.

Some consideration for potential GPS error of the used sUAS platforms may need to be addressed for accuracy of the 3D image of airborne VOC distribution. Global accuracy of a GPS is reflected in circular error probability (GPS World Staff, 1998), and the circular error probability for this research had an error that was consistent with consumer-grade GPS of up to 3 meters. However, the relative errors of positional information were consistent as the sUAS maneuvered across the measurement area. For this research, the global accuracy of the positional information was irrelevant because the position data focused on the relative position of the sUAS to the fuel source and wind, not the global position of the sUAS or source of fuel vapor. However, if in future research or application, one was attempting to locate a fuel source, or setting a boundary for the use of protective equipment, using an sUAS equipped with a real-time kinematic (RTK) GPS solution could improve the relative positional data further. Ground control points could also be used to enhance accuracy, but RTK GPS may provide a greater relative and global accuracy than using manual tie points.

An sUAS has electronic components that may be a hazard in an environment with highly volatile VOCs. For example if a component were to electrically short out and burn up as electronic speed controllers (ESC) may do or get too hot, there is potential for fumes to combust. One way to address this risk would be for the sUAS to descend onto the test site as opposed to moving into the area laterally using the altitude to buffer the combustion risk. With the nature of VOC vapor pressures, vapors tend to settle closer to the ground. Descending into a hazard area would allow for slower integration into the environment and offer a quick and safe method of evacuating the area if the concentration was too hazardous for sUAS operation. Lateral sUAS introduction to the hazard area is vulnerable to wind direction changes that could potentially create unanticipated concentration spikes that may influence the validity of the data and consequently complicate the risk assessment. Wind conditions should be closely monitored prior to sending a sUAS into the situation, but the drop in method described above may be utilized to enter/exit the hazard area in a more safe manner.

Second, the thrust from the sUAS may create conditions for hazard escalation. In a real-world scenario where more than one chemical may be present, and the potential for dangerous incompatibilities exist. The thrust from an sUAS may accelerate chemical reactions or cause other hazards such as spilling or tipping over containers as we observed during the field testing with the fuel pan. This particular scenario was developed for an industrial environment or an accident situation, but the potential for quicker evaporation and larger affected areas due to the faster removal of surface concentrations over the spill could be cause for concern. This precautionary information should be included in any risk assessment of the use of a sUAS for detection levels of chemicals in a hazardous environment.

Conclusions

In this exploratory research much was learned about the characteristics and influencing factors for the sUAS tested. However, the researchers only conducted a brief investigation and further examination and delineation is required. When the impact of rotor wash is fully characterized for each type of sUAS, and the placement of the VOC sensor can be appropriately optimized, sUAS mounted sensor technology may be able to be used to assist emergency responders when responding to accidents, disasters (such as tornados and earthquakes), or other such events to evaluate and gain rapid intelligence on the presence of released hazardous materials without having to put first responders in harm's way. Information may then be gathered more expeditiously and efficiently, especially in hard to reach locations, thus reducing labor costs, resources, equipment usage, and time to respond. However, in this research we discovered some limitations to the use of this technology including the following:

- If the sensor is mounted directly on the sUAS, and the sUAS hovers directly over the spill, the specific sUAS configuration will influence whether the detected vapor concentrations higher or lower than ambient levels without the sUAS present.
- If the sensor is mounted directly on the sUAS, and the sUAS is *not* directly over the spill, the vapors from the spill did not always reach the sensor and were not always detected.
- Sensor data from a hanging sensor at 15, 30, and 45 feet below the sUAS provided similar readings to the static sensor data. However, with the use of a 15 foot tether, rotor wash from the sUAS visibly stirred up the fuel and elevated measured exposure levels, thus interfering with the ability to accurately measure potential emergency responder exposure levels, and the impact of rotor wash varied depending on the type of sUAS platform used and the length of the tether.
- With the sUAS platforms employed for this particular experiment, a 45-foot tether appeared to provide an optimal length of separation from the rotors to be able to estimate exposures above the spill without noticeable influence from the rotorwash. However, using a tether that long is a potential limiting factor due of the potential interference by ground objects and the possible influence of wind speed and direction on the hanging sensor.
- Using a shorter tether between the sUAS and the COTS sensor may be useful if the intent is to only detect the presence of a spill, rather than to determine responder exposure.

Data logged airborne concentrations can be correlated with geospatial positioning information obtained by the sUAS to produce color-coded imagery based on detected airborne concentrations as noted in the Results section and depicted in Figure 11. This type of information could be particularly useful in accident situations as it is imperative to know the presence, boundaries, and dispersion of chemicals or compounds prior to responding to the situation. However, additional research should be performed with a larger volume of spilled material to better represent typical crash or spill conditions.

Recommendations

Relatively inexpensive COTS sensors are ideal for use in hazard assessment situations as described due to the availability, low cost, ease of use, and ability to obtain relatively immediate information to evaluate health and safety or environmental concerns. The potential commercial application of this technique is not only extensive in scope but also in potential risk mitigation. Emergency responders and municipalities can use sUAS mounted COTS sensor technology such as a PID to respond to accidents, disasters such as tornados and earthquakes, or other events involving hazardous materials to evaluate and gain rapid intelligence on the presence of released hazardous materials without having to put responders in harm’s way. Employers will be able to gather information expeditiously and efficiently, especially in hard to reach locations, thus reducing labor and resource costs. By and large general industry is eager to use such technology to perform evaluations of chemical containers such as those found in tank farms or remote storage or operational locations of pipelines or wells, for example. The gain or mitigation factor is not having to put workers in harm’s way and providing a means to evaluate whether and how much chemical release has occurred at the location. By incorporating the use of sUAS and COTS sensor technology into routine inspections of tank farms or other outside chemical storage locations, leaks, spills, or other emission sources may be located more rapidly and potentially reduce the impact on the environment. The tested technique could also be perfected over time for use when performing environmental site assessments for property transfer as specified by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/ Superfund Amendments and Reauthorization Act (SARA) (United States Environmental Protection Agency, n.d.) or other jurisdictional requirement that mandates the potential owner or seller perform due diligence in determining whether the property has any pre-existing environmental contamination.

The research performed in this study was exploratory in nature, and the potential uses of the technique are extensive. Nonetheless, there is much more to be learned in this area, in turn, augment the practicality of utilizing sUAS and COTS sensor technology in assessing hazardous environments. Two areas requiring additional testing and validation is a full characterization of the impact of rotorwash for each type of sUAS, and optimization of the placement of the VOC sensor.

Another area that warrants additional research is an understanding of any adverse effects on the platform material of an sUAS when operating in hazardous environments. Currently, most sUAS are designed and built for operations in normal flying environments. As well, most sUAS platforms have little to no actual maintenance requirements specified by the manufacturers. Therefore the need for special inspections and perhaps scheduled replacements of sUAS components may be prudent and are areas of concern for sUAS operating in hazardous conditions. More data are needed in this area over a period of time and gathered from a variety of environments.

In summation, the research was successful in determining the initial value and application of mounting inexpensive COTS sensors like a PID on sUAS for use in hazard assessment situations. As an emerging technology, the obvious attributes are availability, low cost, ease of use, and ability to obtain relatively immediate information to evaluate health and safety or environmental concerns. But herein, the research team has only scratched the surface by developing and testing the initial technique. The commercial application potential of this technique is extensive, and based on the results, it is recommended that follow on research be conducted in the areas noted.

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The Historical Development of Civil Aviation Security with Applications of Time Series Modeling

Tüzün Tolga İnan
Bahcesehir University

The examination of civil aviation security has started to be examined in more detail after the first successful sabotage event in 1971. The purpose of the study is to determine the affecting factors to the number of sabotage events between the years 1979-2018. The Vector Autoregressive Model was used to analyze this relationship. In the time series model, the series was examined beginning from the year 1979, the beginning period of the crew resource management concept. In this year, human factors also started to be examined in civil aviation accidents. While the number of casualties and the number of total passengers in the events negatively affect the number of sabotage in the short term, their effects disappear in the long term. It was found that the number of commercial passengers had a positive effect on sabotage in the short term. This situation suggests that sabotage events trigger terrorist acts against commercial passengers in order to make an impression in the world. For this reason, the rules should be structured in the most effective way to prevent sabotage events.

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In the early period of civil aviation security, the X-ray scanning security check system started to be implemented in the early 1970s. After 9/11, the World Trade Center terrorist attacks, the developments in civil aviation security has changed drastically. After the year 2001, the civil aviation security concept became significantly improved at airport security checkpoints around the world. For this reason, numerous passengers are uncomfortable due to long waiting times. Therefore, there is a problem among the passengers' claims to reduce waiting times and the requirement for reducing the security checkpoint which passengers expect. An effective queue structure for airport security checkpoints--without any reduction in terms of security criteria--is an essential subject for civil aviation security (Podemska-Mikluch & Wagner, 2017). Usually, passengers' identity documents, passports along with their luggage and body scans at the airport security checkpoints constitute the basic needs of civil aviation security. Although the objects that are forbidden to be transported are almost the same at different airports, security screening procedures could be reasonably dissimilar (Janic, 2007). For instance, at some airports (e.g. Canada) passengers are required to wait in a single queue prior to entering the security checkpoint, while in other airports (e.g. China) passengers wait in two distinct security checkpoints. Consequently, these strategies influence the control point efficiency, even when the same security control principles are used. Looking at the identical conditions, people can wait in queues at one or two security gates. Therefore, it is possible that the waiting time in queues will be dissimilar (Schwartz, 1974). The importance of security in air transportation has increased over the years and security is essential to avoid injuries and fatalities. The consequences of a terrorist attack can be incalculable that would involve national reputation, public interest, and commercial trust (Gordon, Moore & Richardson, 2009). Generally, the community could be influenced by violations in air transportation security, despite having national protection, and boundary guards. These security services are identified as the public economy that is financed from the common treasury related to nations. The protection of the airport and passengers is a more complicated, significant, and expensive process. Beside the security personnel, x-ray machines and handheld detection equipment are expensive, hence they must be used by qualified and educated personnel. The boundary of civil aviation security depends on the revenue that airline companies receive from their passengers. The countries which receive these payments are classified as; Canada, the United States, the United Kingdom, Germany, and Spain (Aviation Security, 2007). This study aims to identify the affecting factors of a possible sabotage event. The literature review consists of two parts: privatization of airport security, and evaluation of the impact of 9/11 on civil aviation security.

Literature Review

When the concepts and institutions are examined, crew resource management (CRM) is defined as the management of all resources that are available to the crew rather than the resources themselves. In other words, it is a management process that enables aircrew to use their cognitive abilities--technical and non-technical skills--to effectively display expected behavioral performance by using time, information, human, and equipment effectively (Lauber, 1984). Secondly, the Canadian Air Transport Security Authority (CATSA) is a representative establishment which is funded by parliamentary appropriation and responsible to the Parliament owing to the Minister of Transport. CATSA is accountable for ensuring effective, efficient, and continuous screening of persons that access aircraft or restricted areas, and the belongings or baggage which they offer to an air carrier for transportation (Canadian Air Transport Security Authority, 2020). The Canada Revenue Agency is accountable for directing the Air Travelers Security Charge (ATSC) that came into influence on April 1, 2002. Since then, the fee has been gathered by air carriers or their representatives at the time of buying (Air Travellers Security Charge, 2020).

For instance, the Canadian Air Transport Security Authority (CATSA) carries out passenger screening and other security tasks. CATSA informs the parliament owing to the Ministry of Transport and all payments are paid from the common treasury. In addition, the airport finance district applies the Air Travelers Security Charge system to arrange payoffs from the treasury to CATSA for passengers. In line with this system, passengers using air transportation in Canada have to pay privately to benefit from national security services. Poorly designed taxation policies may have undesirable consequences for the economy. Increasing airline-related taxes reduce overall taxes collected for aviation-related economic activities. High taxes that increase expenses, reduce the competitiveness in exports and the domestic market. Taxing air transportation also reduces the demand for tourism. For example, the activities of secondary service tasks such as hotels and restaurants will be negatively affected by applied tax policies (Canadian Air Transport Security Authority, 2020). ATSC has produced a solution in this regard, with taxes attached to an airline ticket, thereby reducing the tax rate of Canadian passengers using air traffic. The Canadian attempt in air security strategy was progressively and structurally in line with the U.S. aviation implementations, but after the 9/11 attacks the ATSC was subsidized by the government because of substantial budget deficits (Prentice, 2015).

Table 1
Remarkable Terrorist Attacks Related to the Security of Air Transportation

Years	Events
1985	The bombing of Air India Airlines.
1988	The explosion over Scotland on Flight 103 of PanAM Airlines with a concealed bomb.
September 11, 2001	Terrorist action by using aircraft as weapons.
2001	The presence of a bomb in the shoe.
2004	Russian aircraft destroyed by suicide bombers (remote detonation by device).
2006	UK authority published a strategy used to eliminate the problems that happened before by drafting laws related to liquids.
2007	Attack on Glasgow Airport with special vehicles.
2009	An Unsuccessful attempt by the underwear bomber.
2010	Explosive toner cartridges shipped by air cargo transportation.
2011	Terrorist attack in the public area of Moscow airport.

Source: (Plungis, 2013).

After 2011, the 2014 Jinnah International Airport attack, the 2015 Paris Charles de Gaulle Airport attack, the 2016 Brussels Airport bombing, andthe 2016 Atatürk Airport terrorist attacks were additional, remarkable examples of civil aviation security (Plane Crash Info Database, 2020). Table 1 presents several terrorist attacks against the security of air transportation that shapes the development of the aviation security strategy. These attacks were remarkable examples of sabotage incidents in the history of civil aviation. These events started at the beginning of 1985. This strategy developed and based on abduction incidents and international obligations. So, international obligations with the concept of privatization and the density of airports have also increased accordingly. Terrorist attack attempts have also increased so that they would make an impression all over the world (Cooper, 1971). In December 1970, the International Civil Aviation Organization (ICAO) held conferences which ensued in the Hague Convention on blocking the illegal seizure of aircraft. Security precautions were related to the concept of security by Canada in ICAO Annex 17, defined at international meetings in line with the measures for the protection of International Civil Aviation against illegal activities (International Civil Aviation Organization, 2019). As a result of these meetings, Canada has been identified as liable for the progress of national policies about civil aviation security. On December 26 1971, U.S. citizen Thunder Bay was armed with a pistol and grenade, forcing Air Canada airline pilots to fly to Toronto, refuel and fly to Cuba (Airliners, 2020). Later, the armed citizen was forced to land the aircraft and delivered to Canada. On June 8 1972, in the destination of Prague Airport to Marianske Lázně, the captain was killed in the cockpit. Ten hijackers (including three women, one with an infant) escaped and were later caught by the police. As a result of these incidents, carrying weapons and explosives in the aircraft's cabin (next to the passenger) was described as a crime with the amendment made in the Canadian Criminal Code in 1972 (Aviation Safety, 2020).

Time Process of Privatization Concept in Airport Security Privatization of Airport Security

In 1973, the Air Transport Law was altered to allow airline companies to set up and operate security programs at their self-expenditure (Canadian Air Transport Security Authority, 2020). Transport Canada as the possessor and operator of national airports in Canada, stated that it is necessary to purchase metal detectors and X-ray machines for controlling passengers with luggage. Airline laws have also been updated to ensure that all checked baggage must be scanned by X-ray machines. Since 1985 more stringent measures have been applied, such as passenger and baggage matching on international flights. Technically, the concept of airport security privatization started in 1973 when the government made it mandatory for airlines to pay for passenger screening. After 21 years, the following process in security privatization emerged as part of the National Airports Policy (1994), which created authorities to manage 26 airports which formed the national airport framework of airports in Canada (CAA). Afterwards, all procedures were prepared for the screening of passengers and pieces of baggage related to the rules of CAAs and police security. As of 2003, all international airports in Canada were commercialized. The timeline for the privatization of civil aviation security is shown in table 2.

Table 2
Timeline of the Aviation Security Privatization Concept

Years	Events
1973	Aviation Law Amendment.
1985	Aviation Law Amendment.
1992 - 2000	Commercialization of airports.
2001 - Present	Safety procedures in air transport.
2001 - Present	Charges of safety equipment on airlines (purchase of x-ray equipment).
2001 - Present	Detectors that detect explosives in line with the baggage matching strategy have started to be used in airlines.
2001 - Present	Airports are allocated an area to be assigned to the police for security calls.
2001 - Present	Establishment of CATSA and ATSC institutions.

Source: (Prentice, 2015).

Following the implemention of the National Airports Policy (1994), the commercialization of airports dramatically increased between 1994 and 1996. Hence, 26 airports were commercialized all over the world. By the end of 2000, this number increased to more than 100 airports. Increasing the appropriations for aviation security after the 9/11 attack enabled airports to become more equipped to perform security functions. There have been radical changes in aviation security after the 9/11 terrorist attacks. For example, CATSA was established on April 1 2002 (Canadian Air Transport Security Authority, 2020). This law mandated the inspection of passengers and luggage for screening and limited access of non-passengers to the customs areas of airports. Transport Canada is an aviation agency that has been identified as responsible for civil aviation security. However, an important part of the transport security strategy has been passed from the relevant agency to the Ministry of Finance. In this case, the security fee allowances of airline passengers fall under the responsibility of the Minister of Finance. The concept of airline passengers' security fee was set at the level of $12 for domestic passengers and $24 for international passengers in 2002. It was thought that the air passenger traffic in Canada increased by ten percent, but no progress has occurred in the following years. However, air traffic data recovered faster than hoped and the Ministry of Finance started to charge more taxes than other aviation security disbursing under CATSA. As a result of the complaints received with the reflection of these taxes on ticket prices, the relevant tax rates were reduced in the following years (Prentice, 2015). While entering an airport, great numbers of passengers are oblivious about the institutional infrastructure available to mitigate potential security threats. However, in the event of a crisis with the institutional infrastructure, appropriate and coordinated decisions should be taken to ensure the safety of airport employees and through all processes of passengers (Comfort et al. 2010; Barbash et al. 1986).

When security officers and managers need to make decisions under extreme time pressure, the most accurate decisions can be made in a way that will not harm daily airport operations. However, since the concept of safety comes first in the priority of such decisions, the importance of the sustainability of the operations comes second. However, companies build airports that work with security experts to plan the designs of airports with safety and security principles in mind. They design the airports by bulk-operated engineering structures that focus on technology and logistics (De Neufville et al. 1995; Horonjeff et al. 2009). From a security aspect, the security level of airports is evaluated to utilize technology for improving regulations related to safety and security required by federal regulators (United States Government Accountability Office, 2005; Transportation Security Act, 2011). In this context, compliance with the rules infers compliance with airport security standards. Better-planned security technology ensures better security coverage. Manipulating passengers and employees with system engineering create a strategy to remove the human element as much as possible in safety-related decision-making. With this strategy, decreasing human interposition in security determination operations is the most appropriate decision (Harris, 2002). For that purpose, technology has undergone a significant operational process to ensure security. In this way, decisions are made by security software. Such software does not only detect objects that represent potential threats, it can also detect behavioral abnormities that could be evaluated as threats. This aspect is related to the principal security access outlined by security agencies and regulative agencies. Briefly, when the rules of security are followed at airports, security is provided for passengers and airport personnel that are at risk. This security strategy has been largely examined at most security checkpoints across the airport. Thereupon, in spite of the interferences to reduce human-based decision-making on security issues at airports, the proof is the gathering of the effort that has not been completely accomplished (European Union Aeronautics Research, 2006; Transportation Security Act, 2011; Federal Aviation Agency, 2013).

Evaluation of September 11th, 2001 Impact on Civil Aviation Security

Since the hijack of five aircraft simultaneously on 9/11, the World Trade Center Attacks, the procedures about civil aviation security concept has increasingly developed over time. Therefore, the important articles are classified related to the operation of security criteria during flight communication with the cockpit:

- Communication between the cockpit and the cabin is provided through the interphone.
- The company must have a cryptic word used in flight evasion and similar emergencies.
- When this word is said to the cockpit, the pilots can realize that the plane has been hijacked.
- The cockpit personnel should never open the cockpit door in any case.
- It should also be quickly given information to the cockpit in cases where there are unserious, uneasy, impatient, and similar passenger profiles (Lee, Oh & O'Leary, 2005, p. 356).

After 9/11, Standards, and Recommended Practices (SARPs) related to the certification of aerodromes were presented inside ICAO Annex 14, Volume I. This document has demonstrated a powerful source to guarantee the aerodrome facilities and operations conformity with the appropriate SARPs. These SARPs are applied for promoting the safety, regularity, and efficiency of aircraft operations. Besides ICAO Annex 14, the primary SARPs are concerned with the ICAO Annexes of 6, and 11 (Lee, Oh & O'Leary, 2005).

In the following part of the study, a sample of data analysis is examined with five selected time series. The aim was to find the parameters which had an impact on sabotage. For this reason, the time series modeling was conducted and the affecting parameters were found. To show the efficiency of security precaution, on September 11 2001, the World Trade Center was included in this study as a case stdu. The pairwise comparisons of the ratio of sabotage in the total event, and the ratio of fatalities in the total passenger in total events were examined in two-phase as the years between 1979-2001, and 2002-2018.

Methodology

This paper includes yearly data released by deaths and incidents per year according to ACRO and Bureau of Aircraft Accident Archives (2020) data, and Plane Crash Info Database (2020) from 1979 to 2018. All the variables are taken from commercial civil aviation databases. All of the countries which share the accident and incident information are examined in this time series model. In this analysis, it cannot be examined in 2019, because the data was not available. Time series modeling is used in this research to determine the factors affecting sabotage. This model shows the effectiveness of the precautions, rules, and regulations taken over time. The decreasing trend in the number of sabotage over the years shows the effectiveness of the precautions, rules, and regulations taken in civil aviation security. This efficiency is statistically proven in the light of the numerical data obtained in this study. So, total events, the total number of casualties, the total number of passengers in these events, the total number of commercial passengers are taken as endogenous variables thought to affect the sabotage events in the Vector Autoregressive (VAR) Model. After creating the VAR model, impulse response functions are shown the relationship between Sabotage and the other endogenous variable. After mentioning the important developments in the history of civil aviation security, the concept of sabotage related to civil aviation security is examined in this section with four time series. These selected series were evaluated in order to make an inference as they give the total number of commercial passengers in air transportation as well as the total number of events, casualties, and the total commercial passengers which took place in air transportation accidents.

Table 3
Description of Sample Data

Total Events	Total Number of Casualties	Total Passenger In These Events	Total Commercial Passengers	Sabotage
This data is related to the number of flights that ended with the fatal injury of passengers.	This data is related to the number of fatal injury passengers which is a death lower than 30 days duration following the accident (World Trade Organization, 2020)	This data is related to the number of passengers which were in fatal injury flights.	This data is related to the number of commercial passengers who used civil air transportation.	This data is related to the intentional intervention of aircraft during flights. Its meaning is different from abduction but it usually evaluated as the hijacking of aircraft.

Source: (Security and Facilitation, 2020).

These data are related to the outcomes of all accidents. Total events give the number of such accidents. The total number of casualties gives the number of fatalities about these accidents that resulted in death within 30 days. The total passengers in these events give the number of people that take part in the accidents. Total commercial passengers are related to the yearly number of passengers who used civil air transportation. Sabotage deals with security-related events that include intentional intervention of aircraft. These data have the possibility to threaten civil aviation security in terms of sabotage as it is specified in the Aviation Security Manuel (Doc 8973-Restricted) and ICAO Annex 17 (The ICAO Annex 17 Aviation Security Manual, 2020).

The original monthly series are shown in Figure 1 to indicate the range of the real values. It can be seen that the series have stationarity during the yearly period. The term *stationarity* is explained in the following section. Series are standardized in order to avoid variability to interpret the results correctly by subtracting the mean and dividing the standard deviation in time series modeling. The time series analysis is conducted in R 4.0.2.: "TSA, vars packages" (Pfaff, 2008, p. 12).

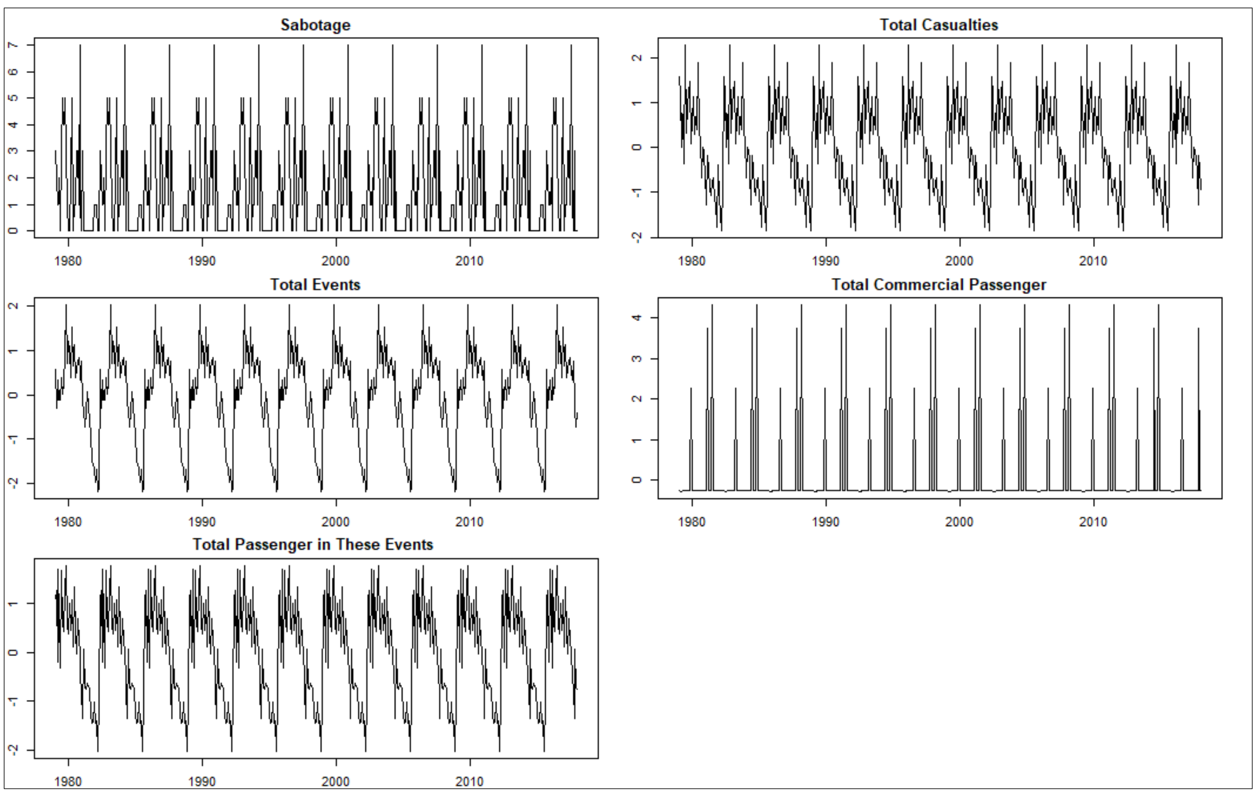

Figure 1. The Time Series Plot of the Original Series

Unit Root Test

The concept of *stationarity* has great priority for the time series analysis. The concept of stationarity is expressed as the mean and variance of a time series are constant and the covariance between the two values of the series depends not only on the examined time but only on the difference between the two-time series. In order to apply the time series models, the series should be adjusted from the trend and seasonality (time-invariant). A subjective way to evaluate stationarity is using Augmented Dickey-Fuller (ADF) test statistics (Dickey & Fuller, 1979; Dickey & Fuller, 1981). The null hypothesis is that the series has a unit root. The alternative hypothesis is that the time series is stationary (or trend-stationary). As it can be seen in Table 4, the null hypothesis is rejected at the 0.05 significance level for the variables of the number of Total Events (S_TE), the number of Total Casualties (S_TC), the number of Total Passenger in These Events (S_TPE), the number of Total Commercial Passenger (S_TCP) and the number of Sabotage (S_S).

Table 4
ADF Test Results for Evaluating Stationarity

	S_TE	S_TC	S_TPE	S_TCP	S_S
ADF test value	-5.4208	-8.0372	-7.356	-17.1845	-12.2473
p	<0.001	<0.001	<0.001	<0.001	<0.001

When the standardized series (Figure 2) are examined, it is obvious that there is stationarity and the relationship between sabotage and other series can be examined. Therefore, the cointegration test is not necessary, and it can be used the series in the estimation of regressions for causality analysis.

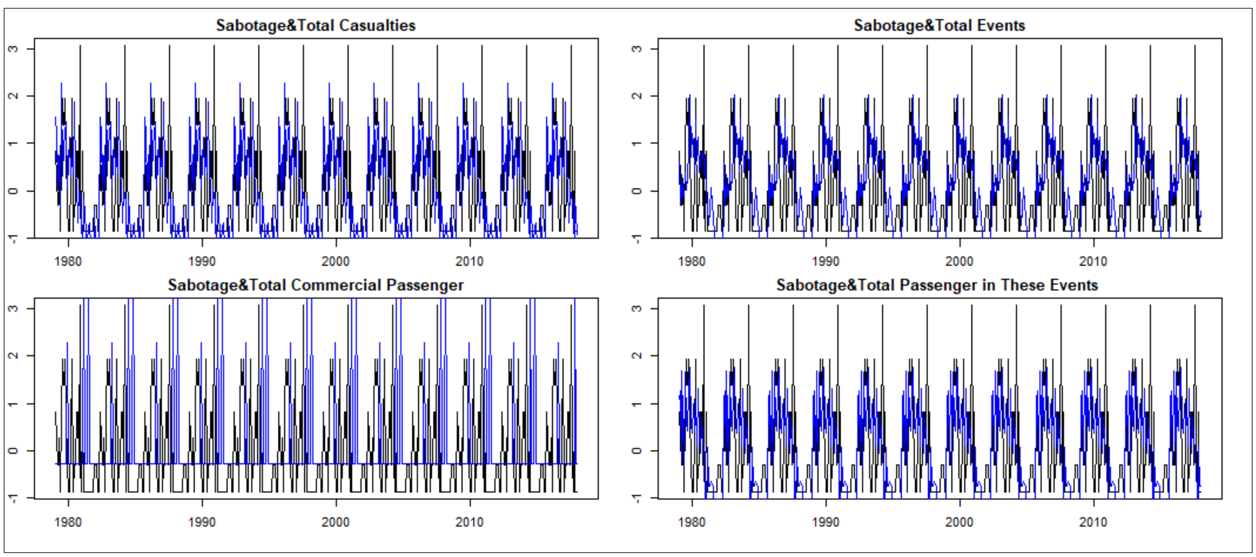

Figure 2. The Time Series Plot of S_S (Black Legend) And The Other Series (Blue Legend)

The VAR Model

The vector autoregressive (VAR) model takes each endogenous variable as the delay value of all endogenous variables to create the model and then generalizes the univariate regression model to a vector consisting of the multivariate time series variable regression model. The VAR (p) model involves the estimation of the following equations (Lütkepohl, 2005):

$$y(t) = a_1\, y(t-1) + a_2\, y(t-2) + \cdots + a_p\, y(t-p) + \varepsilon_t$$

In the formula, the vector of endogenous variables (S_TE, S_TA, S_TPE, S_TCP, S_S); *p* is the order of lags, ,…,is the coefficient matrix, each of vector of the lag endogenous variables and is a vector of systems' random error. The lag length *p* in VAR is selected by the minimum Akaike Information Criterion (AIC) by using the "VARselect" function with maximum lag equals 8. Table 5 shows the estimated VAR results. The greater *t*-values are showing a significant relationship with high evidence.

Table 5
Estimated VAR Model Results (for S_S)

Variables (lags)	**Estimate**	**Variables (lags)**	**Estimate**	**Variables (lags)**	**Estimate**	**Variables (lags)**	**Estimate**
S_S (1)	-1.223e+00 (-2.105e+13)	**S_S (2)**	-3.827e+00 (-1.902e+13)	**S_S (3)**	-1.672e-01 (-1.251e+13)	**S_S (4)**	-2.024e+00 (-2.402e+13)
S_TC (1)	-3.661e+00 (-3.004e+13)	**S_TC (2)**	-2.479e+00 (-1.902e+13)	**S_TC (3)**	-2.645e+00 (-1.209e+14)	**S_TC (4)**	-8.866e+00 (-2.074e+13)
S_TE (1)	5.929e-01 (9.873e+12)	**S_TE (2)**	-9.643e-01 (-3.091e+13)	**S_TE (3)**	-2.804e+00 (-1.278e+13)	**S_TE (4)**	2.931e+00 (9.882e+12)
S_TCP (1)	6.301e-01 (5.087e+12)	**S_TCP (2)**	-3.651e+00 (-2.102e+13)	**S_TCP (3)**	-1.894e+00 (-1.344e+13)	**S_TCP (4)**	1.146e+00 (4.867e+13)
S_TPE (1)	7.763e-01 (9.115e+12)	**S_TPE (2)**	6.656e+00 (2.036e+13)	**S_TPE (3)**	4.945e+00 (3.701e+13)	**S_TPE (4)**	8.081e+00 (2.265e+13)
Variables (lags)	**Estimate (t)**	**Variables (lags)**	**Estimate (t)**	**Variables (lags)**	**Estimate (t)**	**Variables (lags)**	**Estimate (t)**
S_S (5)	-1.716e-01 (-3.535e+12)	**S_S (6)**	-1.856e-01 (-3.602e+12)	**S_S (7)**	1.914e+00 (1.794e+13)	**S_S (8)**	-1.594e+00 (-2.796e+13)
S_TC (5)	-7.258e-01 (-1.008e+13)	**S_TC (6)**	-5.420e+00 (-2.977e+13)	**S_TC (7)**	-6.915e+00 (-3.276e+13)	**S_TC (8)**	-6.666e+00 (-1.995e+13)
S_TE (5)	-6.295e+00 (-3.107e+13)	**S_TE (6)**	-6.143e+00 (-2.031e+13)	**S_TE (7)**	-2.616e+00 (-6.519e+12)	**S_TE (8)**	7.151e+00 (1.687e+13)
S_TCP (5)	3.520e-01 (1.163e+13)	**S_TCP (6)**	-6.913e-01 (-5.138e+13)	**S_TCP (7)**	-1.426e+00 (-2.596e+13)	**S_TCP (8)**	2.008e+00 (-1.767e+13)
S_TPE (5)	2.020e+00 (1.549e+13)	**S_TPE (6)**	1.039e+01 (2.300e+13)	**S_TPE (7)**	1.036e+01 (2.044e+13)	**S_TPE (8)**	4.953e+00 (1.879e+13)

Impulse Response Functions

According to the estimated VAR model of each endogenous variable, it can be demonstrated an impulse response function analysis of the interactive relationship between S_S and the other series.

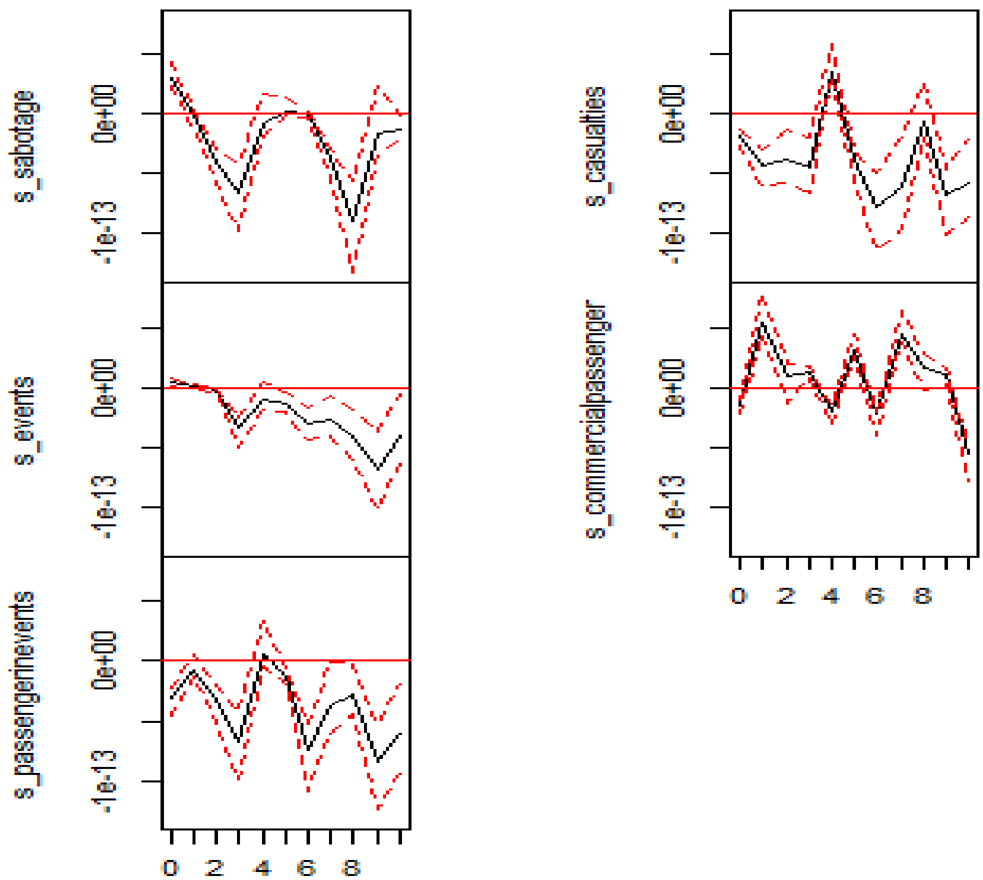

Figure 3. S_S Impulse Response.

In the first graph the impulse-response of S_S to S_S, at the initial period, a positive shock on S_S will obviously lead the S_S to go up by the shocking amount. Thus, the initial value is greater than zero. S_casualties (S_TC) graph shows that after being impacted by S_TCP, S_S remains negative in the short term. At stage 4, this impact becomes positive. The graph on the middle left-hand side shows that S_S began to rise after being impacted by S_events (S_TE) and then the impact slowly decreased. The graph on the middle right-hand side shows that S_S began to rise after being impacted by S_commercial passengers (S_TCP). The short term positive effect of commercial passenger numbers on sabotage can be attributed to the terrorists trying to make an impression with these actions. The graph on the bottom left-hand side shows that S_S stays negative after being impacted by S_passenger in events (S_TPE), and then impact slowly decreased in long term (Figure 3). Civil aviation is protected in the short term in line with the precautions, rules, and regulations applied in civil aviation, but as time passes, terrorist acts develop sabotage actions against these precautions, rules, and regulations. In the long term, this effect develops in the direction of increasing the number of sabotage.

Granger Causality Test

According to the VAR model, the Granger Causality Test is used to verify whether the S_S and S_TE, S_TA, S_TPE, S_TCP have Granger Causal Relation. The main idea of the Granger

Causality Test is to test whether the past values of a time series have the ability to predict the future values of another time series. If it is provided statistically significant information about future values, there will be a Granger Causal Relationship between these time series. On the contrary, if it is not achieved statistically significant information there has no Granger Causal Relationship (Granger, 1999, p. 165).

Table 6
Results of the Granger Causality Test

	F	***p***
S_TC	5.405	<0.001
S_TE	14.738	<0.001
S_TCP	14.100	<0.001
S_TPE	20.029	<0.001

The p-value stands for the rejection probability of Granger Causality. If the p-value is less than 0.05, the null hypothesis is rejected. As can be seen in Table 6, S_TC, S_TE, S_TCP, S_TPE has a significant impact on S_S. So, it can be established a causal relationship. During the period of 1979-2018, the Twin Tower Attacks on September 11th, 2001 have played an important role in sabotage events. So, before and after the year 2001 is examined in terms of the ratio of sabotage in total events and the ratio of fatalities in the total passenger in total events in the following section.

Table 7
The results of comparisons between the years 1979-2001 and 2002-2018

	1979-2001	**2002-2018**	***p***
The ratio of sabotage in total events	53/1,363 (3.89%)	7/608 (1.15%)	0.0014
The ratio of fatalities in total passenger in events	45,820/71,530 (64.06%)	16714/25,336 (65.97%)	**<0.001**

According to Table 7, the ratio of sabotage in total events is found statistically significantly higher between the years 1979-2001 than 2002-2018. Furthermore, between the years 1979-2001, the ratio of fatalities in the total passenger in total events is found statistically lower than 2002-2018 (Fisher's Exact, $p<0.05$). These numbers show that the ratio of sabotage events has dramatically decreased, so it can be said with the security applications after September 11, 2001, civil aviation security is more secure. However, the ratio of the fatality level in total events has not decreased (there is a slight increase), despite these applications after September 11, 2001.

Conclusions

In this paper, the civil aviation security concept was expressed in detail with historical developments and examples of applications. Furthermore, the terms were defined with the description of the sample data. In civil aviation, accidents have usually occurred from safety and security problems. First of all, the safety concept is related to the factors such as human errors, weather conditions, mechanical problems, air traffic control, ground crew, maintenance error and, other reasons such as that harmed passengers, facilities, airports. These factors are included in nearly all phases of accidents. Besides safety, this study is related to the security concept that included intentional events. To examine the 40-year accident data, all the information was taken from ACRO and Bureau of Aircraft Accident Archive (2020) and plane crash info database (2020). These data are related to the total number of casualties, total commercial passengers, total passengers in these events, and the total number of events. These four variables are examined against sabotage which only a part of civil aviation security. Sabotage means carry out intentional event against the rules and procedures about civil aviation safety. So, the reason for security problems is based on only one term that specified as sabotage. In general, sabotage is the most dangerous intentional activity in civil aviation security and it is related to having damage to civil aviation safety that means corrupt the system (Plane Crash Info Causes, 2020). Furthermore, at the end of the literature review and the time series analysis, the VAR model is explained in detail. According to the VAR model; there is a significant relationship between sabotage and total casualties, commercial passengers, passengers in these events, total events. The most significant causality of the sabotage is related to the number of total passengers that involved these events according to the Granger Causality Test. The second significant causality (with a slight difference) of the sabotage is the number of total events, and the third causality of the sabotage is the number of total commercial passengers. Finally, the fourth and the last significant causality of the sabotage is the number of total casualties. According to the impulse response functions, the number of total casualties has a negative short-term impact on sabotage. This situation means when the number of total casualties are increased, the number of sabotage will be decreased for a short period of time. To prevent these events, the rules and regulations in civil aviation are designed for the safety of civil aviation. Civil aviation is safe when these rules are implemented in an effective process. To show the efficiency of the rules and regulations, the Twin Tower Attacks on September 11th, 2001 played a dramatically important role in civil aviation. It has seen that the number of sabotage events decreased after 2001 with the implementation of new security precautions. So, this situation shows that civil aviation security has more secure more than three times after the year 2001. It is found a significant effect on sabotage events with the selected variables in this study. In future studies, the reasons for sabotage events can be discussed and classified in terms of the different parameters.

Acknowledgement

The author would thank previous researchers who work in civil aviation security and safety. With this researches, I got inspired to compare these two concepts and I wish to contribute to the social sciences in this way.

Disclosure Statement

In this article, it is declared that there is no conflict of interest related to not have any competing financial, professional, or personal interests from other parties. In this study, all of the data were taken from websites, so there is no need for ethical permission.

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Women's Perceptions of the Aviation Workplace: An Exploratory Study

Lindsay Stevenson
Embry-Riddle Aeronautical University

Katie S. Kirkpatrick
Embry-Riddle Aeronautical University

Haydee Maria Cuevas
Embry-Riddle Aeronautical University

Marisa D. Aguiar
Embry-Riddle Aeronautical University

Katya K. Rivera
Embry-Riddle Aeronautical University

Jorge L.D. Albelo
Embry-Riddle Aeronautical University

The purpose of this exploratory study was to garner a better understanding of the following research question: What factors may contribute to women's retention in aviation occupations in the United States? The Aviation Occupation Survey was developed drawing from the published literature in organizational retention and diversity in aviation to explore this research question. The survey consisted of 50 Likert-scale items on nine subjects related to career retention. A total of 188 participants (women = 70, men = 118) completed the survey. Results revealed similarities between women and men on perceptions about numerous aspects of their workplace, particularly job satisfaction, professional growth opportunities, challenging work, monetary benefits, non-monetary benefits, work-life balance, management practices, and aviation passion. However, results also revealed women reported significantly greater concerns than men on sexual harassment and gender bias in the workplace. Women also reported feeling less comfortable bringing concerns to management significantly more than men. These findings are consistent with other studies indicating a major obstacle facing women in aviation occupations stems from working in an environment with a pervasive male-dominated culture.

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In the past 90 years, the workforce has been diversified in many fields, yet gender diversity for occupations in the aviation domain (e.g., pilots, air traffic controllers, aircraft maintenance technicians, aviation educators) has grown at a much slower pace (Data USA, 2018a; Data USA, 2018b; Federal Aviation Administration, 2018; Luedtke, 1994; Lutte, 2019; McCarthy, Budd, & Ison, 2015; Stevenson, Cuevas, Kirkpatrick, Rivera, & Aguiar, 2020). Promoting gender diversity is essential to ensure a strong aviation workforce in the future. As noted by Hansen and Oster (1997), this will involve opening aviation occupations to all society members, leveraging the untapped potential in groups historically underrepresented in the industry. Although Hansen and Oster's (1997) report was published more than two decades ago, the aviation industry still has not achieved a balanced gender diversity representation. The key research question explored in this study was: What factors may contribute to women's retention in aviation occupations in the United States? The present study sought to answer the research question by developing an Aviation Occupation Survey based on existing literature. Furthermore, this study targeted only those who identify as women (e.g., cisgender, transgender, gender fluid) to participate in the Aviation Occupation Survey.

Factors Influencing Retention

Historically, gender bias in the workplace has contributed to perpetuating structural inequalities (Bridges, 2017; Coleman, 2020; Cundiff, Ryuk, & Cech, 2018; Ridgeway, 1997). Particularly, elements such as professional growth, monetary benefits, the role of management, and job satisfaction were identified as areas of interest affecting retention of women in the aviation workplace when the Aviation Occupation Survey was developed (Angle & Perry, 1981; Applebaum et al., 2003; Cabrera, 2009; Elizur & Koslowsky, 2001; Taneja, Pryor, & Oyler, 2012). Yet cultural ideals and gender inequality have affected women's overall progression in the workplace throughout the years (Dashper, 2019; Ming-Li & Boateng, 2020; Rubin, Paolini, Subasic, & Giacomini, 2019; Turesky & Warner, 2020; Webster, Adams, Maranto, & Beehr, 2018). Stamarski and Hing (2015) noted "if women are underrepresented in a particular educational program or a particular job type, and those credentials or previous job experience are required for selection, women are being systematically, albeit perhaps not intentionally, discriminated against" (p. 3). Essentially, hiring practices and policies for fields such as the aviation industry can be inherently biased against a particular group (e.g., women).

Equivalently, gender stereotypes in the workplace affect the lens through which employers describe their ideal workers. For example, Dashper (2018) claims "it is easier for men to embody the masculine traits, behaviors, and practices associated with workplace success than it is for women" (p. 543). However, through professional skills, individuals can generate a contextualized and personalized worldview of integrating themselves into their particular field. Ideally, employers should consider the employees' perceptions of their learning, experiences, and growth opportunities in an effort to promote a healthy workplace atmosphere (Coleman, 2020; Ming-Li & Boatend, 2020; Rubin et al., 2019).

Moreover, organizational retention has been studied extensively over the past few decades. For example, Applebaum et al. (2003) conducted a survey study among aerospace engineers, based on a sample size of 155 participants, and found commercial engineer women were more committed to their organizations than their male counterparts. Further, Applebaum et al. (2003) found job satisfaction was positively influenced by professional growth, challenging work, non-monetary benefits, work-life balance, remuneration, and management practices. The survey results showed an average response of 4.1 on a 5-point scale to “Do you wish to continue to work at xxx?”, which is well in the positive range (Applebaum et al., 2003, p. 274). The survey results also found employees provided the lowest ratings for opportunities for challenging work and better professional growth. To address these concerns, Applebaum et al. (2003) proposed solutions including more challenging work tasks, providing clear promotion criteria, improving training, and rotating staff through various departments based on the factors that encouraged the highest organizational commitment level.

Similarly, Taneja et al. (2012) conducted a study that explored retention principles for women in the workforce across multiple disciplines, such as work-life balance; “when individuals are satisfied with their careers, those individuals will try to keep their careers because a work/life component is significantly rewarding” (p. 48). Work-life balance positively influences the retention rate of the employees and the growth of the company in the competitive market. Monetary factors also affect retention rates. As Taneja et al. (2012) point out, women made 77% of men’s median weekly earnings in 2000, but in 2011 women made only 73.4 cents on every dollar men earned, based on the 2011 reportings of the Bureau of Labor Statistics. In 2011, women comprised 46.7% of the total workforce in businesses, yet of this total, 37% constituted lower and mid-level management positions, 26% were senior managers, and only 2.8% of women were CEOs at Fortune 500 companies (Taneja et al., 2012). Though Taneja et al. (2012) do not articulate the exact sample size or the specific population, their study suggests women encounter roadblocks preventing them from aspiring to higher level positions.

Saxena, Geiselman, and Zhang (2019) conducted a quantitative study to explore the social and organizational factors leading to greater retention of women and fewer incidences of workplace incivility. The primary focus was to “facilitate positive workplace experiences for women in STEM by reducing incivility” and thereby improve the retention rates (p. 590). The finding in Saxena et al. (2019) indicate that “prototypical threat” (harassment) and “lack of work” (challenging work) contributed to more incivility in the workplace and lower retention of women. Conversely, Saxena et al. (2019) recommended building social support and fostering a culture of openness and inclusion to improve women’s retention in the workplace based on the psychological nuance of workplace barriers women face in STEM fields.

While Saxena et al. (2019) provide a good generalizable foundation of social and organizational factors leading to greater retention of women in the workplace, qualitative research has shown women encounter profound challenges that cannot be quantified. For example, Annabi and Lebovitz (2018) conducted a comparative qualitative case study to better understand the organizational interventions required to improve women retention in the instructional technology (IT) workforce as described by women themselves. Given the pure qualitative nature of Annabi and Lebovitz’s (2018) study, their results are hard to transfer across multiple disciplines outside IT. However, their study shows some of the retention barriers women experience are related to management practices, professional growth opportunities, and perceived gender bias. Annabi and Lebovitz's (2018) findings raised questions about what factors may contribute to women's retention in aviation occupations.

Methodology

The Aviation Occupation Survey was created purposely for this study, drawing from the published literature in organizational retention and diversity in aviation (e.g., Angle & Perry, 1981; Applebaum et al., 2003; Cabrera, 2009; Elizur & Koslowsky, 2001; Taneja et al., 2012). The survey consisted of six demographic items (gender, current occupation, years in current occupation, previous occupation, years in previous occupation, and education). Since this exploratory study's research question explicitly focused on gender, information on other demographic variables (e.g., age, racial/ethnic background, socioeconomic status, sexual orientation, and gender identity) was not collected in the survey.

Following the demographic items, participants were presented with 50 Likert-scale items on nine categories related to career retention: job satisfaction (k = 7), professional growth opportunities (k = 8), challenging work (k = 5), monetary benefits (k = 4), non-monetary benefits (k = 4), work-life balance (k = 6), management practices (k = 3), gender-related concerns (k = 8), and aviation passion (k = 5). The survey items for the aviation passion category were adapted from Petitt (2019). Participants were asked to indicate the degree to which they agree with each statement using a five-point Likert-scale ranging from *Strongly Disagree* (1) to *Strongly Agree* (5). The statements were randomly presented both within and across categories.

The survey was administered online using Google Forms and was available from January 2020 through March 2020. For this initial exploratory study, no minimum sample size was established. Information about the survey was disseminated via various venues, including two professional conferences (Women in Aviation International, National Training Aircraft Symposium) and a social media outlet (aviation blog). Prior to conducting the survey study, an application was submitted to the university's Institutional Review Board for review and approval. All participant responses were anonymous and analyzed in aggregate.

Results

Demographic Items

A total of 188 participants (women = 70; men = 118) completed the Aviation Occupation Survey. Descriptive statistics for the demographic items are shown in Figures 1 through 5. As shown in Figure 1, a large percentage of respondents (68.82%) reported *Aircraft Pilot* as their current occupation. Examples of responses submitted for the *Other* option included: RPAS operator executive, private pilot, flight attendant, aviation human factors specialist, educator, FAA ASI, and terminal operations. As shown in Figure 2, almost half the respondents (48.66%) reported having spent more than 10 years in their current occupation.

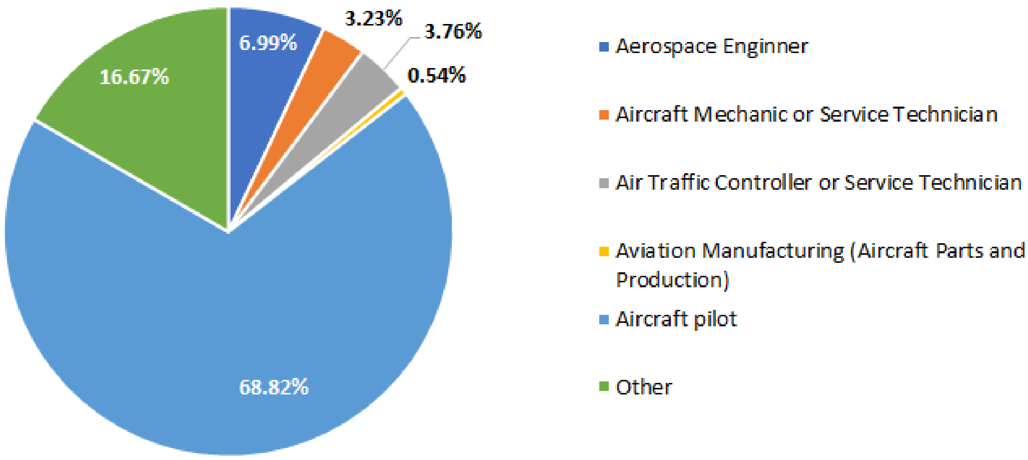

Figure 1. Participant Responses to Current Occupation (n = 186)

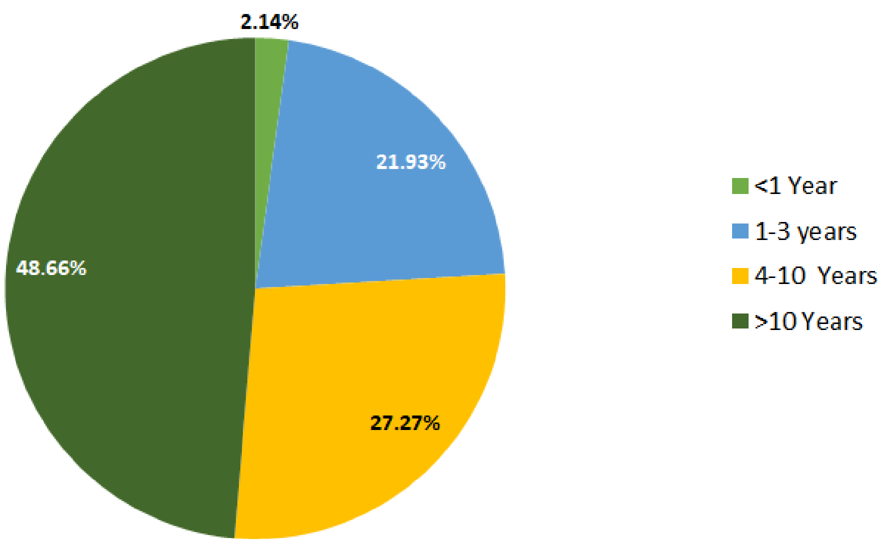

Figure 2. Participant Responses to Years in Current Occupation (n = 177)

As shown in Figure 3, for their previous occupation, a large percentage of respondents (61.05%) selected the *Other* option, with example responses including: student, military, Airline CFO, ATC/ATM engineer, professor, and NASA instructor. Further, as shown in Figure 4, almost half the respondents (47.50%) reported having spent 4-10 years in their previous occupation.

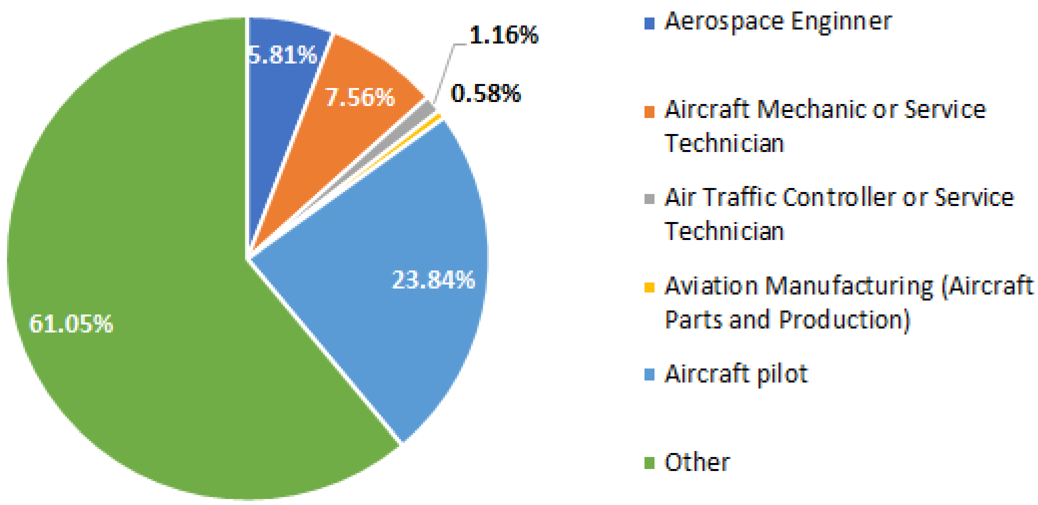

Figure 3. Participant Responses to Previous Occupation (n = 168)

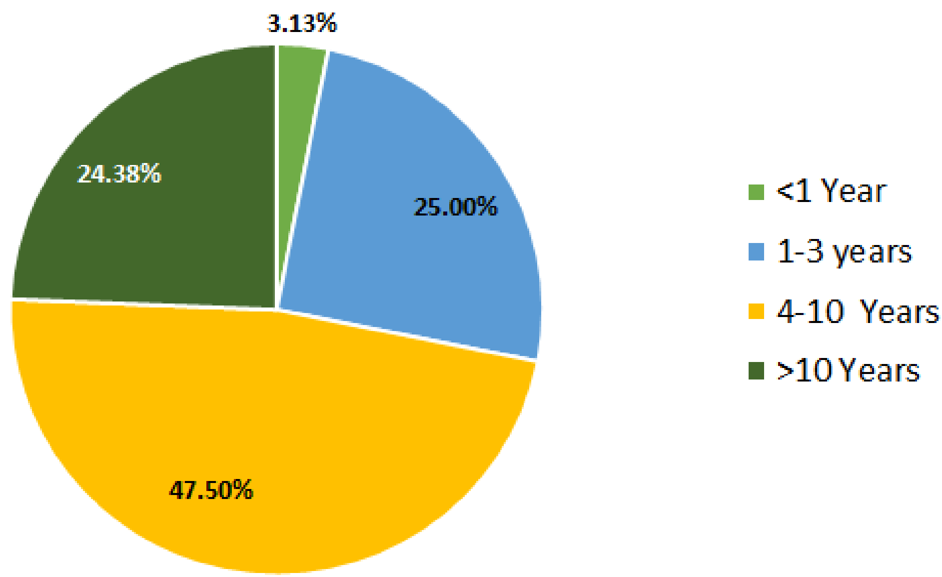

Figure 4. Participant Responses to Years in Previous Occupation (n = 147)

As shown in Figure 5, most respondents (93.62%) reported having some college education. A small number (8.51%) reported having some college credit, but no degree. Almost half the respondents (47.87%) reported having at least a bachelor's degree and about a quarter of respondents (26.06%) reporting having a master's degree.

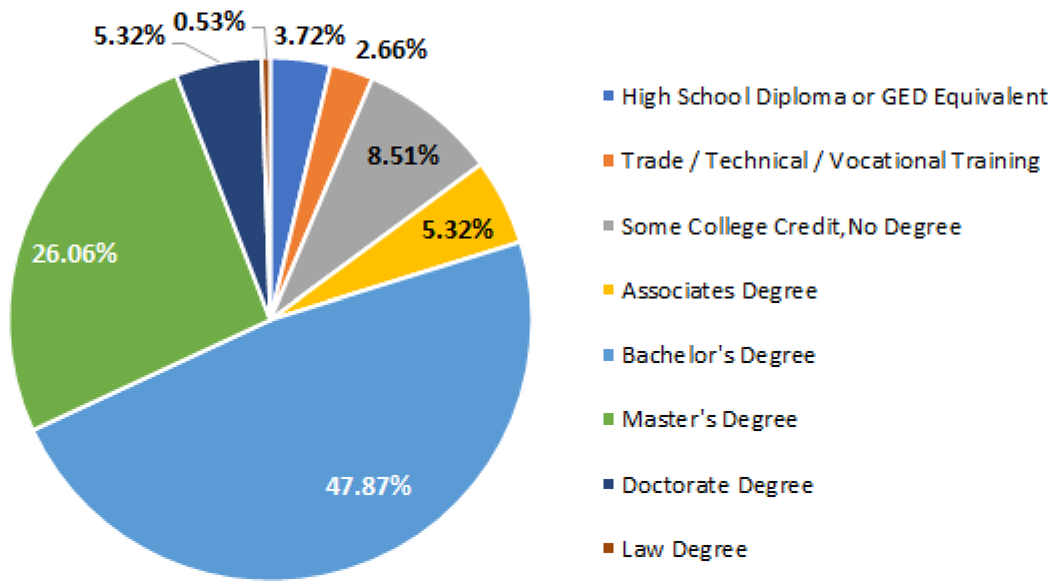

Figure 5. Participant Responses to Highest Level of Education Completed (n = 188)

Aviation Occupation Survey Items

Responses to the Aviation Occupation Survey were analyzed using a non-parametric test, which is appropriate for Likert-scale items since the responses, ranging from *Strongly Disagree* (1) to *Strongly Agree* (5), are treated as ordinal data. The Mann-Whitney Test (two independent samples) was used to analyze the survey data, with gender (female vs. male) as the grouping variable and responses to the Likert-scale items as the dependent variables. Separate tests were conducted for each survey category. Alpha was set at $p < .05$. Median values are reported for statistically significant differences between groups. Eleven survey items were negatively phrased, with a response of *Strongly Agree* viewed as negative and *Strongly Disagree* viewed as positive. The values for these items were reverse coded prior to analysis and are marked with a ^ symbol. Cronbach's coefficient alpha was used to test the internal consistency of the items in each survey category. Results are listed in Table 1.

Table 1
Cronbach's Coefficient Alpha for Aviation Occupation Survey Categories

Survey Category	α	*k*	*n* (valid)
Job Satisfaction	.798	7	188
Professional Growth Opportunities	.805	8	187
Challenging Work	.561	5	187
Monetary Benefits	.565	4	186
Non-Monetary Benefits	.612	4	187
Work-Life Balance	.475	6	188
Management Practices	.720	3	188
Gender-Related Concerns	.829	8	186
Aviation Passion	.695	5	188

Note. α = Cronbach's coefficient value; *k* = number of items; *n* (valid) = number of valid participant responses.

Job Satisfaction

Table 2 shows the mean ranks and test statistics of the between-groups comparison for the Job Satisfaction survey items. No significant differences for gender were found on any of the survey items, with responses for women and men generally falling within the *Neutral* (3) to *Agree* (4) range.

Table 2
Mean Ranks and Test Statistics for Gender on Job Satisfaction

Survey Item	Gender	MR	*U*	*p*
I enjoy working at my current place of employment.	Female	100.40	3717.00	.228
	Male	91.00		
I enjoy working with my peers.	Female	96.77	3971.00	.633
	Male	93.15		
The work I do makes a difference.	Female	103.29	3514.50	.072
	Male	89.28		
I feel fulfilled by my job.	Female	93.90	4088.00	.903
	Male	94.86		
My co-workers respect me and treat me fairly.	Female	87.22	3620.50	.127
	Male	98.82		
I see myself staying at my current place of employment for at least the next five years.	Female	97.42	3925.50	.556
	Male	92.77		
I am likely to seek another job in the next three months.^	Female	91.64	3929.50	.547
	Male	96.20		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance); ^ = item reverse coded.

Professional Growth Opportunities

Table 3 shows the mean ranks and test statistics of the between-groups comparison for the Professional Growth Opportunities survey items. No significant differences for gender were found on any of the survey items, with responses for women and men generally falling within the *Neutral* (3) to *Agree* (4) range.

Table 3
Mean Ranks and Test Statistics for Gender on Professional Growth Opportunities

Survey Item	Gender	MR	*U*	*p*
Employee promotion decisions are handled fairly.	Female	102.84	3546.00	.097
	Male	89.55		
Promotions are important to me.	Female	94.61	4122.50	.982
	Male	94.44		
My employer provides me the training I need to perform my job.	Female	98.74	3833.00	.391
	Male	91.98		
My supervisor is aware of my skills	Female	97.71	3905.00	.517
	Male	92.59		
Experienced co-workers provide me with constructive criticism	Female	87.36	3630.50	.147
	Male	98.73		
I am allowed to develop additional skills when I want to.	Female	103.16	3524.00	.082
	Male	89.36		
My place of employment offers challenging opportunities to excel.	Female	98.76	3742.50	.341
	Male	91.22		
I have opportunities for advancement at work.	Female	103.05	3531.50	.084
	Male	89.43		

Note. $n = 188$; MR = Mean Rank; U = test statistic for Mann-Whitney Test; p = p-value (test significance).

Challenging Work

Table 4 shows the mean ranks and test statistics of the between-groups comparison for the Challenging Work survey items. Overall, women and men responded similarly to the survey items in this category, with responses generally falling within the *Neutral* (3) to *Agree* (4) range. No significant differences were found. Notably, both women and men rated highly the survey item ‘I can meet the deadlines set for me’ (*Mdn* = 5.00).

Table 4
Mean Ranks and Test Statistics for Gender on Challenging Work

Survey Item	Gender	MR	*U*	*p*
My job makes the best use of my abilities.	Female	99.86	3755.00	.284
	Male	91.32		
My workload is challenging but achievable.	Female	98.04	3882.50	.470
	Male	92.40		
I can meet the deadlines set for me.	Female	98.31	3793.00	.279
	Male	91.42		
My supervisor has clear expectations of me.	Female	96.79	3970.00	.643
	Male	93.14		
The workload on my job prevents me from doing my best every day.^	Female	99.01	3814.00	.362
	Male	91.82		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance); ^ = item reverse coded.

Monetary Benefits

Table 5 shows the mean ranks and test statistics of the between-groups comparison for the Monetary Benefits survey items. A significant difference for gender was found for the survey item 'I am paid competitively for my skills,' (U = 3313.50, p = .024). Results indicated women (*Mdn* = 4.00) reported a higher rating for this survey item significantly more often than men (*Mdn* = 3.00) (see Figure 6). No significant differences were found on the other survey items, with responses for women and men generally falling within the *Neutral* (3) to *Agree* (4) range.

Table 5
Mean Ranks and Test Statistics for Gender on Monetary Benefits

Survey Item	Gender	MR	*U*	*p*
I am paid competitively for my skills.	Female	105.16	3313.50	.024
	Male	87.32		
I would leave my current company if another company offered me more money.^	Female	102.22	3504.00	.103
	Male	89.19		
My job offers a competitive benefits package (health, pension, etc.).	Female	100.00	3745.00	.269
	Male	91.24		
Monetary compensation is important to me.	Female	89.51	3781.00	.291
	Male	97.46		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance); ^ = item reverse coded.

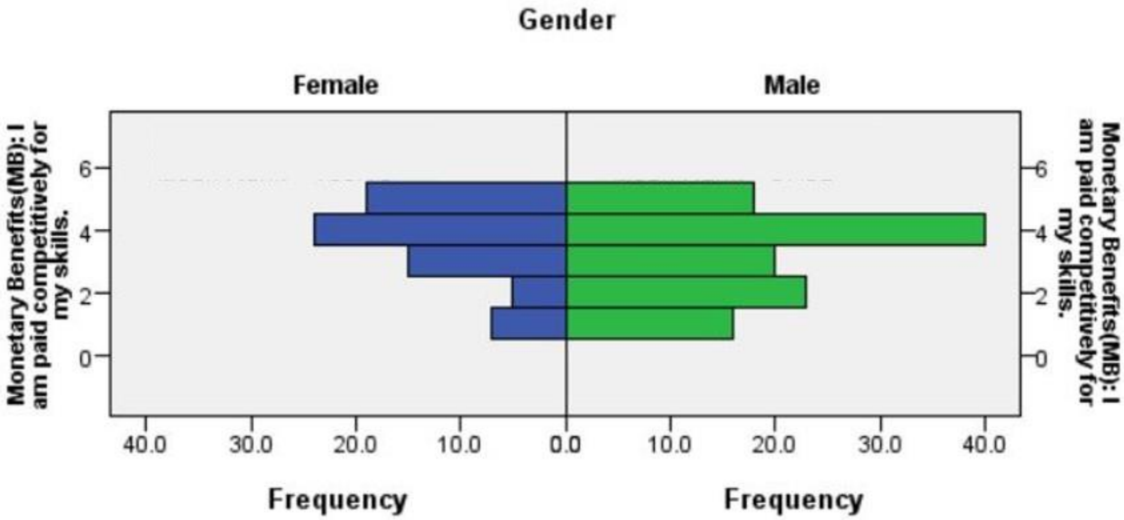

Figure 6. Distribution of Likert Responses for Survey Item 'I am paid competitively for my skills'. *Note*. MB = Monetary Benefits; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

Non-Monetary Benefits

Table 6 shows the mean ranks and test statistics of the between-groups comparison for the Non-Monetary Benefits survey items. No significant differences for gender were found on any of the survey items, with responses for women and men generally falling within the *Neutral* (3) to *Agree* (4) range. Notably, both women and men rated highly the survey item 'My job security is important to me' (*Mdn* = 5.00).

Table 6
Mean Ranks and Test Statistics for Gender on Non-Monetary Benefits

Survey Item	Gender	MR	*U*	*p*
My job security is important to me.	Female	93.34	4049.00	.878
	Male	94.39		
I feel that my job is secure.	Female	103.91	3471.50	.058
	Male	88.92		
I get recognized for my contributions.	Female	92.89	4017.50	.748
	Male	95.45		
I get rewarded for my efforts.	Female	95.64	4050.00	.819
	Male	93.82		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance).

Work-Life Balance

Table 7 shows the mean ranks and test statistics of the between-groups comparison for the Work-Life Balance survey items. Overall, women and men responded similarly to the survey items in this category, with no significant differences found. Responses for women and men generally fell within the *Neutral* (3) range. Notably, both women and men reported high ratings for the survey item 'Having a flexible work schedule is important to me' (*Mdn* = 5.00).

Table 7
Mean Ranks and Test Statistics for Gender on Work-Life Balance

Survey Item	Gender	MR	*U*	*p*
Working at my place of employment allows me to have a greater quality of life.	Female	96.68	3977.50	.657
	Male	93.21		
I struggle to balance my work and home life effectively.^	Female	92.26	3973.00	.653
	Male	95.83		
My employer cares about the health of their employees.	Female	96.21	4010.00	.733
	Male	93.48		
My job interferes with my responsibilities at home.^	Female	93.71	4074.50	.875
	Male	94.97		
Access to employer-sponsored childcare is important to me.	Female	98.82	3827.50	.383
	Male	91.94		
Having a flexible work schedule is important to me.	Female	98.19	3871.50	.396
	Male	92.31		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance); ^ = item reverse coded.

Management Practices

Table 8 shows the mean ranks and test statistics of the between-groups comparison for the Management Practices survey items. No significant differences were found on any of the survey items, with responses for women and men generally falling within the *Neutral* (3) range.

Table 8
Mean Ranks and Test Statistics for Gender on Management Practices

Survey Item	Gender	MR	*U*	*p*
Managers at my place of employment are adept at resolving conflicts.	Female	100.50	3710.00	.229
	Male	90.94		
Management portrays strong leadership skills.	Female	98.67	3838.00	.406
	Male	92.03		
My place of employment promotes diversity in leadership positions.	Female	86.95	3601.50	.131
	Male	98.98		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance).

Gender-Related Concerns

Table 9 shows the mean ranks and test statistics of the between-groups comparison for the Gender-Related Concerns survey items. For the purpose of this study, Gender-Related Concerns encompassed the following subjects: sexual harassment, gender bias, and management support. Note six survey items were negatively phrased and were reverse coded prior to analysis. Thus, a lower rating indicates a negative view on this statement.

A significant difference for gender was found for six of the eight survey items. Results indicated women (*Mdn* = 4.00) more often reported being concerned about sexual harassment in the workplace than men (*Mdn* = 5.00, *U* = 2788.00, *p* < .001) (see Figure 7). Women (*Mdn* = 4.00) also more often reported feeling uncomfortable reporting sexual harassment in their workplace than men (*Mdn* = 5.00, *U* = 2935.00, *p* < .001) (see Figure 8). Women (*Mdn* = 5.00) more often reported they have considered quitting their job because of sexual harassment at their workplace, compared to men (*Mdn* = 5.00, *U* = 3262.00, *p* = .001) (see Figure 9).

With regard to gender bias, women (*Mdn* = 4.00) more often reported having received fewer opportunities in their workplace because of their gender, compared to men (*Mdn* = 5.00, *U* = 2494.50, *p* < .001) (see Figure 10). Men (*Mdn* = 4.00) more often reported employees are treated equally in their workplace regardless of gender, compared to women (*Mdn* = 4.00, *U* = 3038.00, *p* = .004) (see Figure 11). Women (*Mdn* = 3.00) also more often reported feeling uncomfortable bringing concerns to management, compared to men (*Mdn* = 4.00, *U* = 3312.00, *p* = .020) (see Figure 12). No significant differences were found on the two survey items ‘Management at my place of employment takes sexual harassment seriously’ and ‘I rarely feel supported by management,’ with responses for women and men generally falling within the *Neutral* (3) to *Agree* (4) range.

Table 9
Mean Ranks and Test Statistics for Gender on Gender-Related Concerns

Survey Item	Gender	MR	*U*	*p*
I am concerned about sexual harassment in my workplace.^	Female	75.33	2788.00	<.001
	Male	105.87		
I feel uncomfortable reporting sexual harassment at my workplace.^	Female	77.43	2935.00	<.001
	Male	104.63		
Management at my place of employment takes sexual harassment seriously.	Female	86.77	3589.00	.115
	Male	99.08		
I have considered quitting my job because of sexual harassment at my workplace.^	Female	82.10	3262.00	<.001
	Male	101.86		
I have received fewer opportunities in my workplace because of my gender.^	Female	71.14	2494.50	<.001
	Male	108.36		
Employees are treated equally in my workplace regardless of gender.	Female	79.03	3038.00	.004
	Male	102.03		
I rarely feel supported by management.^	Female	102.96	3538.00	.092
	Male	89.48		
I feel uncomfortable bringing concerns to management.^	Female	82.81	3312.00	.020
	Male	101.43		

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance); ^ = item reverse coded.

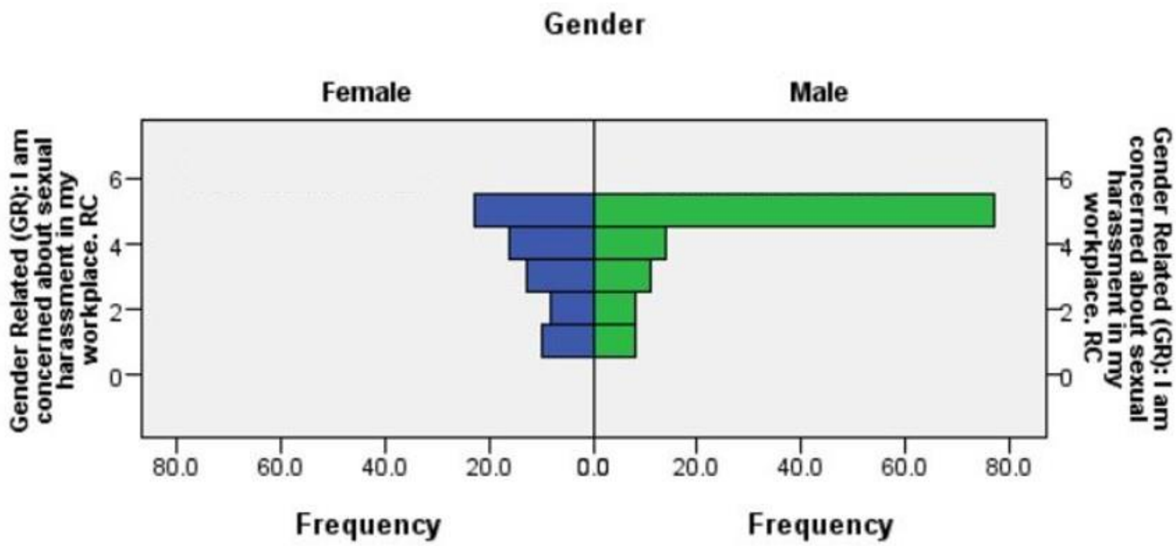

Figure 7. Distribution of Likert Responses for Survey Item 'I am concerned about sexual harassment in my workplace'. *Note*. GR = Gender-Related Concerns; RC = reverse coded; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

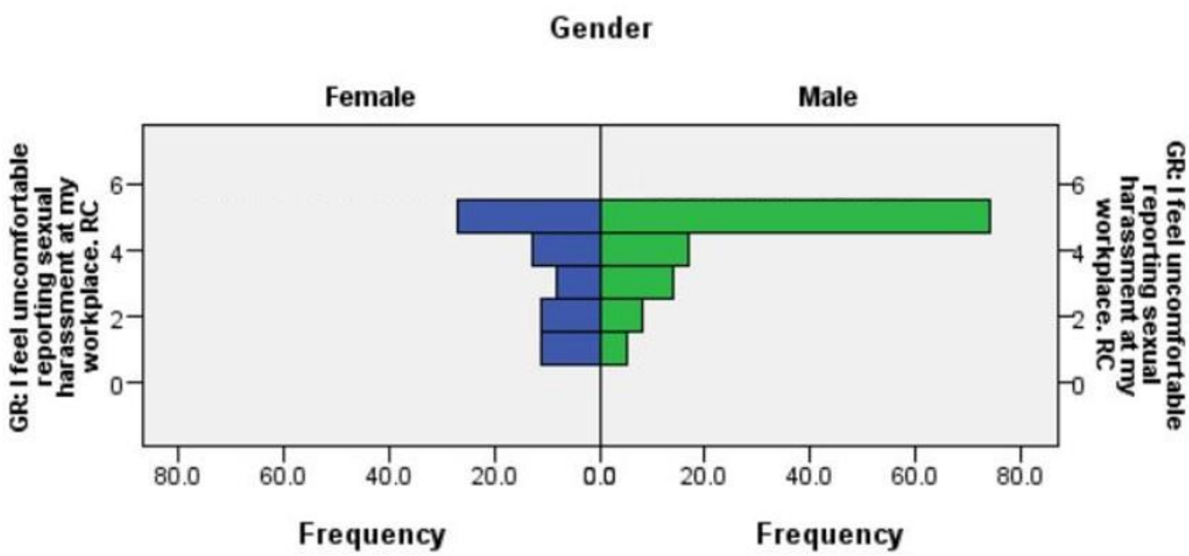

Figure 8. Distribution of Likert Responses for Survey Item 'I feel uncomfortable reporting sexual harassment at my workplace'. *Note*. GR = Gender-Related Concerns; RC = reverse coded; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

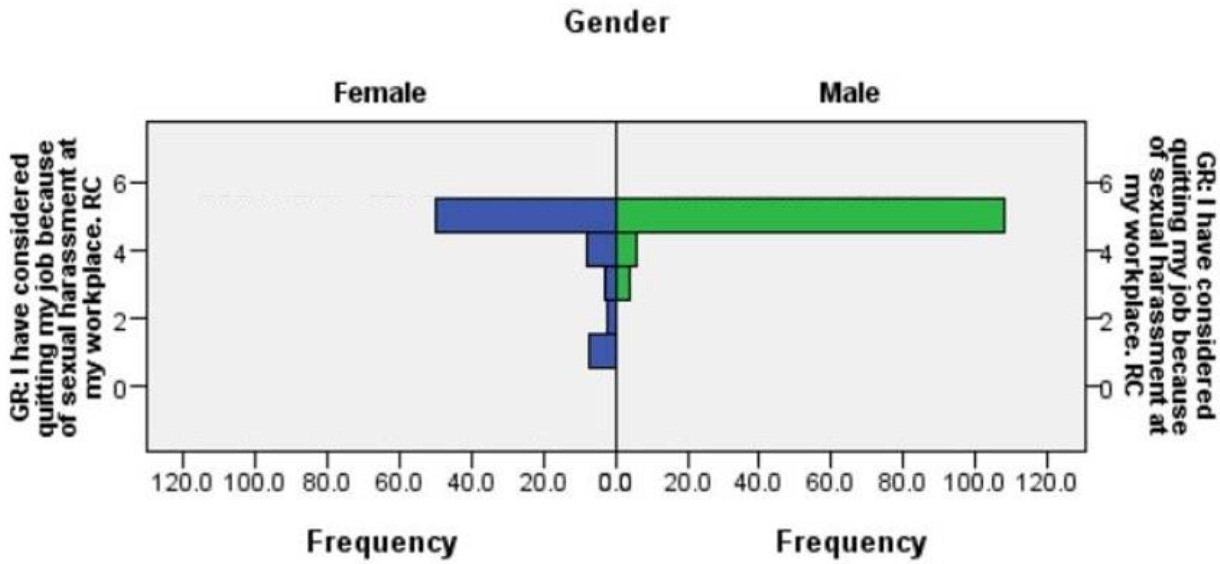

Figure 9. Distribution of Likert Responses for Survey Item 'I have considered quitting my job because of sexual harassment at my workplace'. *Note*. GR = Gender-Related Concerns; RC = reverse coded; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

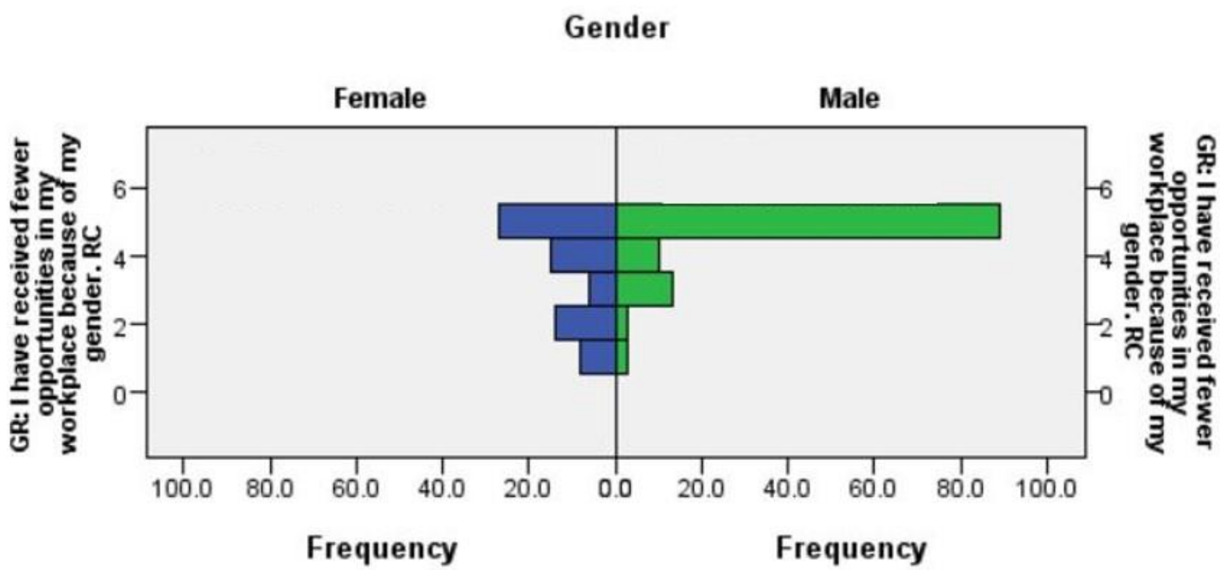

Figure 10. Distribution of Likert Responses for Survey Item 'I have received fewer opportunities in my workplace because of my gender'. *Note*. GR = Gender-Related Concerns; RC = reverse coded; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

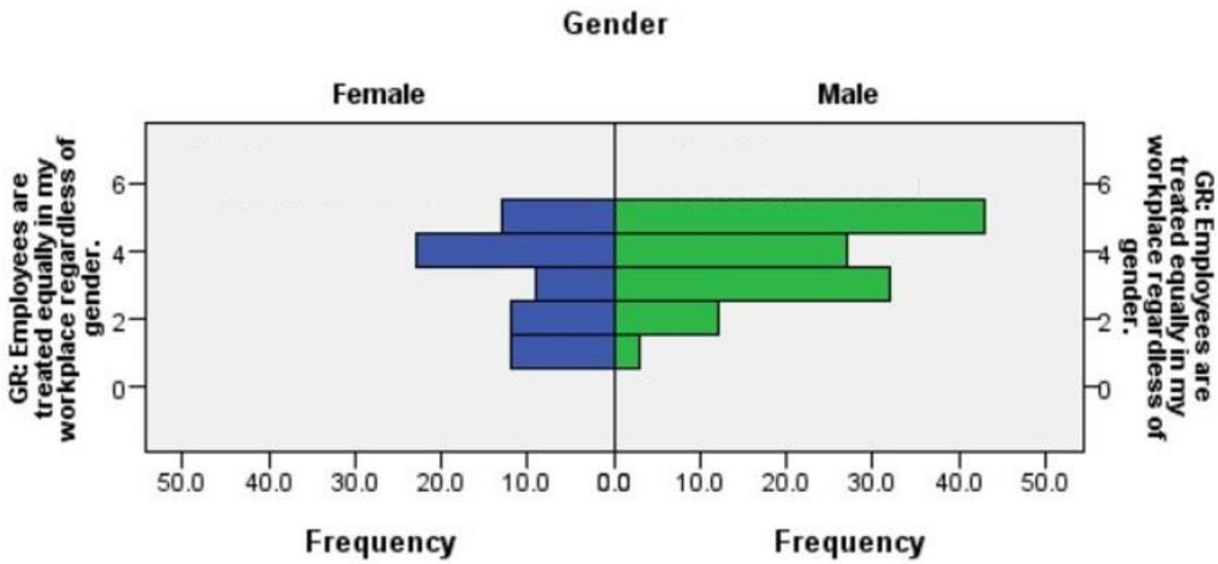

Figure 11. Distribution of Likert Responses for Survey Item 'Employees are treated equally in my workplace regardless of gender'. *Note*. GR = Gender-Related Concerns; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

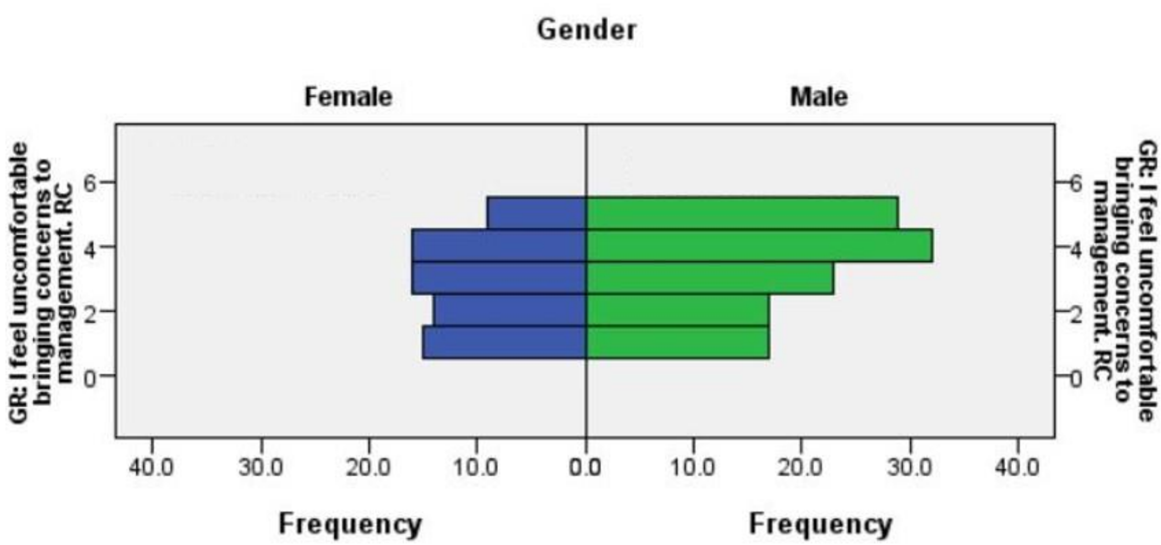

Figure 12. Distribution of Likert Responses for Survey Item 'I feel uncomfortable bringing concerns to management'. *Note*. GR = Gender-Related Concerns; RC = reverse coded; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

Aviation Passion

Table 10 shows the mean ranks and test statistics of the between-groups comparison for the Aviation Passion survey items. A significant difference for gender was found for only one survey item. Women (*Mdn* = 5.00) more often reported owning aviation-themed products than men (*Mdn* = 4.00, *U* = 3448.00, *p* = .038) (see Figure 13). No significant differences were found on the other four survey items, with responses for women and men generally falling within the

Neutral (3) to *Agree* (4) range. Notably, both women and men reported high ratings for the survey item 'I feel great pride in working in the aviation domain' (*Mdn* = 5.00).

Table 10
Mean Ranks and Test Statistics for Gender on Aviation Passion

Survey Item	Gender	MR	*U*	*p*
I own aviation-themed products, such as aircraft models, t-shirts, artwork, or coffee mugs.	Female Male	104.24 88.72	3448.00	.038
I read aviation books or magazines for enjoyment.	Female Male	96.40 93.37	3997.00	.703
I frequent social media sites to connect with others in the aviation profession.	Female Male	98.84 91.92	3826.00	.385
I feel great pride in working in the aviation domain.	Female Male	101.19 90.53	3662.00	.113
My aviation occupation defines who I am.	Female Male	94.74 94.36	4113.50	.963

Note. *n* = 188; MR = Mean Rank; *U* = test statistic for Mann-Whitney Test; *p* = p-value (test significance).

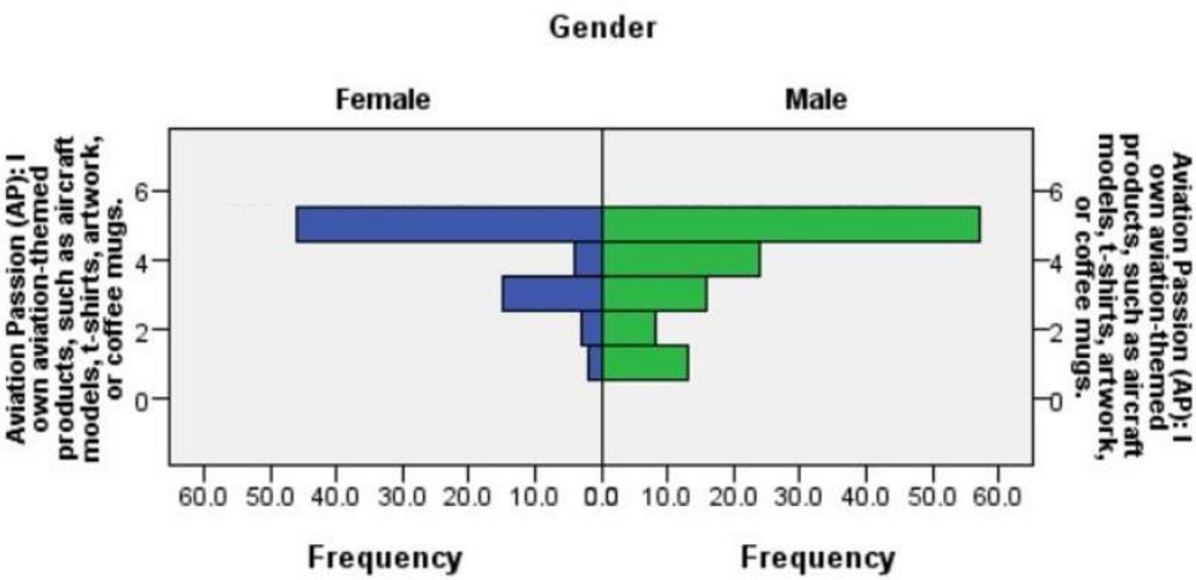

Figure 13. Distribution of Likert Responses for Survey Item 'I own aviation-themed products, such as aircraft models, t-shirts, artwork, or coffee mugs'. *Note*. AP = Aviation Passion; range from *Strongly Disagree* (1) to *Strongly Agree* (5).

Discussion

The purpose of the Aviation Occupation Survey developed for this exploratory study was to provide insights into the research question: What factors may contribute to women's retention in aviation occupations in the United States? Overall, results revealed similarities between women and men on perceptions about numerous aspects of their workplace related to retention, particularly job satisfaction, professional growth opportunities, challenging work, monetary benefits, non-monetary benefits, work-life balance, management practices, and aviation passion. Notably, both women and men agreed on the importance of monetary compensation, job security, and a flexible work schedule. Also, both women and men reported feeling they can meet the deadlines set for them as well as feeling great pride in working in the aviation domain.

However, results also revealed women reported significantly greater concerns than men on sexual harassment and gender bias in the workplace. Women also reported feeling less comfortable bringing concerns to management significantly more than men. These findings are consistent with other studies indicating a major obstacle facing women in aviation occupations stems from working in an environment with a pervasive male-dominated culture (Bridges, Neal-Smith, & Mills, 2014; Germain, Herzon, & Hamilton, 2012; Hansen & Oster, 1997; Luedtke, 1994; McCarthy et al., 2015).

To illustrate, Mitchell, Krisovics, and Vermeulen (2006) conducted a gender study of 1114 pilots (female = 143; male = 971) in Australia. The survey was given to both women and men, and they were asked to answer both qualitative and quantitative questions about the same and opposite gender. Comments reported by male respondents to the survey ranged from "I think standards have been lowered for feminine [sic] commercial pilot entry" to "gender should not be an issue" to the more degrading, "women's lives are dominated by their ovulation, menstruation and emotions" (Mitchell et al., 2006, p. 45). In comparison, female responses included, "a good woman pilot is capable of outclassing the male equivalent," "I think it is the skill of the individual rather than the gender," and "*another empty kitchen* comment is still made" (Mitchell et al., 2006, p. 45).

Similarly, Walton and Politano (2014) conducted a study with a sample of 83 pilots (female = 31; male = 52) on gender-related perceptions among female and male pilots. Results supported prior research suggesting female pilots are at greater risk for negative perceptions and sexism by male pilots, as evident by some comments expressed by male pilots toward female pilots in the course of the study, such as "I'm sure most of us would agree, female pilots would be better served sticking to acts of distaff [a woman's domestic work] than aviating," and the disturbing off-color comment, "Beavers are for *after* flying" (Walton & Politano, 2014, p. 71).

In a recent study, Lutte (2020) reported the results of a survey administered to members of Women in Aviation International. Of the 1,323 respondents who completed the survey, the perceived existence of a 'good old boy' network was one of the top three factors negatively influencing their decision to pursue a career in aviation (35%) or to remain in the aviation industry (41%). As noted by Lutte (2020), workplace culture continues to be "a deterrent to the ability to recruit and retain women in aviation" (p. 17).

Study Limitations and Implications for Future Research

The exploratory nature of this research limits drawing definitive conclusions about the study's findings. Further, the small sample size, compared to the aviation workforce population, and the unequal number of women and men who responded to the survey, precluded a rigorous validation of the survey. The internal consistency of some of the survey categories (Challenging

Work, Monetary Benefits, and Work-Life Balance) was lower than ideal. Thus, future research is necessary to revise the items and validate with a larger sample to increase these survey categories' internal consistency. Finally, the implication of COVID-19 was not considered in this research, as the study was conducted before the pandemic took hold of the country.

With consideration for these limitations, research is warranted to more systematically investigate the concerns highlighted in this study, both in terms of garnering a better understanding of why these negative perceptions and attitudes exist as well as increasing awareness of the harmful consequences of sexual harassment and gender bias disproportionately affecting women in aviation. In addition, over the past few decades, gender has become a broad term encompassing biological gender, gender identity, gender fluidity, transgender, and so forth. Further research is warranted to examine the factors influencing the retention of these distinct groups. Beyond gender, future research must also investigate other key demographic variables such as age, racial/ethnic background, socioeconomic status, and sexual orientation.

Conclusion

Findings from this exploratory study highlighted areas where women and men shared similar perceptions on factors related to retention, suggesting that organizational policies and practices could increase the retention of women by providing them with equitable access to these benefits. However, consistent with prior research, findings highlighted critical areas for improvement to increase the retention of women. Although recruitment is key to attracting more women to aviation careers, retaining women already working in the aviation industry is equally important. In both the private and public sectors, organizational stakeholders must work together to identify viable solutions to restructure the system to accelerate gender parity and create a safe work environment open to all employees regardless of gender, whether cisgender, transgender, or gender fluid.

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What Type of Person Would Prefer Driverless Cars Over Commercial Flight?

Mattie N. Milner
Embry-Riddle Aeronautical University

Sean R. Crouse
Embry-Riddle Aeronautical University

Stephen Rice
Embry-Riddle Aeronautical University

Scott R. Winter
Embry-Riddle Aeronautical University

Prior research has investigated ground and air transportation industries independently; however, few people have considered the impact driverless cars will have on commercial aviation. This study created a regression equation to predict what type of individual would prefer driverless cars over commercial flights. Participants (n = 2,016) provided demographic information, individual travel behavior, and preference for the two travel modes in two stages. Stage 1 created an equation through backward stepwise regression. In Stage 2, participants' scores were predicted using the Stage 1 equation compared to their actual scores to validate the Stage 1 equation through the four scenarios. Significant predictors from all scenarios were Upper Social Class, Vehicle Affect, Airplane Affect, and Vehicle Comfort. These factors accounted for nearly half the variance from the data. The equation was then tested in Stage 2 tested using a t-test, correlation, and comparison of cross-validated R^2. The model fit was demonstrated to be strong in all scenarios. These predictors will aid in identifying possible early adopters of autonomous vehicles. Implications of the findings with suggestions for future research are discussed in detail in this study.

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As technology matures at an ever-increasing rate, industries evolve with processes that develop automation rapidly. The new technology is formed simultaneously with user interactions, directly molding the designs. The automotive industry has created a focal point in their *drive* for a fully autonomous vehicle (AV) (i.e., driverless). While most research has focused on the usability, functionality, and factors that influence a consumer's willingness to adopt the technology, limited research has looked at other transportation industries' impact. Individuals often choose travel methods after exploring several factors: personality, preferences, travel distance, price, etc. This study explores consumers' preferences and attempts to identify factors that possibly influence their penchant for AVs or commercial aircraft (CA). The study creates and validates a model to predict the participants' choice (AV or CA) using several factors backed by literature.

Literature Review

According to the National Highway Transportation Safety Administration (NHTSA), there are six accepted vehicle automation levels in current standards: 0 – No automation, 1 – Driver Assistance, 2 – Partial Automation, 3 – Conditional Automation, 4 – High Automation, and 5 – Full Automation. Leading automobile manufacturers, such as Tesla, Waymo, and Uber, have been attempting to deliver a safe and effective level five vehicle to the general public (NHTSA, 2015; Reimer, 2014). A common claim among these companies is the technology will function in every condition a human could negotiate, but without the human. Research and development have focused on safe and effective systems that can carry passengers and safely interact with other vehicles on the road, their drivers, and pedestrians. This research often does not consider a consumers' behavioral intentions towards automated vehicles or the technologies' impact on other transportation industries.

Existing research has explored travelers' opinions on the preferred mode of travel, with over 2/3 of participants preferring driverless cars over a commercial flight on a 5-hour, midrange trip (Rice & Winter, 2018). Despite airline tickets' perceived costliness, companies only profit $10-$20 from each ticket. Conservatively, if airlines lose 1 in 10 passengers, there would be severe financial ramifications. To mitigate the losses, airlines may be forced to increase ticket prices, reduce the number of routes, or add additional micro-transactions to make up for this loss, resulting in a higher number of customers finding alternative travel.

Currently, in the United States, travelers have limited efficient options for traveling. CA travel brings with it many drawbacks for travelers. Customers must arrive early to go through security screening, travel through crowded airports, cram into a small seat surrounded by strangers, all for the convenience of shortened travel. Furthermore, recent health concerns around the COVID-19 pandemic have further decreased the public's willingness to fly and cast a foreboding cloud on commercial aviation's future success (Lamb, Winter, Rice, Ruskin, & Vaughn, 2020; Whitley, 2020). Travel in an automobile usually can provide more comfort due to the traveler's control of setting their schedule. However, long-distance car travel can be exhausting and dangerous. Drivers may attempt to cover their trip without stopping, which can cause mental and physical exhaustion increasing the inherent risk in driving. Understanding the types of travelers who would likely choose an AV over CA could provide a litany of information to the industries.

The push for integrating autonomous transportation is the main narrative through the media, research organizations, and consumer safety reports (Rice, Winter, Mehta, & Ragbir, 2019). Despite this push, there is little consideration into the effect of AV on commercial aviation. Historically, the commercial aviation industry financially performed well, although the current economic crisis created from COVID-19 has negatively impacted the aviation industry (International Civil Aviation Organization (ICAO), 2020). Aviation is approaching an interesting period with its lowest recorded profit per flight (McCartney, 2018) and consumer enjoyment levels down (Kloppenborg & Gourdin, 1992; Nadiri, Hussain, Ekiz, & Erdogan, 2008; Young, Cunningham, & Lee, 1994).

Many speculative reports predict the impact of AV on the transportation industry. Thus far, the main conclusion is that as AV technology matures, travelers will opt for AVs over other transportation types. This outcome may be due to the increased level of comfort and convenience they can provide. However, only a single prior study investigated AVs' possible impact on CA (Rice & Winter, 2018).

Predictive Factors

This study considered 20 factors that could predict an individual's preference for riding in an AV. These factors vary from demographic information (age, gender, social class, and ethnicity) to financial questions (price and perceived value), as well as technology-based questions (familiarity, fun factor, wariness of new technology). Other identifying factors include individual personality (based upon openness, conscientiousness, extraversion, agreeableness, and neuroticism), and finally, vehicle and airplane specifics (comfort, affect, external factors). A summary and justification of these predictors follow.

Age. Age brings about physical and mental obstacles (i.e., delayed reaction, reduced mobility, reduced vision, etc.) that often increase an individual's dependency on others or causes them to isolate themselves. Increased isolation can harm mental health (Marottoli et al., 1997; Ragland, Satariano, & MacLeod, 2005). With this in mind, senior citizens may view AVs as a way to remain independent and keep their freedoms without relying on other individuals for transportation (Harper, Hendrickson, Mangones, & Samaras, 2016; Howard & Dai, 2014). It can be assumed that they generally earn more as one ages, making it easier to purchase newer technologies that may increase individual freedoms and mobility, such as an AV (Reimer, 2014).

Gender. When faced with the same situations, women often shy on the side of caution (Borghans, Heckman, Golsteyn, & Meijers, 2009; Byrnes, Miller, & Schafer, 1999; Charness & Gneezy, 2012; Fehr-Duda, de Gennaro, & Schubert, 2006; Rice & Winter, 2019). This finding has been replicated in numerous scientific studies on financial decisions, social situations, lifestyle choices, and others. For example, Rice and Winter (2019) showed women were less willingness to fly aboard an autonomous aircraft. Anania et al. (2018) showed the same results for robotic dentistry, and Winter et al. (2019) found the same results for walking in front of a driverless vehicle.

Social class. Social class is comprised of several variables (income, education level, employment, etc.) that define the individual's social-economic status (SES) (Ames, Go, Kaye, & Spasojevic, 2011). Each of the individual variables that determine a person's SES could increase the likelihood of a person's willingness to accept new technology or use it, in particular high-risk technology. Prior studies show the higher an individual's social status, the more positively they view newer technologies and have more experience using more recent technologies (Maldifassi & Canessa, 2009).

Ethnicity. Cultural identity is tied to the inherent personality traits of individuals in a community. Western cultures (i.e., United States) are much more individualist than Eastern cultures' collectivism (e.g., Asian and the Middle East). Individuals' emotional responses and behaviorisms towards autonomous technology have been identified through ethnographical research (Mehta, Rice, Winter, & Eudy, 2017; Srite & Karahanna, 2006). Specifically, collectivistic societies generally will trust newer technology and are more willing to adopt it so long as it benefits the community as a whole (Haboucha, Ishaq, & Shiftan, 2017; Hofstede, 1980, 2001; Markus & Kitayama, 1991; Mehta et al., 2017).

Perceived value. According to the Technology Acceptance Model and the Unified Theory of Acceptance and Use of Technology (UTAUT), an individual's perceived usefulness of a specific technology is generally a strong prognosticator of user behavior. Perceived value can often determine how useful a product or service is to an individual. The perceived value, in theory, is "the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given" (Zeithaml, 1988, p. 14).

Familiarity. Previous consumer behavior research explored familiarity and its impact on a product. As the individual's experience and knowledge with the product grow, they develop a set of heuristics for decision-making (Alba & Hutchinson, 1987; Bozinoff, 1981; Kinard, Capella, & Kinard, 2009). Therefore, the understanding of external stimuli, such as technology, is familiarity.

Fun factor. As mentioned earlier, hedonic motivation is often a significant influencer in a consumers' willingness to use a product and their intent. An individual's perceived level of enjoyment while using technology can predict behavioral intention. Nordhoff, de Winter, Kyriakidis, van Arem, & Happee (2018) discovered that individuals "gave high ratings for thinking that they would enjoy taking a ride in a driverless vehicle…[and] higher ratings for believing that people important to them would like it when they use driverless vehicles" (p. 3).

Wariness of new technology. Technology has matured faster in the last 50 years than the previous two hundred in Western society (Berman & Dorrier, 2016). This acceleration can be attributed to the significant advancements in science, technology, engineering, and mathematics. One disadvantage of this rapid development of technology is that many individuals cannot keep up with these continually evolving areas and lack understanding in many breakthroughs. When presented with new technology, it is normal for individuals to question potential risks from this technology. The lack of knowledge can affect the users' trust (Merritt & Ilgen, 2008) and lead to their wariness of adopting the technology in question (Lee & Moray, 1992; Lee & See, 2004; Muir, 1987; Riley, 1989).

Personality. Existing research has examined "perceptions of user acceptance of, concerns about, and willingness to buy AV technology" (Clark, Parkhurst, & Ricci, 2016, p. 17). However, it should be noted that an individual's personality traits only show a weak correlation with AVs' perceptions (Clark et al., 2016; Kyriakidis, Happee, & de Winter, 2015). Other research has identified that highly extroverted people are more likely to initially trust new technology, which can have a positive effect on behavioral intent (Merritt & Ilgen, 2008). With this in mind, there is no specific literature to support that personality will affect consumers' decisions either way since personality positively affects the decision-making processes.

Technology acceptance. Despite AV technology maturing and becoming more available, one cannot assume that availability positively correlates with a consumer accepting and using the technology. The Unified Theory of Acceptance and Use of Technology (UTAUT) lists several factors that affect an individual's behavioral intent and how they accept the new technology and its uses (Venkatesh, Morris, Davis, & Davis, 2003). A recent study used these factors to measure how accepted the various adaptive driver assistance systems (i.e., lane assist, collision avoidance, adaptive cruise control, etc.) were. The findings displayed perceived usefulness and ease of use, the performance and effort expectancy, and attitude all were predictors of behavioral intention in an individual (Rahman, Lesch, Horrey, & Strawderman, 2017).

General affect. Researchers traditionally studied individual decision-making processes in finance due to economist, marketers, and the industry's desire to understand how the consumer made complex decisions and choices (Frydman & Camerer, 2016; George & Dane, 2016; Sokol-Hessner, Raio, Gottesman, Lackovic, & Phelps, 2016). It is known that the most efficient process would be the individual to consider every advantage and disadvantage, and only then selecting the best choice (Frydman & Camerer, 2016; Slovic, Peters, Finucane, & MacGregor, 2005). Despite this highly effective process, research shows that emotion plays a seemingly significant role when an individual makes a decision (Lerner, Li, Valdesolo, & Kassam, 2015; Peters, Västfjäll, Gärling, & Slovic, 2006; Schwarz & Clore, 2003; Slovic et al., 2005). Without experience or knowledge of the technology or situation, individuals may rely on their emotions to guide their decisions.

Current Study

The purpose of the current study was twofold. First, to build a regression equation that accurately described the data. Second, to validate a predictive model that could be used to predict future datasets accurately. Participants were presented a series of questions through an electronic survey instrument. The dataset was then randomly divided into two stages. The first dataset used in Stage 1 created the regression equation, while the second dataset for Stage 2 was used to test for model fit and validation.

Methods

Participants

Two thousand and sixteen people (54.5% female) participated in this study with a mean age of 38.48 (*SD* = 11.94) years. The data was collected via convenience sampling techniques through Amazon's ® Mechanical Turk ®. Previous research has shown that this data is as valid as data collected through in-person surveys (Berinsky, Huber, & Lenz, 2012; Buhrmester, Kwang, & Gosling, 2011; Coppock, 2018; Deutskens, de Jong, Ruyter, & Wetzels, 2006; Germine et al., 2012; Rice, Winter, Doherty, & Milner, 2017). Participants who completed the survey were compensated for their time with a payment of 50 cents.

Materials and Procedure

Participants were presented with an electronic consent form to begin the study and then were provided with instructions. In the AV section of the survey, participants read the following scenario: "*Imagine a time in the future where driverless cars are available to the general public and they have a safety record equal to, or better than, regular cars. You have to travel from one major city to another for work related business, but the autopilot would do all the work and you could even sleep along the way.*" Next, participants were asked to respond to the Perceived Value scale, Familiarity scale, Fun Factor scale, Wariness of New Technology scale, a General Affect scale, the Vehicle Comfort scale, and Vehicle External Factors scale (see Appendix B for a complete listing of these scales).

In the CA section, participants read the following scenario: "*Imagine you have to travel from one major city to another for work related business. You decide to take a commercial flight.*" Next, participants were asked to respond to the same questions from the previous section, except 'AV' was replaced with 'airplane,' and they also were presented two additional scales (Airplane Comfort scale and the Airplane External Factors scale (see Appendix B for a complete listing of these scales). Google Forms ® randomized each section's order for each survey, and items within each scale were randomized. The scale's instructions read, "*Please respond to each of the statements below indicating how strongly you agree or disagree with each statement.*"

To understand the preferred travel method, participants were presented with the following scenario: "*Imagine a time in the future where autonomous cars are available to the general public and they have a safety record equal to, or better than, regular cars. You have to travel from one major city to another for work related business. The autopilot would do all the work and you could even sleep along the way. The alternative would be to take a regular commercial flight*" and then were asked to respond to the Travel Method Preference Scale (see Appendix A). This scale consisted of four statements and was answered with a five-point scale anchored from Strongly Disagree to Strongly Agree with a neutral option. Since the scale demonstrated extremely high internal consistency, as measured by Cronbach's alpha values, an average of these four statements was calculated to be used as the main DV for each of the four statistical models.

To determine if the duration of the trip affected the participants' responses, they were presented the following before responding to the Travel Method Preference scale: "*Imagine the drive will take you about 4 hours. The airline flight itself will take about 1-hour gate to gate; however, this does not encompass travel to/from the airport, security, baggage collection, etc. Given this information, which method of travel would you prefer?*" Participants were presented this scenario four different times, with the time schedules changing in each instance (4-hour drive/1-hour flight, 8-hour drive/1.5-hour flight, 12-hour drive/2-hour flight, and 16-hour drive/2.5-hour flight).

Lastly, participants provided their demographic data. After completing the survey, participants received instructions to claim their monetary compensation. Before the main data analysis, the data sample was randomly divided into two groups to facilitate the two-stage processes of building a regression equation and assessing model fit. After the initial data analysis and halving the dataset, the first stage (N = 863) was used to construct the regression equation, and the second stage (N = 882) was used for assessing the model fit and validation.

Proposed Data and Statistical Analyses

The purpose of Stage 1 was to develop the regression equation needed to predict the preferred travel methods of the participants. Before data analysis, data were tested and satisfied the regression's required assumptions, described in the Initial Data Analysis section below. To determine which variables significantly predicted participants' preferred travel method, a backward stepwise regression was used. This method removes statistically insignificant predictors until the model only is left with statistically significant predictors. While there are several methods researchers may select when conducting regression, backward stepwise was determined to be the most appropriate for two reasons. First, due to the exploratory nature of the current study, and without a robust theoretical aspect to ground the entry/exit method of variables, stepwise conduct these processes based on statistical assessments. Second, due to dummy-coded categorical predictors, all dummy coded variables must be entered in the analysis at the same step, which occurs when using backward stepwise regression. Preferences from the participants' survey were used across the four scenarios based upon travel times as described above.

The purpose of Stage 2 was to validate the regression equations generated in Stage 1. This validation was accomplished by calculating the participants' predicted score for Preferred Travel Method using the regression equation from Stage 1 then comparing it to their actual scores in Stage 2. This assessment was accomplished by conducting a t-test, Pearson's correlation, and then cross-validating the R^2.

Limitations to the Study

The first limitation was the use of Amazon's ® Mechanical Turk ® (MTurk). Despite the large group of individuals on MTurk, it significantly limits the generalizability of the results to members of MTurk. Despite this, other research has shown that data collected from MTurk is as valid as data collected through in-person surveys (Buhrmester et al., 2011; Germine et al., 2012; Rice et al., 2017).

Another limitation is that participants could not provide behavioral data to be collected and analyzed due to the limited availability of AVs in the general public. This limitation resulted in only behavioral intentions and perceptions to be collected. Despite actual and intentions not being the same thing, perceived actions correlate with an individual's actual behavior (Ajzen, 1991; Davis, 1985; Davis, Bagozzi, & Warshaw, 1989; Fishbein & Ajzen, 1975). Therefore, it is crucial to consider this study within the limit of perceptual intentions.

Results

Initial Data Analysis

Missing or Incomplete Data. An initial review of the data was completed to examine for excessive missing data. For summed scales, such as the personality scores, a single missing response resulted in the inability to calculate a correct score, and thus these cases were removed. More than two missing answers were considered excessive and removed for items on reflective scales that were averaged, such as familiarity or fun factor. Due to missing or incomplete data, 99 cases in Stage 1 and 96 cases from Stage 2 were removed.

Assumptions of Regression. When conducting regression, several assumptions must be met. For each model, there is one continuous, dependent variable. This assumption was satisfied by taking the average score for the dependent variable (justified due to the high Cronbach's alpha values). Of note, while Likert items may technically be ordinal, several studies cite the ability to treat these values as interval (Boone & Boone, 2012; Joshi, Kale, Chandel, & Pal, 2015; Rickards, Magee, & Artino, 2012; Sullivan & Artino, 2013), and also, the advantage of taking the average score helps ensure a continuous-like value for each participant (Brown, 2011). At least two or more independent or predictor variables was satisfied through the 20 independent variables used in the study. The independence of observations is measured by the Durbin-Watson statistic. Values are suggested to be between 1.5-2.5 (Field, 2009), and the current studies have values close to 2. Next, one must ensure that there are no issues with multicollinearity between variables. This assumption was determined to be met by examining each model's output and ensuring all VIF values were less than 10. An assessment of outliers was reviewed based on Mahalanobis Distance. Seventy-six cases (or 3.7%) of the data were determined to exceed this cutoff value and were removed (46 from Stage 1 and 30 from Stage 2). All other assumptions were verified to be met, and an example of normality is found in Figure 1.

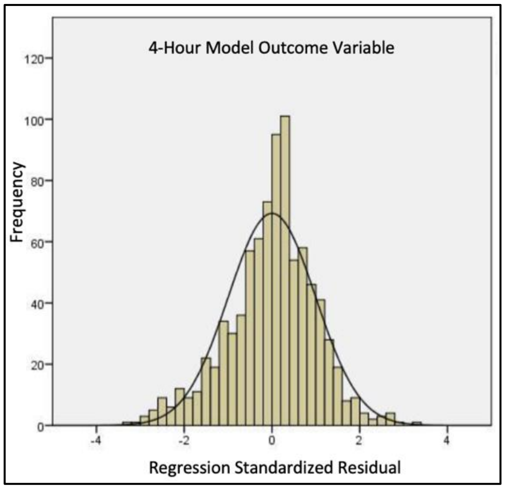

Figure 1. Histogram of the standardized residuals demonstrating normality for the dependent variable for the 4-hour model.

Descriptive Statistics

Stage 1. After removing incomplete or missing data and outliers, N = 863 for Stage 1, which included 406 males (47%). The mean age of participants was 38.77 (SD = 11.95) years. The descriptive statistics for Stage 1 are summarized in Table 1.

Table 1
Summary of Stage 1 Descriptive Statistics

Variable		*N*	*M*	*SD*
	Age	863	38.77	11.95
Gender	Male	406 (47%)		
	Female	457 (53%)		
Social Class	Upper Class	6 (0.7%)		
	Upper Middle Class	233 (27%)		
	Lower Middle Class	357 (41.4%)		
	Working Class	213 (24.7%)		
	Lower Class	54 (6.3%)		
Ethnicity	Caucasian	684 (79%)		
	African descent	61 (7.1%)		
	Asian descent	52 (6%)		
	Hispanic descent	42 (4.9%)		
	Indian	8 (0.9%)		
	Other	16 (1.9%)		

Stage 2. After removing incomplete or missing data and outliers, N = 882 for Stage 2, which included 387 males (44%). The mean age of participants was 38.19 (SD = 11.92) years. The descriptive statistics for Stage 2 are summarized in Table 2.

Table 2
Summary of Stage 2 Descriptive Statistics

	Variable	*N*	*M*	*SD*
	Age	882	38.19	11.92
Gender	Male	387 (44%)		
	Female	495 (56%)		
Social Class	Upper Class	7 (0.8%)		
	Upper Middle Class	242 (27.4%)		
	Lower Middle Class	379 (43%)		
	Working Class	212 (24%)		
	Lower Class	42 (4.8%)		
Ethnicity	Caucasian	638 (72.3)		
	African descent	76 (8.6%)		
	Asian descent	87 (9.9%)		
	Hispanic descent	52 (5.9%)		
	Indian	6 (0.7%)		
	Other	23 (2.6%)		

Inferential Statistics

Stage 1. Table 3 summarizes the regression analysis, while Table 4 identifies the significant regression coefficients for each model. Each of the four models is described below, and Appendix C presents the full regression output.

Four-hour trip. The final model for this scenario included ten significant predictors: Vehicle Affect, Fun Factor, Perceived Value, Plane Affect, Vehicle Comfort, Extraversion, Openness, African, Asian, and Upper Class. The resulting regression equation was:

$$Y = .169 + .297X_1 + .229X_2 + .290X_3 - .106X_4 - .106X_5 - .020X_6 + .016X_7 - .222X_8 - .302X_9 - .670X_{10}$$

Y is participants' preference for riding in an autonomous vehicle, and $X_1 – X_{10}$ are Vehicle Affect, Fun Factor, Perceived Value, Plane Affect, Vehicle Comfort, Extraversion, Openness, African, Asian, and Upper Class, respectively. This model resulted in an $R^2 = .507$ (adjusted $R^2 = .501$), accounting for roughly 50% of the participants' preferred travel method variance. This model was statistically significant, $F(10, 852) = 87.549$, $p < .001$.

Eight-hour trip. The final model for this scenario included thirteen significant predictors: Vehicle Affect, Vehicle Comfort, Wariness of New Technology, Value, Familiarity, Plane Affect, Plane Price, Agreeableness, Conscientiousness, Gender, African, Asian, and Upper Class. The resulting regression equation was:

$$Y = .552 + .367X_1 + .094X_2 + .088X_3 + .221X_4 - .196X_5 - .291X_6 - .100X_7 - .023X_8 - .021X_9 - .203X_{10} - .390X_{11} - .391X_{12} + 1.367X_{13}$$

Y was participants' preference for riding in an autonomous vehicle, and $X_1 – X_{13}$ is Vehicle Affect, Vehicle Comfort, Wariness of New Technology, Value, Familiarity, Plane Affect, Plane Price, Agreeableness, Conscientiousness, Gender, African, Asian, and Upper Class, respectively.

This model resulted in an R^2 = .333 (adjusted R^2 = .322), thus accounting for roughly 32% of the variance in participants' preference for riding in an autonomous vehicle. This model was statistically significant, $F(13, 849) = 32.544$, $p < .001$.

Twelve-hour trip. The final model for this scenario included twelve significant predictors: Vehicle Affect, Vehicle Comfort, Wariness of New Technology, Familiarity, Plane Affect, Plane External Factors, Plane Price, Extraversion, Conscientiousness, Neuroticism, Asian, and Upper Class. The resulting equation was

$$Y = -.445 + .454X_1 + .132X_2 + .117X_3 + .135X_4 - .363X_5 + .111X_6 - .110X_7 + .017X_8 - .022X_9 + .027X_{10} - .339X_{11} + 1.307X_{12}$$

Y was participants' preference for riding in an autonomous vehicle, and $X_1 – X_{12}$ are Vehicle Affect, Vehicle Comfort, Wariness of New Technology, Familiarity, Plane Affect, Plane External Factors, Plane Price, Extraversion, Conscientiousness, Neuroticism, Asian, and Upper Class, respectively. This model resulted in an R^2 = .269 (adjusted R^2 = .259), thus accounting for roughly 26% of the variance in participants' preference for riding in an autonomous vehicle. This model was statistically significant, $F(12, 850) = 26.052$, $p < .001$.

Sixteen-hour trip. The final model for this scenario included twelve significant predictors: Vehicle Affect, Vehicle Comfort, Wariness of New Technology, Familiarity, Plane Affect, Plane External Factors, Plane Price, Extraversion, Neuroticism, Asian, Lower Class, and Upper Class. The resulting equation was

$$Y = -.946 + .431X_1 + .179X_2 + .136X_3 + .150X_4 - .356X_5 + .177X_6 - .140X_7 + .023X_8 + .030X_9 - .295X_{10} + .330X_{11} + 1.334X_{12}$$

Y was participants' preference for riding in an autonomous vehicle, and $X_1 – X_{12}$ are Vehicle Affect, Vehicle Comfort, Wariness of New Technology, Familiarity, Plane Affect, Plane External Factors, Plane Price, Extraversion, Neuroticism, Asian, Lower Class, and Upper Class, respectively. This model resulted in an R^2 = .267 (adjusted R^2 = .256), thus accounting for roughly 25% of the variance in participants' preference for riding in an autonomous vehicle. This model was statistically significant, $F(12, 850) = 29.260$, $p < .001$.

Table 3
Analysis of Regression Model Summaries from Stage 1.

	Four-Hour	Eight-Hour	Twelve-Hour	Sixteen-Hour
R^2	.507	.333	.269	.267
Adj. R^2	.501	.322	.259	.256
F	87.55	32.54	26.05	29.26
df	10, 852	13, 849	12, 850	12, 850
p	< .001	< .001	< .001	< .001

Table 4
Statistically significant regression coefficients from Stage 1.

	Four-Hour	Eight-Hour	Twelve-Hour	Sixteen-Hour
Constant	.169	.552	-.445	-.946
Vehicle Affect	.297	.367	.454	.431
Plane Affect	-.106	-.291	-.363	-.356
Vehicle Comfort	-.106	.094	.132	.179
Plane Comfort				
Plane Price		-.100	-.110	-.140
Plane External Factors			.111	.177
Perceived Value	.290	.221		
Fun Factor	.229			
Familiarity		-.196	.135	.150
Wariness of New Tech.		.088	.117	.136
Extraversion	-.020		.017	.023
Openness	.016			
Agreeableness		-.023		
Conscientiousness		-.021	-.022	
Neuroticism			.027	.030
African	-.222	-.390		
Asian	-.302	-.391	-.339	-.295
Gender		-.203		
Upper Class	-.670	1.367	1.307	1.334
Lower Class				.330

Stage Two

Table 5 shows these values for all four scenarios. From this table, we can see that all *t*-tests were non-significant, all correlations were highly significant, and all cross-validated R^2 values were nearly identical. These results indicate a strong model fit for all four regression equations.

Table 5
Model Fit Summaries using Actual vs. Predicted Scores (Stage 2).

	t-test			Correlation		Original R^2	Cross-Validated R^2
	t	df	Sig.	*r*	Sig.		
Four Hour	-.176	1762	.860	.653	<.001	.507	.484
Eight Hour	.576	1762	.564	.516	<.001	.333	.301
Twelve Hour	-.335	1762	.737	.445	<.001	.269	.234
Sixteen Hour	-.490	1762	.624	.412	<.001	.267	.232

Discussion

Continued efforts to deliver a safe and efficient AV require the adoption of public perceptions to make it a success. Once AVs become available to the general population, they will significantly impact other transportation industries such as commercial air. Many consumers will choose to ride in an AV over flying on a CA. Therefore, it is paramount to understand the consumer's motives who would prefer an AV over other transportation modes to assist the industries in future operational planning.

A predictive model was created to investigate consumer perceptions towards AV and CA. This study was accomplished in a two-stage approach. The first stage consisted of 20 predictive factors that could impact users' choice of using an AV rather than CA. Participants were presented with four scenarios then backward stepwise regression was used to create the equations. Stage 2 tested the equations for model fit by comparing the calculated scores against their actual scores using a *t*-test, Pearson's correlation, and cross-validating the R^2.

Since this research is exploratory, it included a large number of variables to explore. A breakdown of each of the variables in the study follows.

Age, Social Class, and Ethnicity. Age was not significant in any scenario, and gender only showed significance in the 8-hour scenario. Social class and ethnicity predictors showed at least one item as significant for each of the scenarios. Previous research suggests that certain people may prefer using technology or feel comfortable with it based upon ethnicity, social class, age, and gender (Borghans et al., 2009; Byrnes et al., 1999; Charness & Gneezy, 2012).

Perceived Value, Fun, Wariness of New Technology, and Familiarity. The research focused on the acceptance of new technologies (i.e., TAM, UTUAT, TPB) provided factors that may influence a consumers' perception, willingness to use, and overall acceptance of new technology (Ajzen, 1991; Davis, 1985; Legris, Ingham, & Collerette, 2003; Venkatesh et al., 2003). Perceived value was significant during the 4-hour and 8-hour scenarios. Only the 4-hour scenario showed fun as significant. All scenarios except the 4-hour one showed wariness of new technology and familiarity as a significant predictor. One can assume that those who adopt technology at early stages likely perceive a benefit or enjoy using the latest technology (Chai, Malhotra, & Alpert, 2015; Eckoldt, Knobel, Hassenzahl, & Schumann, 2012; Jones, Reynolds, & Arnold, 2006; Mathwick, Malhotra, & Rigdon, 2001), which could explain these significant predictors.

Personality Factors. Existing research indicates that highly extroverted and open people are typically more welcoming of newer technology and show more yearning to use it (Merritt & Ilgen, 2008). This research found openness significant in the 4-hour scenario, while extroversion was significant in the 4-, 12-, and 16-hour scenarios. Despite extroversion being significant, it displayed a negative coefficient in the 4-hour trip, signaling that as an individuals' extroversion increased, their preference for an AV over CA decreased. A possible reason for this is that riding in an AV means being in isolation vs. a CA, where they can engage with other people throughout their journey.

Affect. Vehicle and plane affect were included to measure a users' emotional reaction to riding in an AV and CA. Prior research indicates that an individual's emotions can play a significant role in their decision-making (Lerner et al., 2015; Peters et al., 2006; Schwarz & Clore, 2003; Slovic et al., 2005), predominantly when in a seemingly dangerous, unfamiliar situation. These variables were all significant predictors in all four scenarios. However, an important finding was that airplane affect showed a negative coefficient, meaning that as the affect decreased, their preference for AVs over CA increased.

Comfort and Price. Vehicle comfort attempted to capture users' satisfaction and experience of riding in the vehicle, such as the ability to fall asleep. Previous research showed that a consumer's satisfaction with their trip was influenced by the vehicle comfort in other modes of transportation (i.e., trains, planes, public buses, etc.) (Kloppenborg & Gourdin, 1992; Nadiri et al., 2008; Young et al., 1994). All four scenarios displayed vehicle comfort as a significant predictor, likely due to consumers wanting to be comfortable while traveling for an extended amount of time. Additionally, the importance of the plane ticket price was significant in the eight- twelve- and sixteen-hour conditions, but inversely. Suggesting that participants' level of importance over plane ticket price increased, participants' willingness to prefer a driverless vehicle decreased.

Plane External Factors. Airplane external factors focused on the users' experience while riding in a CA and how different factors, such as limited schedules, sharing space with strangers, ability to rest on the plane, etc., influenced a consumer. Previous research focusing on consumer preferences and the factors that affect a traveler's comfort level concentrate on these areas (Kloppenborg & Gourdin, 1992; Nadiri et al., 2008; Young et al., 1994); ergo, the inclusion into this study. This variable was significant in the 12-and 16-hour scenario. This finding can be interpreted in that passengers are not as concerned with plane external factors for shorter trips, but as the trip increases in time, these factors are more important for travelers.

Summary of Significant Variables in All Models. The four variables present in all scenarios were individuals identifying as upper social class, vehicle and airplane affect, and vehicle comfort. Those identifying as an upper social class had the highest indication of selecting an AV compared to the other classes. This result supports other research that discovered upper social class citizens look at technology more positively and are more accepting of it (Maldifassi & Canessa, 2009; Porter & Donthu, 2006). An emotional reaction is indicated by traveling in an AV; positive emotions for riding in an AV where negative emotions are evoked for CA travel. Industry experts could focus on this research to understand why consumers are enthusiastic about riding in an AV to understand better their intended users' profile or ways to adapt CA to fit those user needs.

Practical Applications

Despite this research being exploratory, it can prove beneficial to both the automotive and aviation industries. Understanding the users will enable companies' design teams to tailor a product that will appeal to consumers. This research is unique in that AV technology is still relatively new, so any investigations will assist the design process from the beginning, resulting in a more mature product upon release.

The aviation industry can use this research to account for consumers who will switch to AV technology and adapt to their preferences. Consumers show an emotional reaction to AV technology's use through the entertainment and enjoyment of the ride. How can the airlines increase the enjoyment of flying for consumers to retain their business? It may result in the aviation industry capitalizing on the convenience factor of longer trips. Thus, they can adapt long-haul flights to be increasingly comfortable and focus on those customers to counteract short-haul users' loss.

Conclusions

As autonomous vehicles become readily available for consumers, it is pivotal to understand and plan for the impact they will most assuredly have on others in the industry. The current research focused on acceptance and preference of the technology over CA travel. This two-stage approach developed a predictive model of an equation to determine the type of person who would prefer to ride in an AV over CA through backward stepwise regression. The equation was then tested to verify model fit by comparing predicted scores to actual scores using a *t*-test, Pearson's correlation, and cross-validating R^2. The best predictive model was developed from the four-hour scenario, which accounted for 50% of the variance. The most common predictors throughout all scenarios were upper social class, vehicle affect, airplane affect, and vehicle comfort, indicating the importance of emotions on consumers' decision-making process along with comfortable travel and identifying early adopters, such as upper-class citizens. Future research should be conducted from this study, but its results will contribute to the automotive industry and CA industry's understanding of consumer preferences while traveling via these two methods.

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Appendices

Appendix A – Travel Method Preference Scale

The Preferred Travel Method scale has a Cronbach's Alpha of .93 and Guttman's Split Half of .92. Correlations between items ranged from r = .69 to .88. All of the aforementioned statistics indicate high internal consistency and high reliability. Participants read the following information:

Please respond to each of the statements below indicating how strongly you agree or disagree with each statement.

1. I would prefer the driverless car.
   Strongly disagree Disagree Neither disagree nor agree Agree Strongly Agree
2. I would be more comfortable riding in the driverless car.
   Strongly disagree Disagree Neither disagree nor agree Agree Strongly Agree
3. I would choose the driverless car.
   Strongly disagree Disagree Neither disagree nor agree Agree Strongly Agree
4. I would be happier with the driverless car.
   Strongly disagree Disagree Neither disagree nor agree Agree Strongly Agree

Appendix B – Other Scales Used in the Study

All scales provided responses to each of the statements below using a 5-point Strongly Disagree to Strongly Agree, and a Neither disagree nor agree option.

	SD	D	N	A	SA
Perceived Value Scale					
1. I think driverless vehicle technology is useful.					
2. A driverless vehicle would be something valuable for me to own.					
3. There would be value in using a driverless vehicle.					
4. If driverless vehicles were available, I think it would be beneficial to use one.					
5. A driverless vehicle would be beneficial to me.					
Familiarity Scale					
1. Driverless vehicles have been of interest to me for awhile.					
2. I have a lot of knowledge about driverless vehicles.					
3. I have read a lot about driverless vehicles.					
4. I know more about driverless vehicles than the average person.					
5. I am familiar with driverless vehicles.					
Fun Factor Scale					
1. I am interested in trying out a driverless vehicle.					
2. I think it would be cool to use a driverless vehicle.					
3. I've always wanted to use a driverless vehicle.					
4. I think it would be fun to use a driverless vehicle.					
5. I am familiar with driverless vehicles.					
Wariness of New Technology Scale					
1. New technology scares me.					
2. In general, I am wary of new technology.					
3. I tend to fear new technology until it is proven to be safe.					
4. New technology is not as safe as it should be.					
5. New technology is likely to be dangerous.					
General Affect Scale					
1. I feel good about this.					
2. I feel positive about this.					
3. I feel favorable about this.					
4. I feel cheerful about this.					
5. I feel happy about this.					
6. I feel enthusiastic about this.					
7. I feel delighted about this.					
Vehicle Comfort Scale					
1. I enjoy traveling in a car if I don't have to drive.					
2. I enjoy how much space I have in a car.					
3. I enjoy sleeping while traveling in a car.					
Vehicle External Factors Scale					
1. I enjoy the freedom to stop and eat wherever and whenever I want.					
2. I enjoy having schedule flexibility (the ability to leave when I want).					
3. I can easily maintain my hygiene standards while traveling in a car.					
Airplane Comfort Scale					
1. I enjoy traveling in an airplane.					
2. I am ok with how much space I have on an airplane.					
3. I can easily maintain my hygiene standards while traveling in an airplane.					
4. I enjoy sleeping while traveling in an airplane.					
5. I can easily fall asleep while traveling on an airplane.					
Airplane External Factors Scale					
1. I enjoy waiting in the airport before I leave my departure point.					
2. I am ok having a limited choice over my departure time and arrival time.					
3. I enjoy going through TSA security.					

Appendix C – Full Regression Output for the Four Models

Regression Coefficients for four-hour trip (Model 18)

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. error	Beta			Zero-order	Partial	Part
18	(Constant)	.169	.146		1.157	.248			
	VehicleAffect	.297	.058	.259	5.102	.000	.630	.172	.123
	FunFactor	.229	.059	.220	3.859	.000	.647	.131	.093
	Value	.290	.058	.258	4.953	.000	.659	.167	.119
	PlaneAffect	-.106	.035	-.091	-2.978	.003	-.068	-.102	-.072
	PlaneComfort	-.106	.040	-.081	-2.627	.009	-.097	-.090	-.063
	Extraversion	-.020	.007	-.070	-2.768	.006	-.040	-.094	-.067
	Imagination	.016	.009	.045	1.816	.070	.097	.062	.044
	African	-.222	.114	-.048	-1.943	.052	-.081	-.066	-.047
	Asian	-.302	.120	-.061	-2.513	.012	-.032	-.086	-.060
	UpperClass	.670	.345	.047	1.943	.052	.075	.066	.047

a. Dependent Variable: Preferred Travel Method

Regression Coefficients for eight-hour trip (Model 15)

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. error	Beta			Zero-order	Partial	Part
15	(Constant)	.552	.228		2.422	.016			
	VehicleAffect	.367	.066	.302	5.592	.000	.455	.188	.157
	VehicleComfort	.094	.051	.061	1.823	.069	.229	.062	.051
	WaryTech	.088	.041	.068	2.172	.030	-.118	.074	.061
	Value	.221	.060	.186	3.685	.000	.457	.125	.103
	Familiarity	.196	.043	.144	4.527	.000	.268	.154	.127
	PlaneAffect	-.291	.037	-.237	-7.966	.000	-.142	-.264	-.223
	PlanePrice	-.100	.034	-.085	-2.966	.003	-.050	-.101	-.083
	Agreeableness	-.023	.011	-.061	-2.042	.041	-.022	-.070	-.057
	Conscientiousness	-.021	.011	-.054	-1.872	.061	-.086	-.064	-.052
	Gender	-.203	.076	-.081	-2.674	.008	.018	-.091	-.075
	African	-.390	.141	-.080	-2.768	.006	-.095	-.095	-.078
	Asian	-.391	.149	-.075	-2.623	.009	-.049	-.090	-.074
	UpperClass	1.367	.428	.091	3.191	.001	.128	.109	.089

a. Dependent Variable: Preferred Travel Method

Regression Coefficients for twelve-hour trip (Model 16)

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. error	Beta			Zero-order	Partial	Part
16	(Constant)	-.445	.280		-1.589	.112			
	VehicleAffect	.454	.045	.385	10.141	.000	.372	.329	.297
	VehicleComfort	.132	.051	.089	2.588	.010	.216	.088	.076
	WaryTech	.117	.042	.093	2.797	.005	-.046	.095	.082
	Familiarity	.135	.044	.102	3.056	.002	.234	.104	.090
	PlaneAffect	-.363	.042	-.303	-8.672	.000	-.150	-.285	-.254
	PlaneExtFact	.111	.049	.080	2.250	.025	.015	.077	.066
	PlanePrice	-.110	.034	-.096	-3.196	.001	-.086	-.109	-.094
	Extraversion	.017	.009	.058	1.823	.069	.067	.062	.053
	Conscientiousness	-.022	.012	-.059	-1.851	.065	-.115	-.063	-.054
	Neuroticism	.027	.011	.082	2.472	.014	.078	.084	.073
	Asian	-.339	.151	-.067	-2.244	.025	-.054	-.077	-.066
	UpperClass	1.307	.434	.090	3.011	.003	.126	.103	.088

a. Dependent Variable: Preferred Travel Method

Regression Coefficients for sixteen-hour trip (Model 16)

Model[a]		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. error	Beta			Zero-order	Partial	Part
16	(Constant)	-.946	.191		-4.948	.000			
	VehicleAffect	.431	.046	.358	9.456	.000	.355	.309	.278
	VehicleComfort	.179	.052	.118	3.443	.001	.236	.117	.101
	WaryTech	.136	.043	.107	3.198	.001	-.022	.109	.094
	Familiarity	.150	.045	.111	3.310	.001	.250	.113	.097
	PlaneAffect	-.356	.043	-.293	-8.359	.000	-.112	-.276	-.246
	PlaneExtFact	.177	.050	.125	3.536	.000	.071	.120	.104
	PlanePrice	-.140	.035	-.121	-4.005	.000	-.116	-.136	-.118
	Extraversion	.023	.010	.074	2.328	.020	.088	.080	.068
	Neuroticism	.030	.010	.090	2.887	.004	.071	.099	.085
	Asian	-.295	.154	-.057	-1.917	.056	-.050	-.066	-.056
	LowerClass	.330	.152	.065	2.168	.030	.050	.074	.064
	UpperClass	1.334	.443	.090	3.014	.003	.130	.103	.089

a. Dependent Variable: Preferred Travel Method

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Divergent Attitudes Regarding the Benefits of Face Masks in Aviation Colleges and Universities

Andrew R. Dattel
Embry-Riddle Aeronautical University

Hanzi Xie
Embry-Riddle Aeronautical University

Maxine E. Lubner
Vaughn College of Aeronautics and Technology

Peiheng Gao
Embry-Riddle Aeronautical University

Opinions and practices regarding face masks (FM) to attenuate COVID-19's spread remains polarized across the United States. We examined whether these attitudes extend to the aviation collegiate community. A 14-question survey was sent to 90 aviation colleges and universities throughout the country. Responses were solicited from students, faculty, and staff. Of the 598 respondents, 77% were students, 13% were faculty, and 10% were staff. Pilots comprised 66% of the respondents. A Principal Component Analysis reduced the questions to two scales: Benefits and Inconvenience. Females, non-pilots, and older respondents reported greater benefits to wearing a FM and fewer inconveniences. A multiple regression showed aviation colleges and universities located in states which had FM mandates, higher likelihood of community compliance, lower rates of COVID-19 in their state, and reports of less inconvenience predicted attitudes of greater benefits of wearing a FM. Additional comments were provided by 28% of the respondents, showing strongly polarized attitudes about the benefits of FMs. Respondents who had negative attitudes about the benefits of wearing FMs, nevertheless reported compliance on college campus. As leaders in education, collegiate aviation has a responsibility to educate their students, faculty, and staff of the importance of public health measures, dispelling misinformation, and modelling behavior to increase compliance with wearing FMs.

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The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes the pandemic disease COVID-19. This highly contagious novel coronavirus arrived in the United States (US) in January 2020. In February 2021, there were over 28.3 million confirmed cases and over 500,000 deaths in the US. (The New York Times [NYT], 2021). The pandemic has also resulted in severe societal, economic, and political disruptions globally and domestically (Reiner et al., 2021).

The U.S. Food and Drug Administration (FDA) issued the first emergency use authorization for a vaccine for the prevention of COVID-19 in people 16 years of age and older in December 2020 (FDA, 2020). Vaccine approval occurred after this study was conducted. Nevertheless, despite the rapid development of vaccines, all public health measures recommended by the World Health Organization (WHO) and U.S. Department of Health and Human Services' Centers for Disease Control (CDC) remain in effect at the time of this writing (CDC, 2021).

Vaccines, therapeutics, and non-pharmaceutical interventions provide layers of protection against the pandemic. The latter measures include wearing a face mask (FM), frequent hand washing, cleaning surfaces, social distancing (e.g., keeping 6 feet apart, avoiding crowds), and frequent testing and contact tracing. These recommendations evolved since the start of the pandemic with varying adherence patterns (CDC, 2021; WHO, 2021). Wearing FMs is a simple, effective technique, with few economic and social consequences, yet it has divided the US socially and politically (Kessel & Quinn, 2020). The purpose of this study was to examine attitudes about FMs among US aviation colleges and universities.

Transmission

According to WHO (2021) and CDC (2021), the pathogens are spread from an infected person's mouth or nose in liquid particles, ranging from larger respiratory droplets to smaller aerosols, when they talk, cough, sneeze, sing, or breathe heavily. Infections occur when the virus gets into another person's mouth, nose, or eyes, which is more likely to happen when people are in close contact; in indoor, crowded and inadequately ventilated spaces; when infected people spend more than 15 minutes with others; or when people touch contaminated surfaces and then their faces without cleaning their hands first (CDC, 2021; Nishiura et al., 2020; WHO, 2021).

Transmission of the disease occurs in the symptomatic phase, pre-symptomatic phase and among asymptomatic cases (Buitrago-Garcia et al., 2020; Furukawa, Brooks & Sobel, 2020). The CDC (2021) reports that about half of new infections come from people who are unaware they are infectious. Some transmission has occurred when enough airborne virus remains in the area to cause infections in others who are further away than 6 feet or pass through the space shortly afterwards (Burnett & Sergi, 2020).

Unlike most commercial aircraft that have sophisticated air filtration systems (American Airlines, 2020; Janzen, 2020), general aviation trainers do not. Pilots in general aviation trainer cockpits will be in an indoor setting; usually for long periods; sitting closer together than 6 feet; and frequently touching several surfaces throughout the flight. Similarly, traditional college classes are usually held in indoor spaces for long time periods. The risks of morbidity and mortality increases with older age, minority ethnic status, lower socio-economic status, and males (CDC, 2021). Pilots tend to be male (CAPA, 2018; Twombly, 2019); many students tend to be younger and have less income than faculty and staff (Semega, Kollar, Shrider, & Creamer, 2020). Thus, the major sub-populations in collegiate aviation are represented in several risk categories for contracting COVID-19.

Prevention

To target the transmission of COVID-19 by respiratory droplets, FMs that cover the nose and mouth are among the recommendations of public health authorities worldwide (WHO 2021, CDC 2021). There is a large body of research, based on a variety of methodologies that demonstrate the effectiveness of FMs to reduce the transmission of respiratory viruses, including SARS-CoV-2 (Burnett & Sergi, 2020).

Sharma, Mishra, and Mudgal (2020) searched a variety of databases on the effectiveness of homemade FMs. They found that the effectiveness of cloth FMs' filtration varied, depending on the type of material, number of layers, fit, and amount of moisture in the FM.

Scheid, Lupien, Ford, and West , (2020) found that the physiological effects of wearing FMs for prolonged periods of time, including special considerations, such as during exercise or for those with pre-existing, chronic diseases do not appear to cause any harmful physiological alterations. Dattel, O'Toole, Lopez, and Byrnes(2020) found that Instructor Pilots suffered no respiratory health effects or issues with the safety of flight. They were slightly more comfortable wearing cloth than paper FMs at simulated altitudes of 5000 feet (Dattel et al., 2020). Over time, the pilots found the nuisance of wearing FMs decreased (Dattel & Agha, Unpublished Manuscript).

Airplane cockpit and classroom settings require several new modifications, restrictions, and procedures to comply with public health measures to reduce the spread of COVID-19. FMs to reduce the spread of respiratory droplets and aerosols therefore remain a vital preventive measure against infections in collegiate aviation programs.

Attitudes

Haischer et al. (2020) observed shoppers (*n* = 9,935) entering retail stores in the summer of 2020. They found that those wearing FMs were older, 1.5 times more likely to be female, and about four times more likely to be in an urban or suburban setting. In June 2020, 41% of the sample wore a FM, but when FM mandates were enacted in July and August, compliance increased to over 90%. Several other studies have supported the relationship between demographics and FMs (Jarry, 2020; Kessel & Quinn, 2020; Scheid et al., 2020). Wearing FMs is also associated with attitudes, social, and psychological factors about as often as understanding the physical benefits of doing so. These authors also note that FM mandates appear to be effective in increasing compliance (Jarry, 2020).

Public health messages may impact compliance regarding FMs. At first, there was a delay in recommending FMs, with WHO making this recommendation in early June 2020 and CDC some weeks later. WHO initially recommended that only people who were sick, or who were caring for people suspected of having COVID-19, should wear FMs. The CDC informed the public that cloth face coverings would slow the transmission of the virus, but they are not as effective as surgical or N95 FMs, which in any case, should be reserved for health care workers who are at higher risk (Burnett & Sergi, 2020). These delays may have hampered the widespread adoption of FMs with a detrimental effect (Burnett & Sergi, 2020; Morawska et al., 2020). In the US, the messaging from top-level government officials has been inconsistent, further reducing compliance (Breslow, 2020).

Kessel and Quinn (2020) of the Pew Research Center noted that wearing FMs has divided the US. They conducted an online survey of 9,220 U.S. adults between August 31-September 7, 2020, using a national, random sampling of residential addresses that was weighted to be representative of the US adult population by gender, race, ethnicity, partisan affiliation, education, and other categories. Respondents were asked to describe how their lives have been made difficult or challenging since the beginning of the pandemic. Overall, 14% of U.S. adults mentioned "face mask" when asked about the impacts of COVID-19. "Face mask" tied with "friend" as the fourth most common word mentioned, after "family" and "work", which were each mentioned by 19% of the public.

Katz, Sanger-Katz, and Quealy (2020) examined the entire US at the county level to find the likelihood of encountering five people wearing a FM when going outside one's home, based on self-reports of how often people wore them. They noted that encountering others wearing FMs varies greatly by state and county, as well as over time. Again, political affiliation appeared to be associated with the likelihood of wearing FMs.

It is well established that many factors influence the correlation between attitudes and behaviors, but it is generally accepted that specific attitudes will predict specific behaviors (Frymier & Nadler, 2017). Scheid et al., (2020) noted that the potentially life-saving benefits of wearing FMs outweigh the discomforts. However, controversy over FM wearing in the US continues. Psychological factors may explain attitudes and behaviors regarding wearing FMs, unrelated to physical impacts or public health explanations. Scheid et al. (2020) discussed three basic psychological needs including: competence where people (more often men) wish to avoid appearing to be fearful or weak by wearing a FM; autonomy, where people who want the freedom to make their own decisions feel forced to comply with authorities; and, relatedness or the need to be part of an "in-group," such as belonging to a political party.

Jarry (2020) notes that many studies report the trends of elderly people, women, more educated individuals, and certain minorities being more likely to wear a FM and wash their hands. Jarry (2020) discussed five sets of reasons that are commonly provided for not wearing FMs and offered some remedies. The most common reasons are:

- Medical, like difficulty breathing, which are incorrect (Dattel et al., 2020). Addressing misinformation is a solution.
- FMs can make people--particularly men--feel negatively about themselves, like looking weak. A remedy is to avoid shaming.
- Distorting science or pseudoscience, such as saying that COVID-19 is no worse than the flu. A remedy is to address representative heuristic fallacy.
- Reactance or balking at a perceived limit on personal freedom. Leading by example can be a remedy.
- Conspiracy theories, which are comforting during times of great social anxiety. A remedy is to address uncertainty.

Collegiate Aviation

Within state guidelines, colleges and universities have developed their own policies and communications systems for ensuring the safety of their students, faculty, and staff. For example, some schools require FMs indoors and outdoors, while others require FMs indoors only. Therefore, we expect behaviors and attitudes to wearing FMs among college students, faculty, and staff to vary, despite public health recommendations. To examine attitudes about FMs among US aviation colleges and universities we asked the following research questions:

- Do attitudes about wearing FMs differ by age?
- Do attitudes about wearing FMs differ by gender?
- Do attitudes about wearing FMs differ by status within the college/university (i.e., student, faculty, staff)?
- Do attitudes about wearing FMs differ by pilot status?
- Do attitudes about wearing FMs differ by state mandate?

Collegiate flight training faces specific challenges. The general aviation training aircraft and simulators were not designed with infection control in mind, so the spaces will necessarily exceed public health guidelines to prevent the spread of infection of limiting time spent inside, maintaining social distancing, providing excellent ventilation, etc. Those not wearing a FM would remove another layer of protection against COVID-19.

Methodology

Participants

Following Institutional Review Board approval (21-043), the survey request was emailed to all University Aviation Association (UAA) US points of contract (POC). There are approximately 90 UAA POCs in the US as a few institutions have more than one POC. Several POCs reportedly did not see the email requests. The POCs were requested to forward the Google Form questionnaire link to their students, faculty, and staff in each of the collegiate aviation programs. Responses were received from 598 (408 male, 148 female) people associated with 14 programs from November 20 - December 2, 2020, with 80% received during the first 5 days of this period.

Instrument

The survey contained 14 questions on attitudes to wearing FMs (see Appendix A). These questions had a 10-point response scale with only the poles labelled. The question items were generated by several researchers and independently validated by one faculty member and one staff member, who are experts in the collegiate aviation field. The question items were also tested by two samples of Pilot Instructors (n = 21 and n = 82). Additionally, a subset of these question items was tested in a subsequent study (Dattel et al., 2020). Demographic questions included age, gender, pilot status, faculty/staff status (student, faculty, staff), and institution name. About 28% of respondents chose to answer the open-ended comments section.

Data Preparation and Analyses

Because names or identifying information from respondents were not available to the researchers, we could not easily determine if respondents duplicated their submissions or if they saved their surveys often. Therefore, we eliminated individual responses with the same time stamps. Because faculty and staff constituted only about 13% and 10% of respective responses, we combined faculty and staff as one level of faculty/staff status with students being the other level.

Once two scales (Benefits and Inconvenience) were determined from a Principal Component Analysis (PCA), we conducted three mixed ANOVAs comparing the scales based on gender, pilot status, and faculty/staff status. We did not conduct multivariate factorial analyses on these demographic variables to preserve the independence of data because the same person could be represented twice in categories of gender, faculty/staff, and pilot status.

Other variables included policies (e.g., FM mandates) and environment (percentage of people wearing FMs in the community). The environment variable was based on a study by Katz et al. (2020), which reported how often a person would be likely to encounter five others wearing a FM by county. We identified the schools' counties and matched each respondent to the likelihood percentages reported by Katz et al. (2020).

Open-ended responses were reviewed independently initially, then together by the authors. Each response was categorized as positive, negative, or neutral attitudes to the benefits of wearing FMs. There were very few discrepancies, which were discussed where agreement was easily reached.

Results

The mean age of all respondents was 27.63 years (SD = 13.65). The median age of all respondents was 21. About 77% of the respondents were students (n = 462), 13% of the respondents were faculty (n = 75), and 10% of the respondents were staff (n = 61). Approximately 66% of the respondents identified as pilots. The mean age of the students was 22.58 years (SD = 6.90), staff was 38.64 years (SD = 14.76), and faculty was 49.81 years (SD = 16.52).

A PCA using Varimax (orthogonal) rotation showed 13 of the 14 questions loaded on two factors (see Table 1), which explained 63.84% of the total variance. Kaiser-Myer-Olkin was .926 and Bartlett's Test of Sphericity was significant $\chi^2(91) = 5618.87$, $p < .001$. The first factor, labeled *Benefits*, explained 51.7% of the variance, with a Cronbach's α of .94. The second factor, labeled *Inconvenience*, explained 12.15% of the variance, with a Cronbach's α of .88. See Table 2 for additional descriptive statistics.

Table 1
Principal Component Analysis of Face Mask Survey Factor loadings and Communalities (n = 598)

	Benefits	Inconvenience	Communalities
What is your current experience with wearing a face mask?	**.776**	-.279	.680
Does wearing a face mask help to prevent the spread of airborne illnesses like Covid-19 to others?	**.852**	-.324	.832
Does wearing a face mask protect you from catching an illness like Covid-19?	**.836**	-.221	.747
Does wearing a face mask cause decreases in O_2 saturation levels?	-.199	**.772**	.636
In general, do you feel that wearing a mask makes it harder to be heard when you talk?	-.363	**.700**	.621
Does wearing a face mask affect your comfort level?	-.446	**.657**	.631
Does wearing a face mask cause the user to inhale higher concentration of CO_2 than normal?	-.216	**.787**	.667
In general, how well does the face mask fit your face?	.407	-.012	.166
Does wearing a face mask restrict your physical movement (e.g., reaching, turning your head) in any way?	-.208	**.616**	.423
Does wearing a face mask cause you to become fatigued?	-.186	**.787**	.655
Should the college/university require students, faculty, and staff to wear face masks when INSIDE campus buildings?	**.835**	-.305	.790
Should the college/university require students, faculty, and staff to wear face masks when OUTSIDE campus buildings, but still on campus?	**.753**	-.330	.676
Does wearing a face mask make your body feel warmer/hotter?	-.123	**.717**	.530
Overall, do the advantages of wearing a face mask outweigh the disadvantages?	**.851**	-.440	.885
Eigenvalue	7.237	1.700	

Table 2
Descriptive Statistics of Face Mask Survey

	# of items	*M (SD)*	Skewness	Kurtosis
Benefits	6	6.67 (2.78)	-.49	-1.08
Inconvenience	7	5.07 (2.21)	.17	-.89

ANOVAs by College University Status/Pilot Status/Gender

From reducing the FM survey to two scales (Benefits and Inconvenience), we conducted ANOVAs and *t*-tests between gender, pilot status, and faculty/staff status (i.e., student; faculty and staff combined). A 2 (Scale) x 2 (Gender) mixed ANOVA showed a main effect for *Scale*, $F(1,596) = 112.71$, $p < .001$, partial $\eta^2 = .158$, a main effect for *Gender* $F(1,596) = 59.40$, $p < .001$, $\eta^2 = .041$, and an interaction $F(1, 596) = 33.27$, $p < .001$, $\eta^2 = .053$. Post hoc analyses, using a Bonferroni adjustment showed females reported greater *Benefits* than males and that females reported fewer *Inconveniences* than males (see Figure 1).

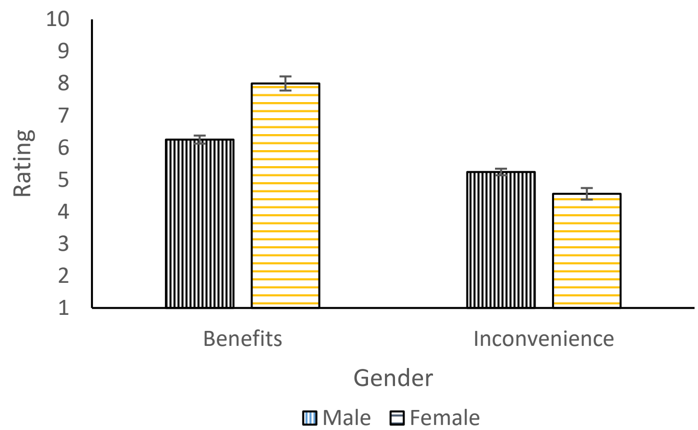

Figure 1. Ratings of Benefits and Inconveniences of Wearing a Face Mask by Gender

A 2 (Scale) x 2 (Pilot status) mixed ANOVA showed a main effect for *Scale*, $F(1,589) = 90.18$, $p < .001$, partial $\eta^2 = .133$, a main effect for *Pilot Status*, $F(1,589) = 21.22$, $p < .001$, $\eta^2 = .035$, and an interaction $F(1, 589) = 18.34$, $p < .001$, $\eta^2 = .030$. Adjusting for age of pilot did not change the results for *Pilot Status*. Post hoc analyses, using a Bonferroni adjustment, showed non-pilots reported greater *Benefits* than Pilots and that non-pilots reported fewer *Inconveniences* than Pilots (see Figure 2).

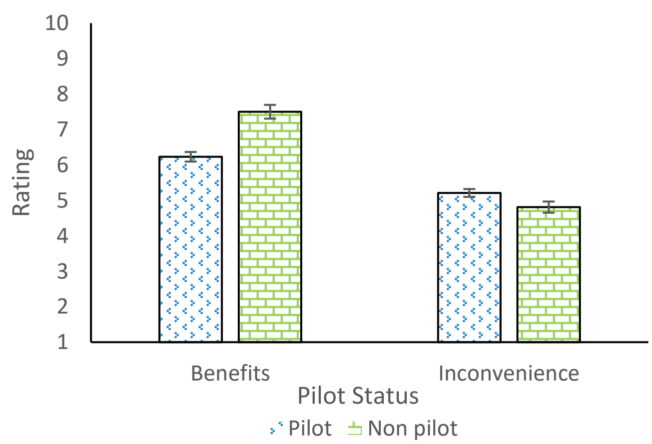

Figure 2. Ratings of Benefits and Inconveniences of Wearing a Face Mask by Pilot Status

A 2 (Scale) x 2 (Status: Student/Non Student) mixed ANOVA showed a main effect for *Scale*, $F(1,596) = 94.26$, $p < .001$, partial $\eta^2 = .137$, and an interaction $F(1, 596) = 18.69$, $p < .001$, $\eta^2 = .030$. The main effect for *faculty/staff status* was not significant $F(1,596) = 3.74$, p = .054. Post hoc analyses using a Bonferroni adjustment showed non-students reported greater *Benefits* than males and that non-students reported fewer *Inconveniences* than males. However, after controlling for age for the faculty/staff status analysis, none of the variables remained significant.

ANOVAs by Policies/Environment

ANOVAs were conducted with various environmental and FM state mandates by *Scale*. A 2 x 2 mixed ANOVA of *Scale* (based on FM state mandate) and the college/university was located found an interaction, $F(1,591) = 10.984$, $p = .001$, $\eta^2 = .018$. Post hoc analyses showed that respondents of schools located in states with state FM mandates reported greater *Benefits* of wearing FMs (see Figure 4). Respondents from schools located in states with state mandates reported higher Inconveniences than respondents from schools located in states that did not have state FM mandates. (see Figure 3).

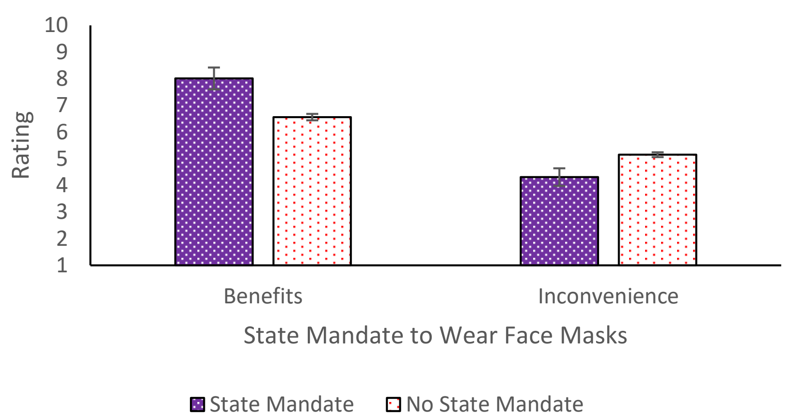

Figure 3. Ratings of Benefits and Inconveniences State Mandate

Correlations

Correlations were conducted between *Benefits*, *Inconveniences*, *State mandate*, *Percent of people in community who wear masks*, and reported COVID-19 *Raw cases* and *Cases per million* leading up to the last 7 days before the survey was distributed (see Table 3). *Benefits* were positively related to state mandates and encountering others wearing a FM. *Benefits* were negatively correlated with ratings of *Inconvenience* and reported *Cases per Million* population.

Table 3
Correlation Table of Ratings of Benefits, Inconvenience, Environment, and Policy

	1	2	3	4	5
1. Benefits	-	-	-	-	-
2. Inconvenience	-.633*	-	-	-	-
3. State mandate	.14*	-.10	-	-	-
4. Raw # of cases last 7 days	.05	.04	-.21*	-	-
5. Cases per million last 7 days	-.133*	-.018	-.14*	-.81*	-
6. Percent of people who wear face masks in community	.156*	-.046	.75*	.21*	-.62*

* $p < .01$

A stepwise multiple regression entering age, faculty/staff status, gender, pilot status, percent of people in community likely to wear a FM, state mandates, cases per million, and ratings of *Inconvenience* to predict ratings on *Benefits* of wearing FMs was conducted. A significant model, $F(5, 571) = 98.21$, $p < .001$ was found where *Age* (p =.014), *Gender* ($p < .01$), *Pilot Status* (p = .012), and ratings of *Inconvenience* ($p < .01$), and *Percentage of Others Wearing a FM* (p =.004) predicted 46% of how respondents rated the *Benefits* of wearing a FM. Faculty/staff Status, *Cases per Million*, and *State Mandates* were not included in the model (see Regression equation below).

Benefits = 10.20 + (017(Age)) + (-1.05(Gender)) + (-.503(Pilot status)) + (-.74(Ratings of Inconvenience)) + (.02(Percent Wear))

Qualitative Data

Most of the open-ended comments were about attitudes toward wearing FMs. Regardless of their attitudes, several respondents said that they appreciated the opportunity to discuss their opinions concerning FMs. An approximately equal number of positive (n = 69) and negative (n = 73), with fewer (n = 25) neutral comments were made. Most of the positive and negative comments were strongly polarized (see Table 4).

Table 4
Selected Positive and Negative Respondents' Comments Regarding Wearing Face Masks

Positive Comments	Negative Comments
• Don't confuse politics with science. Wear a mask. Stay safe. :) • I don't like 'em but I'll wear 'em for the sake of others. • No matter the inconveniences to me, it would be a lot worse to come down with COVID and end up with lasting effects that could invalidate my medical and ruin my career. It is absolutely worth it. • Wearing mask is one of the best way to stop spreading COVID-19. Even though it is really uncomfortable, it is our duty to keep our mask on until the pandemic ends • It should be required world-wide. If not, then at least nation-wide. • Should be enforced more • The only way we are still able to do our jobs is by wearing the face masks and implementing safety precautions. Without them, we would still be out of work and our students would not be able to continue their ratings. Masks are not the cure all, but they greatly reduce the chance of catching the virus. They should be mandated to keep the students and staff safe. • Wish more people would wear masks correctly, I've seen too many people have it not cover their nose or mouth • My hope is that masks become a common courtesy even beyond the pandemic. In the future, I will certainly wear a mask when I feel sick but need to go out in public.	• All wearing a mask does is inconvenience me. I shouldn't have to worry about the health of a few old fogies that I have no relation to. If they catch the virus it doesn't effect my life in any way so why should I care. I don't doubt masks are helpful in reducing the amount of cases the thing is I just couldn't care less about people I don't know. • Mandatory mask wearing is tyranny. Stay inside if you can't handle the risks of everyday life. • Mask mandates are unconstitutional and proven to not work. • We all have the power to govern ourselves. That is why the creator gave us humans the gift to make choices. It harms no one to not wear a mask. However, being forced to do something you don't agree with is slavery. Comparable to rape, assault, and murder. How well I strengthen my immune system is what I can control. I can't make someone else healthy by wearing a mask, nor can someone else stop me from contracting a virus if my immune system is in poor condition. If a mask was a natural form of protection from foreign substances, the creator would have designed a built-in mask that we all have access to attached to our faces. Thank You for conducting this survey. • While the face mask may indeed help for brief distanced interactions inside buildings, it has very little effect outside and especially no effect whatsoever when crammed in a cockpit with another person. If the student and instructor are both comfortable with it, they should be able to take their masks off in flight. I do feel like my mask restricts my head head movement insofar that it messes with my mic boom. Apart from that, I'm ok with wearing a mask inside buildings, but forcing people to wear them outside and in close prolonged situations feels like a big stretch. • The mask is a false-safety. Frankly, I'm sure requiring it to be worn is just for show. "we care about your safety." • It is very hard to breath when flying. It is definitely a huge danger since it's letting pilots become more susceptible to Hypoxia. • It should be up to the person who wants to "protect" themselves. My university is a private institution, they have every right to enact rules (however ridiculous) on their

	property. It is up the the university to remain profitable from their students and therefore should consider the student's feedback if they wanted to remain profitable. The mask wearing is optional according to the state of Florida. I can tell you that people in my age group can care less about COVID. • Stop trying to make people believe in this nonsense.

Discussion

The PCA showed excellent results for reducing attitudinal responses to the *Benefits* and *Inconvenience* factor scales. Female respondents rated *Benefits* of FMs significantly higher than males, and more males rated FMs as *Inconvenient*. These gender differences in attitudes toward FMs reinforce those of Haisher et al. (2020), who found women are more likely to wear FMs in public.

Pilots reported fewer *Benefits* and greater *Inconveniences* of FMs than non-pilots. Although age predicted opinions about *Benefits* of FMs overall, age had no effect on pilots' opinions. That pilots reported fewer *Benefits* and greater *Inconveniences* of FMs is concerning, given that pilots are usually in close contact and longer than 15 minutes in the cramped space of an often poorly ventilated cockpit. Given the evidence of effectiveness of FMs (CDC, 2021; WHO, 2021), it seems one would recognize that the FM "might" be effective.

Dattel et al. (2020), Jarry (2020), Scheid et al. (2020) reported easily-remedied negative attitudes towards FMs, supporting the results that pilots, males, and others reported difficulty breathing, being heard, and threatened autonomy. Dattel et al. (2020) stated that students and Instructor Pilots will most likely adapt to FMs. Humans have a natural inclination toward sensory adaptation where one's perception of a stimulus becomes less sensitive with repeated exposure (Bartley, 1950).

Authorities' contradictory, misleading, or unscientific messaging (Breslow, 2020; Burnett & Sergi, 2020) were mirrored by respondents. Attitudes like invincibility or less social responsibility may explain younger respondents' seeing fewer *Benefits* of FMs. These attitudes may also have arisen from reports of fewer COVID-19 infections among youth (Barone, 2020a, 2020b; CDC, 2020, 2021). This reasoning is flawed because many younger people who become exposed to or ill with COVID-19 and survive, are indisposed for considerable amounts times, or must quarantine (CDC, 2021).

Although it has been recommended that no more than 10 people gather (CDC, 2021), a flight trainer cockpit typically has space for two people. Pilots may have a false sense of security in the cockpit because there are fewer people present.

Despite claims that wearing FMs is politically motivated, (Chiacu, 2020; Feuer & Higgins-Dunn, 2020) we found that when a college/university was in a state with a FM mandate, respondents reported greater *Benefits* and fewer *Inconveniences* of FMs. Similarly, and as found by Katz et al. (2020), respondents reported more *Benefits* of wearing FMs when their college/university was in an area with greater FM compliance. Given that FM mandates improve compliance (Haischer et al., 2020), it is possible that seeing others modeling these behaviors improves attitudes.

The regression analysis showed that respondents who were female, older, had greater likelihood of encountering others wearing FMs, non-pilots, and less *Inconvenience* predicted more *Benefits* of wearing FMs. Being a faculty/staff or student, cases per million in that state, and state FM mandates were not included in the model.

The *Benefits* and *Inconvenience* scales were negatively correlated (-.633). Respondents could have positive attitudes about *Benefits* while also reporting that they are *Inconvenient*. Fortunately, 78% of the respondents reported that they wore FMs most of the time, despite their attitudes.

Limitations and Assumptions

Although several hundred (n = 598) collegiate aviation affiliates responded to the survey, the responses came from 14 UAA member colleges and universities. It is impossible for us to know the true response rate because UAA emailed the survey requests to their POC list. Some institutions have more than one POC, some institutions may have an invalid email address, and some POCs reported anecdotally that they did not receive the request. Because the respondents were from a widely dispersed set of UAA member institutions throughout the US, we believe that this sample provided sufficient representation of affiliates at collegiate aviation programs, providing generalizable results. In addition, the large sample we did receive provided sufficient statistical power for our analyses.

We assume that respondents' answers were honest, with little response bias because the comments seemed to match the quantitative responses, both which were often polarized. Additionally, we assume that self-identified collegiate/aviation status was accurate. Because 80% of data was collected within a 5-day period, we assume media messaging was consistent at that time, thus affecting all respondents equally.

Conclusion

Our findings regarding demographics and reasons for attitudes towards FMs support the literature, including for pilots. However, the reasons for negative attitudes can be effectively addressed. This study also highlighted several findings related to FM state mandates and social modelling (e.g., likelihood of encountering others with FMs), which may improve attitudes towards FMs.

Respondents' reports about FMs were contradictory. These attitudes may be related to public health authorities' messages that have been inconsistent since the start of the pandemic, due to political pressure (Breslow, 2020), and changing knowledge about COVID-19 (CDC, 2021; WHO, 2021). Improved messaging will help to change attitudes and compliance regarding wearing FMs. Collegiate aviation educators have a responsibility to assist this effort and mitigate the spread of COVID-19.

Better management and education are needed to increase compliance with wearing FMs. The leadership within collegiate aviation has played an important role in promoting public health during the pandemic. It is now incumbent upon students, faculty, and staff to continue complying with these critical directives.

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Appendix A
Survey Instrument

Please take a few moments to provide feedback on your opinions about wearing a face covering.

Please state your age (in years) _____

Please select your gender _____ Male _____ Female

Please state the College/University you are affiliated with ____________________

Please select one of the following _____Student _____Faculty _____ Staff

Are you a pilot or student pilot? _____Yes _____No

Please respond to the following questions based on a range of 1 to 10.

Questions for All Respondents

1. What is your current experience with wearing a face mask?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
I never wear a face mask I wear a face mask every time I leave my house

2. Does wearing a face mask help to **prevent the spread** of airborne illnesses like COVID-19 to others?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Not at all Definitely decreases the spread of airborne illnesses

3. Does wearing a face mask **protect you** from catching an illness like COVID-19?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Provides no protection Provides great protection

4. Does wearing a face mask cause decreases in oxygen saturation levels?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Not at all Definitely decreases oxygen saturation levels

5. In general, do you feel that wearing a mask makes it harder to be heard when you talk?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Not at all Extremely difficult to be heard

6. Does wearing a face mask affect your comfort level?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Has no effect on my comfort level Makes me extremely uncomfortable

7. Does wearing a face mask cause the user to inhale higher concentrations of carbon dioxide than normal?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Not at all Definitely increases carbon dioxide levels

8. In general, how well does the face mask fit your face?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Extremely loose Extremely tight

9. Does wearing a face mask restrict your physical movement (e.g., reaching, turning your head) in any way?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Has no effect on my movement Greatly restricts my movement

10. Does wearing a face mask cause you to become fatigued?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Has no impact on my fatigue Cause me to become very fatigued

11. Should the college/university require students, faculty, and staff to wear face masks when **inside** campus buildings?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Not at all Definitely require face masks to be worn

12. Should the college/university require students, faculty, and staff to wear face masks when **outside** of college/university buildings, but still on campus?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Not at all Definitely require face masks to be worn

13. Does wearing a face mask make your body feel warmer/hotter?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
Wearing the mask has no effect on my perceived body temperature — Wearing the mask makes me feel extremely hot

14. Overall, do the advantages of wearing a face mask outweigh the disadvantages?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10
No advantages — Many advantages

Thank you for completing the survey. Please feel free to add any additional comments here.

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How Air Traffic Control Intervention Effects Altitude Deviations on Optimized Profile Descent Arrivals

Donald E. Lyle
Wind Quest Trajectories, LLC

U.S. National Airspace System modernization began with the publication of the Next Generation Air Transportation System Integrated Plan (NextGen) in 2004 to accommodate forecasted air travel demand increases in the United States. This framework proposed an integrated approach to safety, environmental sustainability, reduced fuel burn, and increased airspace and airport capacity by using automated capabilities. One of these capabilities, the Optimized Profile Descent (OPD) is an automated procedure created to link the en route phase of flight with the terminal area within the context of NextGen goals. This type of automated procedure was developed during the NextGen short phase (2004-2012) for both air traffic control and aircraft but continue to be used in a non-integrated manner. It is the confluence of incompatible automated and manual air traffic management techniques that produce a favorable location for an altitude deviation. The purpose of this study is to determine the effect of air traffic control intervention on altitude deviations reported during optimized profile descent arrival procedures in the U.S. National Airspace System from January 1, 2012 to January 1, 2018. Examination of aviation safety reports from this time period showed that air traffic control intervention did affect altitude deviations, specifically in the areas of aircrew error, communication error, and equipment malfunction or limitation. This analysis also demonstrated the failure of the altitude deviation rate to return to normal historic levels after the introduction of NextGen procedures, making altitude deviation a leading safety indicator for the U.S. National Airspace System.

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The purpose of this study was to determine the effect of air traffic control intervention on altitude deviations reported during optimized profile descent arrival procedures in the U.S. National Airspace System (NAS) from January 1, 2012 to January 1, 2018. The *Next Generation Air Transportation System Integrated Plan* (NextGen) (U.S. Department of Transportation [U.S. DOT], 2004) establishes a framework for safety, environmental sustainability, fuel burn and emissions reduction, and increased airport and airspace capacity through the greater use of integrated, complimentary automated capabilities. The literature to date has dealt with concepts and procedures to be used in an increasingly automated NextGen system, with few studies investigating the potential safety implications of using NextGen in a non-integrated fashion. When NextGen is not used as intended, its economic and environmental benefits are not realized, and the safety elements designed into its procedures are bypassed. For example, a single U.S. major airline flew 4,000 flights per day in 2018 (Southwest Airlines, 2018). If one half of those daily flights (2,000) flew an automated optimized profile descent (OPD) arrival uninterrupted, it would save the airline $25 million (US) per year in fuel costs and reduce its carbon emissions by 250 million pounds annually with a jet fuel price of $2 (US) per gallon (Conklin & de Decker, 2021; Lyle, 2020). These economic and environmental benefits are in addition to the increased safety of greater predictability and reduced uncertainty offered by automated NextGen procedures.

Why Air Traffic Control Intervention is Disruptive. An altitude deviation is defined as a departure "...from the assigned altitude (or flight level) equal to or greater than 300 feet...and may result in substantial loss of aircraft vertical or horizontal separation, which could cause a mid-air collision" (Flight Safety Foundation, 2000, p. 65). Sixty percent of reported altitude deviations worldwide take place in the descent and approach phases of flight, with Margison (2014) highlighting a threefold increase in the number of reported altitude deviations from 2011 to 2012. The year 2012 marked the beginning of the NextGen mid phase where many of the procedures developed in the short phase (2004-2012) were deployed for operational use. This is significant because the OPD arrival is made up of the descent and approach phases of flight and is designed to be an automated link between en route and terminal airspace (EUROCONTROL, 2017; FAA, 2017).

An air traffic control intervention is defined as "...airspeed, altitude, or heading instructions issued to the aircraft by air traffic control (ATC) that remove it from or modify the published OPD procedure in some manner" and includes assigning airspeeds, altitudes, or headings different from the published procedure or instructions issued in error (Lyle, 2020, p. 83; Flight Safety Foundation, 2000). Air traffic control intervention on an OPD is generally an instruction requiring the flight crew to remove the aircraft from fully automated flight and downgrade to a reduced level of automation or manual control to comply with ATC instructions. This interrupts the flight management computer (FMC) calculated descent path which provides compliance with published procedure airspeed and altitude restrictions. While the aircraft is not on the published arrival procedure, the FMC does not have a known navigation point and altitude restriction on which to base vertical path calculations and evaluate compliance with those restrictions (General Electric, 2010). If the aircraft is subsequently cleared to rejoin the published procedure, the FMC once again has lateral and vertical navigation information and calculates a new descent profile. At this point the crew may not correctly resume automated flight, there may be an error by the crew or ATC in communicating or understanding the clearance, or compliance with the clearance may exceed the performance capabilities of the aircraft (Lyle, 2020). This is the point where an altitude deviation may occur.

Altitude Deviation as a Leading Safety Indicator. Breaking down a complex system such as the National Airspace System (NAS) to identify potential safety issues involves the use of benchmarks portraying system status. Leading safety indicators are system-specific signals that may show the presence of "…warning signs…" for accident causation and "…directly correlate to future performance…" of the system (Britton, 2019, p. 1). Leading indicators are proactive indices that may point to a need for action when system values exceed certain thresholds, suggesting that system safety has "migrated" to an unacceptable level of risk over time (Leveson, 2015). Further analysis of a leading indicator may also provide insight as to why the system has moved to this increased risk level. Using these definitions, the argument can be made that the altitude deviation rate increasing by a magnitude of three in 2012 and failing to return to historic norms during subsequent years suggest a difference between system design and system use. In the context of the potentially catastrophic consequences of a single mid-air collision where altitude deviation is a factor, however remote, altitude deviation is a leading safety indicator in the NAS, as described by Leveson (2015) and congruent with the proactive safety approach of the *NextGen Integrated Plan* (DOT, 2004; Lyle, 2020).

Background

The Next Generation Integrated Plan is the theoretical construct on which the NextGen airspace modernization program is based (DOT, 2004). Concepts developed during the NextGen short phase (2004-2012) were to be deployed in an integrated fashion during the mid-phase (2012-2020) producing operational data for system improvement and refinement during the long phase, 2020 and beyond (DOT, 2004; Houston, 2017). The FAA's updates and progress reports on NextGen implementation document that the intended integrated deployment has not taken place to date; and, in one instance reported an initiative to target the congested and airspace-constrained northeastern U.S. for a more integrated use of automated NextGen procedures (FAA, 2016, 2018, 2019). More recent FAA performance initiatives have attempted to shift the burden of improving NAS metrics to the airlines without addressing improvements to the underlying system infrastructure and operational philosophy which would enable the airlines to meet these goals (FAA, 2020). The continued presence of altitude deviations reported on OPD arrivals and the failure of altitude deviation rates to return to historic baseline values portray a system that is not being used in its integrated form as it was designed, and consistent with earlier literature arguing that concurrent use of automated and manual procedures would not be compatible (Lyle, 2020).

Literature pre-dating the publication of *The NextGen Integrated Plan* in 2004 addressed the incompatibility of using manual and automated procedures together (Billings, 1997). Billings (1997) cautioned against a system that allows for concurrent manual and automated control because the operator may not have the ability to determine which mode is in use and could circumvent safety features which were designed into the system. Murdoch, Barmore, Baxley, Abbott and Capron(2009) was a seminal study early in the NextGen short phase that reported increased delivery accuracy at the runway threshold by using automated spacing techniques, and aircraft that failed to meet the target spacing parameters did so due to a manual ATC intervention. The findings of Dao et al. (2010) were consistent with those of Murdoch et al. (2009) and reported that "...findings show that current interval management systems perform better at higher levels of automation where there is low human intervention" (p. 25). In their study using the automated capability required time of arrival (RTA) to meld en route and terminal arrival schedules, Hayashi, Coppenbarger, Sweet, Nagle and Dyer (2011) reported a 97% increase in delivery accuracy at the terminal area boundary using RTA when compared to manual techniques. This accuracy increases predictability and reduces uncertainty in the traffic flow, maintains safeguards designed into the automated arrival procedure, and allows for safe reduction in aircraft separation. Reduced separation enables the expansion of airport and airspace capacity.

Method

Theoretical Approach. The exploratory-sequential, mixed-methods approach of qualitative-quantitative- interpretation was used to explore how air traffic control intervention effects altitude deviations on OPD arrivals (Creswell, 2014). Archival data for this study came from two sources: aviation safety reports from the NASA Aviation Safety Reporting System (ASRS) and aviation safety reports from the Aviation Safety Action Program (ASAP) of a U.S. major airline for the study period January 1, 2012 to January 1, 2018. Each of these reports contained textual narratives describing the altitude deviation being reported that enabled the identification of a main theme related to the event. The theme from each narrative was then coded into one of eight independent variables producing numeric values for statistical analysis, the process of quantification described by Landrum and Garza (2015). Correlation analysis was then used to reveal relationships and patterns present in the data that describe the effect of air traffic control intervention on altitude deviations reported on optimized profile descent arrival procedures. "The exploration of these patterns and relationships indicated the use of a mixed-methods approach with its increased depth of understanding and analytic density" (Fielding, 2012; Flick, 2007; Lyle, 2020, p. 69). It is the relationships between variables and the ability to determine effect sizes rather than specific causal factors that is the focus of this study and its methodological approach (Lyle, 2020).

The nature of ASRS and ASAP being voluntary aviation safety reports introduced bias into the data, most notably *self-reporting bias* which includes *recall bias* (Althubaiti, 2016). Additionally, the confidential nature of the reports due to the reporter protections of these programs made reliability and validity testing difficult, even though the data was collected through each program's standardized reporting method. The use of a mixed-methods study addressed bias as well as reliability and validity issues through triangulation, providing a decrease in bias and a cogent option for validation (Kennedy, 2009; Turner, 2016). ASRS limitations specifically state that ASRS data represent the lower boundary of reliability rather than a precise measure, and results reported in this study will document a lower boundary of reliability (NASA, 1996). ASAP data is subject to many of the same limitations and results and will also represent a lower boundary of reliability.

Variables. Eight independent variables were present throughout the literature as main themes related to altitude deviations reported on OPD arrivals. They were: *air traffic control intervention*, *aircrew error*, *collision avoidance*, *communication error*, *equipment malfunction or limitation*, *other*, *terrain avoidance*, and *weather* (Buono, 2014; Flight Safety Foundation, 2017; IATA, 2017; Margison, 2014). These are nominal variables with no intensity or scalar component but do represent a primary theme embedded in the aviation safety report narrative.

Qualitative Analysis. Narrative analysis comprised the qualitative portion of the study. Each aviation safety report was screened to ensure that it met study criteria: occurred within the study period in the U.S. NAS, altitude deviation reported, OPD arrival procedure, and FAR 121 air carrier (Lyle, 2020). Aviation safety reports are the direct observation of the person involved in the event being reported. ASRS and ASAP data are well-suited to the performance, structural, and literary narrative analytical method of Rogan and de Kock (2005) by "…solicitation of specific narrator experiences…" (p. 632), "…probed for a deeper interpretation of meaning through rich evidential detail…" (p. 638), and, "…evidence for interpretation in the stories was also sought by examining the literary convention of plot…and the narrator's connecting logic of the sequence of events" (pp. 641-642). Using this method, the primary theme from each report was coded into one of the eight independent variables using NVivo (Version 12) qualitative analysis software, and the narrative text catalogued in the appropriate variable node to support variable selection. This process was repeated for each report in the initial ASRS and ASAP datasets which produced 393 ASRS cases and 1791 ASAP cases that met study criteria for quantitative analysis (Lyle, 2020). Both sets of data were procured in chronological order from January 1, 2012 to January 1, 2018 and were divided into four 18- month time periods. Once each case was coded into its appropriate independent variable, this allowed for frequency analysis of the total number of cases contained in each variable and the evaluation of frequency changes over time.

Quantitative Analysis. To determine effect sizes and significant relationships between variables, correlation analysis was performed using SPSS 24 statistical software. As stated earlier, the purpose of this study is to determine the effect of air traffic control intervention on altitude deviations on OPD arrival procedures, not causal factors. Therefore, it is important to set statistical significance and statistical power at appropriate levels to detect significant correlations and minimize both Type I and Type II error rates (Field, 2013). A statistical significance level of $p < .01$ and statistical power of .80 were used in this study with both ASRS and ASAP samples ($N = 60$) being large enough to detect large effect sizes (Cohen, 1992). The correlation analysis used a bootstrap sample size of 1,000. Cronbach alpha was not used as an exact measure of reliability in this study due to the archival and confidential nature of the data, but as a "…lower boundary measurement of the presence of variable correlations within the data" (Lyle, 2020, p. 92). A complete description of the determination of these values may be found in Lyle (2020, pp. 89- 92).

Interpretation. To determine how air traffic control intervention effects altitude deviations on OPD arrival procedures, effect sizes were computed for interpretation. This was done by squaring the Pearson's correlation coefficient (r) for two variables calculated in the correlation analysis to produce the coefficient of determination (R^2) or effect size (Field, 2013).

Effect size "…is a measure of the amount of variance in one variable that is shared by the other" or the strength of the relationship between two variables (Field, 2013, p. 276). Effect size (R^2) was interpreted as small = .10, medium = .30, and large = .50 (Cohen, 1992; Field, 2013).

Results

Qualitative Results. Air traffic control intervention effects altitude deviations reported on OPD arrival procedures primarily in the areas of aircrew error, communication error, and equipment malfunction or limitation. Qualitative frequencies from the ASRS and ASAP narrative analysis are shown by 18-month period labeled Alt Dev1, Alt Dev 2, etc. in Tables 1 and 2 (Lyle, 2020). Frequencies are the number of cases coded into each variable for each period.

Table 1
ASRS Altitude Deviation Frequencies

Variable/Time Period	Alt Dev1	Alt Dev 2	Alt Dev 3	Alt Dev 4	**Total**
Air Traffic Control Intervention	33	29	25	24	111
Aircrew Error	24	20	11	13	68
Collision Avoidance	5	6	3	1	15
Communication Error	28	13	6	8	55
Equipment Malfunction or Limitation	33	22	17	24	96
Other	1	1	1	1	4
Terrain Avoidance	0	2	0	1	3
Weather	12	5	12	12	41
Total	136	98	75	84	393

Table 2
ASAP Altitude Deviation Frequencies

Variable/Time Period	Alt Dev 1	Alt Dev 2	Alt Dev 3	Alt Dev 4	**Total**
Air Traffic Control Intervention	206	233	202	126	767
Aircrew Error	138	94	121	84	437
Collision Avoidance	15	5	5	2	27
Communication Error	49	68	67	40	224
Equipment Malfunction or Limitation	53	68	54	39	214
Other	2	6	12	6	26
Terrain Avoidance	0	1	0	0	1
Weather	21	24	31	19	95
Total	484	499	492	316	1791

Quantitative Results. The purpose of this study was to determine how air traffic control intervention effected altitude deviations on OPD arrival procedures. Effect size was determined by squaring the correlation coefficient calculated by correlation analysis for each significant correlation. This produced the coefficient of determination, R^2, or effect size of each significant correlation (Field, 2013). Effect sizes for significant correlations in the ASRS and ASAP data are shown in Tables 3 and 4 (Lyle, 2020). Large effects are >.50.

Table 3
Effect Sizes of Significant ASRS Data Correlations

Correlation	R^2
Air Traffic Control Intervention / Aircrew Error	.92
Air Traffic Control Intervention / Communication Error	.90
Air Traffic Control Intervention / Equipment Malfunction or Limitation	.61
Aircrew Error / Collision Avoidance	.58
Aircrew Error / Communication Error	.86
Aircrew Error / Equipment Malfunction or Limitation	.67
Collision Avoidance / Communication Error	.32
Collision Avoidance / Weather	.48
Communication Error / Equipment Malfunction or Limitation	.85
Terrain Avoidance / Weather	.72

Table 4
Effect Sizes of Significant ASAP Data Correlations

Correlation	R^2
Air Traffic Control Intervention / Aircrew Error	.21
Air Traffic Control Intervention / Collision Avoidance	.18
Air Traffic Control Intervention / Communication Error	.67
Air Traffic Control Intervention / Equipment Malfunction or Limitation	.90
Air Traffic Control Intervention / Terrain Avoidance	.36
Air Traffic Control Intervention / Weather	.24
Aircrew Error / Collision Avoidance	.74
Aircrew Error / Terrain Avoidance	.17
Collision Avoidance / Other	.38
Communication Error / Equipment Malfunction or Limitation	.72
Communication Error / Other	.30
Communication Error / Terrain Avoidance	.34
Communication Error / Weather	.67
Equipment Malfunction or Limitation / Terrain Avoidance	.67
Equipment Malfunction or Limitation / Weather	.17
Other / Weather	.71

The presence of these large effects suggest that altitude deviation is a leading safety indicator in the U.S. National Airspace System. As such, large effects suggest that the U.S. National Airspace System and NextGen specifically are not being used as they were designed. Aircrew error was previously mentioned as a significant correlation with air traffic control intervention. Taking this effect one step further, there exists a large effect between aircrew error and collision avoidance in both the ASRS (.58) and ASAP (.74) data. The data indicate a positive correlation between air traffic control intervention and aircrew error, an increase in one produced an increase in the other. These data also show a positive correlation between aircrew error and collision avoidance. The complex coupled nature of air traffic management in the U.S. National Airspace System illustrate how these variables are interrelated, but not necessarily directly. Air traffic control intervention does not correlate directly with collision avoidance in the data but does correlate with it indirectly through aircrew error. These findings are consistent with Billings (1997) who observed that isolating errors in a complex system may be difficult due to the opacity of indirect relationships and the potential of having automated and manual control in use simultaneously.

Discussion

The results in Tables 3 and 4 show that air traffic control intervention had some of the largest number of statistically significant correlations at $p < .01$ and some of the largest effect sizes (R^2) for both the ASRS and ASAP data groups (Lyle, 2020). Air traffic control intervention had large effects with communication error and equipment malfunction or limitation in both data sets, a large effect with aircrew error in the ASRS data, and small effect with aircrew error in the ASAP data. These effects do not occur in isolation but describe a sequence of events that lead to an altitude deviation with potential safety-related consequences. An example of this would be the large effect between air traffic control intervention and equipment malfunction or limitation. Air traffic control issues a clearance that takes the aircraft off the charted OPD arrival. The aircraft is then issued a clearance to resume the arrival and comply with an altitude restriction that exceeds the performance capabilities of the automated flight management system resulting in an altitude deviation. This example also illustrates the disruption caused by manual intervention in an automated system that had previously calculated aircraft performance requirements that met procedural restrictions.

It is precisely these types of interrelationships that give altitude deviation its value as a leading safety indicator. The frequency data in Tables 1 and 2 do indicate a declining trend in the number of cases citing air traffic control intervention as a factor in a reported altitude deviation. However, Tables 1 and 2 continue to show air traffic control intervention as the leading factor cited in an altitude deviation report during the last 18 months of the study period (Alt Dev 4). Correlation analysis by its definition does not identify a causal factor, but the method does identify relationships and their strength in the data. The continued presence of these frequencies in Tables 1 and 2 and the large effects in Tables 3 and 4 suggest that air traffic control intervention is still affecting altitude deviations. Leading safety indicators identify areas of concern *before* an accident happens, and this information can be used to gain a better understanding of contributing factors even if they are not readily apparent. A more complete understanding of the altitude deviation event and the interplay of contributing factors provide a more comprehensive view of how the system is being used, and insight into the effectiveness of design safety measures. Should these safeguards be inadequate to prevent a migration from the desired level of safety within the system, mitigating procedures may be introduced or enhanced to return the system to the acceptable safety level for which it was designed (Leveson 2015). In this context, the data show that the confluence of automated and manual air traffic control procedures creates a locus for an altitude deviation, and mitigating action is warranted to reduce or eliminate this practice. The failure of the altitude deviation rate to return to historic norms and the continued presence of significant large effects between air traffic control intervention and other study variables indicate that this practice is still taking place and potentially compromising aviation safety.

Conclusions

Air traffic control intervention directly effects altitude deviations reported on OPD arrival procedures primarily in the areas of aircrew error, communication error, and equipment malfunction or limitation. Altitude deviation is a leading safety indicator for the U.S. National Airspace System, and it is suggesting that the system is not being used in the integrated manner outlined by the NextGen *Integrated Plan,* and that the system safety level is being compromised by the continued concurrent use of automated and manual procedures. The literature argued that these two methods of control would not be compatible when used together, and the effect sizes from these data suggest that this is indeed the case. This contradicts the proactive safety thread of the NextGen *Integrated Plan* in that built-in automated safety design is bypassed when manual control is introduced, and there were no provisions or safety planning in the *Integrated Plan* that allowed for combined use of automated and manual procedures. Taking the systems theory view, this hybrid automated/manual control environment has not been vetted for potential safety conflicts or examined in-depth to explore unintended negative safety-related outcomes.

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Moving Beyond Representation: Reimagining Diversity and Inclusion Efforts in the Aviation Industry

Shannon McLoughlin Morrison
The Ohio State University

According to the Federal Aviation Administration's Civil Airmen Statistics, the number of women who hold an Airline Transport Pilot (ATP) Certificate remains low. The numbers of Black, Latinx, Indigenous, and other minoritized individuals remain challenging to identify. Given these numbers, the response on the part of the aviation industry has been to leverage marketing campaigns, particularly around the affinity months of February, March, and June (Black History, Women's History, and Pride month) to perform their support with articles and initiatives like "the first all LGBTQ flight crew," or the first "Black female captain." Despite this work, aviation remains a challenging industry to enter. This position paper asserts that in order for the aviation industry to truly move forward in its diversity and inclusion efforts, then conscientious reflection on the experiences of minoritized individuals is necessary. To do that, we can look to Black feminist and anti-racist scholarship to better understand the ways in which it is imperative that aviation move beyond representation; towards the kind of transformational change that would enhance the industry.

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Diversity and inclusion proponents and practitioners in the United States of America have placed a high value on trying to understand why the numbers of underrepresented individuals remain low in various industries. This is no less true when thinking about the actions of the aviation industry. Sara Ahmed (2012) writes “In the diversity world, there is a great deal of investment in images” (pg. 33). Imagery here is understood as an action that organizations can take to show support for diversity and inclusion. Ahmed argues that by investing in images, organizations can appear to be supportive of diversity and inclusion without having to make substantive changes that would eliminate or drastically reduce the obstacles that exist for minoritized individuals. Focusing on imagery and representation has the added consequence of reinforcing a particular kind of narrative about people who have been minoritized, the belief that their underrepresentation is directly tied to the fact that they do not represent the “norm” (Walcott 2018, Ahmed 2012). In other words, images offer the possibility of maintaining the status quo while also seemingly welcoming diversity. Imagery is important for institutions as it creates the opportunity to make minoritized individuals both invisible and hypervisible. They become hypervisible at the hands of industry when they are needed to demonstrate success at becoming more inclusive, but are yet invisible when organizations continue to ignore the experiences of these individuals which can be in direct juxtaposition of the claim that inclusivity has been achieved.

The Federal Aviation Administration’s (FAA) Civil Airmen Statistics (2020) indicate that, of those who hold an Airline Transport Pilot (ATP) Certificate, a certification necessary to fly for a commercial airline, only a little over 4% are women. Lutte (2019) demonstrates that pilots are not the only profession in aviation where women are underrepresented. Women still represent less than 5% of maintenance technicians and executive leadership roles (e.g. Chief Executive Officer, Chief Operating Officer, etc.). Women also represent less than 20% of dispatchers, aerospace engineers, airport managers, and air traffic controllers. According to an article published by Kaji, Luna, and Sweeney (2020) on ABC News, less than 1% of pilots are Black women, the numbers of LGBTQIA, Latinx, Indigenous, and other people of color is not as readily available. Given the low numbers of diverse representation, aviation is not unlike other industries in its response to calls for creating a more diverse and inclusive workforce.

The challenge that aviation faces, like most other industries, is to move past the acknowledgement of the need for a more diverse and inclusive workforce, into actions that lessen the barriers, and create, not just opportunities, but access. The ways in which the industry currently responds to the call for more diversity and inclusion, is through their marketing and human resources strategies, which are more often than not focused on changing or increasing the representation within the organization. Less often considered, are conversations about how the organization itself is moving past representation alone and towards dialogues about how policies and procedures maintain racism and other socially unjust practices.

One of the best examples of this can be found in the kinds of marketing that occur during the various affinity months of February (Black History Month), March (Women’s History

Month), and June (Pride Month). Take for example, the American Airlines article describing the first all-LGBTQ flight crew to operate an American flight that occurred in June 2019. It was an article which featured the individuals operating the flight and contextualized their position in the industry against the backdrop of the struggle for LGBTQIA rights. Articles like this play an important role in demonstrating the importance of a diverse culture in the airlines, however, this flight alone is not what will change the numbers of LGBTQIA individuals who are pursuing careers in the industry.

Another example of this can be seen with an article that was published by Solomon (2017) on Delta's website in February 2017. Captain Johnson is Delta Air Lines' first Black female captain for the company, a ground-breaking achievement for her. What the Delta article does not describe is how Captain Johnson was upgraded to captain after spending years working as a First Officer, a path which is not particularly unique. Captain Johnson was formerly with Northwest Airlines, which was acquired by Delta in 2008. As part of that merger, Northwest pilots became a part of the Delta team. The result of an article like this, is that Captain Johnson becomes both hypervisible and invisible. Evans (2013) describes this as:

> Hypervisibility is to be observed (and pointed out) as an anomaly, consistent with being on display. Invisibility works in an opposite way-to be invisible is to experience the visceral reaction of being rendered to a position of subordinate status. (pg. 13).

In other words, Delta was able to make Captain Johnson hypervisible; using her success and hard work as their yard stick for successfully supporting diversity and inclusion efforts. However, her promotion to captain was not the result of any institutional or organizational change that Delta had to make, it was the result of a seniority-based system that had been in existence for years. Delta was able to claim Captain Johnson as a success story without having to investigate the organization's climate and culture which made her the first. Evans (2013) furthers this point, writing:

> To be white-washed in order to fit into a corporate culture and survive in the industry is indicative of the daily struggles of going to work and performing a job in which black identity and subsequent labor is not respected. (pg. 121)

This is the challenge of an industry that continues to use representation as its primary benchmark for success in diversity and inclusion. Walcott (2018) writes, "The performative non-performativity of reproducing whiteness is skilled at writing policy and negligent at implementing it, all the while making claims of being committed to doing otherwise" (pg. 88) Diversity that focuses on representation becomes about the performance of support without the substantive work of transforming policies and institutions.

Building on the work of Ahmed, Walcott, and others, I argue that this overreliance on representation in the field of aviation has been detrimental to creating more inclusive and equitable spaces. The overreliance on increasing the representation of minoritized individuals ignores the imperative to evaluate, or provide a critical analysis, of white normativity and systemic inequality in academic and industry institutions. While diversity and inclusion efforts have the potential to provide strategies for institutions, if they do not move beyond thinking about representation it does little to alter the systemic racial, gender, and class inequality that remains pervasive in academic and industry institutions. I suggest that a clear articulation of anti-racist ideas on the part of aviation educators and industry, will also have the unintended consequence of attracting and retaining more minoritized individuals to the field. If the focus shifted from representation to a robust reflection on culture and climate, institution, and educational spaces (and workspaces), it will ultimately become transformative for all.

Diversity Idolized

What makes focusing on representation so appealing to individuals and organizations? In thinking about how organizations respond to calls for diversity, there is typically an imperative to treat these topics as ideals. Or ways of defining institutions who wish to see themselves, and have others view them as progressive. Bell and Hartmann (2007) call this dedication to idealism, 'happy talk.' They write:

> It is not just that Americans are talking about diversity that is extraordinary; it is how they are talking about it: extolling the virtues of difference, celebrating diversity as a value in itself, and describing diversity as the new cornerstone of American idealism. (p.895)

American institutions, including higher education institutions, find themselves celebrating diversity for the sake of diversity. There is rarely, if any, critical reflection on why diversity is needed in the first place. In fact, Bell and Hartmann found in their study that participants had a superficial definition of diversity, most often citing 'difference,' and the idea that America was a 'melting-pot.' However, what participants struggled with was maintaining that optimism when it came to actually implementing or practicing diversity and inclusion efforts. The authors wrote "the 'fun' of diversity is difficult to specify because it is undercut by the frustrations of actually dealing with difference" (p. 900). Study participants expressed concern over fragmentation and cultural unity, demonstrating that diversity discourse, frequently does not include discussion about equity. Their findings suggest that as diversity discussions within organizations are often romanticized, the more challenging conversations around racism, sexism, and policies that maintain white supremacy are less likely to occur.

Brayboy (2003) reinforces this idea that the implementation of diversity is problematic at best and harmful at its worst. He, like Ahmed and others, recognizes that the work of diversity is often left to people of color to create, implement, and sustain. In other words, they are called upon to be the 'cheerleaders' of diversity in an effort to make an organization appear as though it has bought in. Brayboy (2003) writes:

> White institutions of higher education often view diversity as a free-standing policy, and the way that diversity is something that can be implemented without necessarily changing the underlying structure of institutions and its day-to-day operations. Institutions figure, for example, that they can merely offer new courses on diversity, hire a few faculty of color, assign these faculty to cover committee assignments, work with students of color, serve as role models, and offer helpful suggestions on how to be a more user-friendly institution to all the students, including the ones of color. (pg. 73)

Brayboy articulates what many others have criticized about diversity and inclusion initiatives: that they are often more akin to window dressing then actual substantive change. He goes on to further his analogy, comparing diversity policy to a library, essentially the same place it has always been, designed to serve the same people. While Brayboy may have directed his attention specifically to higher education, similarities could be drawn to the aviation industry. Emphasis on hiring Chief Diversity Officers, creating employee resource groups, and leveraging the affinity months for marketing make the lives of those who have always been a part of aviation easier, but it does little to change the culture such that more minoritized individuals have access.

Ahmed (2012) ultimately concludes that “diversity can be a method of protecting whiteness” (p. 147). Ahmed comes to this conclusion by the ways in which diversity and diversity work are deployed at higher education institutions. She describes how diversity and inclusion work are used as a method for maintaining what she calls ‘white normativity,’ or the concept that whiteness is the status quo. Diversity initiatives and strategies at higher education institutions often act as a call to action, solidified with an action plan that is pointed to as evidence that the institution is doing something about diversity and inclusion. She continues, “Organizational pride can take the form of diversity pride. Diversity as public relations can thus be mobilized in defense of an organization and its reputation” (pg. 144). In other words, when someone accuses an individual or program within the institution of being racist (for example) it is much easier to deny the experience or claim it is nonexistent.

The Current Climate for Minoritized Individuals in Aviation

When diversity, as a practice, becomes idolized by people and organizations, it begins to limit the kind and amount of change it can effect. The United States Bureau of Labor Statistics (2019) found that women constitute half of the workforce in most developed nations. However, as Yanıkoğlu, Kılıç, and Küçükönal (2020) note, women are underrepresented in fields that have been traditionally coded or dominated by men. They found that this was in part due to workplace discrimination, but also due to stereotypes that evolve as a particular kind of job becomes coded as male or female. They (2020) write: “women in the aviation industry believe that they need to work harder and demonstrate a higher standard of work within their career field to be accepted and appreciated by their male co-workers” (pg. 3). Their findings suggest that female pilots, who experience gender discrimination in the workforce, are more likely to face a higher psychological burden that ultimately impacts behavior and performance. Davey and Davidson (2000) received similar responses through their research on the experiences of female pilots. They argue that women in aviation have had to adapt themselves to a male-dominated culture and are less likely to challenge the system in order to survive and maintain their careers. This perception of the obstacles to being successful (in this particular career) have the potential to maintain barriers to accessing the industry.

Evans (2013) identifies something similar after interviewing Black pilots and flight attendants about their experiences working in the aviation industry. Evans suggests that there is an increase in the amount of emotional labor that these individuals experience when working their jobs. She writes:

> Emotional labor is therefore multidimensional in that labor by people of color, in this historically white industry, is both gendered and raced; it is performed within the context of work as well as within the context of relationship management, all within an inescapable environment. (pg. 11)

Evans describes a kind of emotional labor that is part of the everyday experiences of Black people in the aviation industry. Through her numerous interviews, Evans found that companies may express support for diversity and inclusion, but that the reality is that they were nowhere near creating an inclusive and equitable environment. In this case she writes “diversity, as defined in theory and practice, are not synonymous with equality” (pg. 128). Evans reinforces here the primary challenges presented to diversity and inclusion efforts within the aviation industry; or the belief that focusing on changing the representation alone is going to be the solution to a challenge that continues to persist. Evans and Feagin (2012) further recount the ways in which African Americans face continued discrimination, despite the efforts that the aviation industry has made to suggest otherwise with their marketing campaigns (aforementioned Delta article, American article). They write, “The deeply held belief in racial equality rescues most whites by denying their participation in contemporary racism and racial oppression” (pg. 652). Evans and Feagin were able to interview a number of African American pilots and flight attendants who were able to share their experiences working in the industry. These individuals regularly expressed instances where co-workers or passengers demonstrated outright racism, ultimately creating an additional burden and emotional labor that the individuals become responsible for managing.

By acknowledging the experiences of these individuals, we come to find that the diversity and inclusion the industry wishes to present, through marketing strategies and imagery, differ greatly from one another. Despite the existence of organizations like the National Gay Pilots Association (NGPA), Women in Aviation, International (WAI), the Organization of Black Aerospace Professionals (OBAP), and the creation of a Women in Aviation Advisory Board by the Federal Aviation Administration, there has not been a significant alteration in the actual representation of minortitized individuals in the industry. Reflecting on the work of Evans and Feagin and others suggests that the problem of underrepresentation in the industry cannot be solved by increasing that representation alone. While the focus of the industry remains on increasing the numbers of people who have historically been underrepresented, it does not directly address the challenges and the experiences of those who are minoritized.

This notion of protecting ‘whiteness’ and maintaining anti-blackness at institutions is supported by Walcott (2018), who argues that diversity work often obscures racist or anti-black rhetoric, “The work of diversity can often obscure anti-blackness and the impenetrable structures that continually produce Black peoples as out of place, as things, and as non-human” (pg. 90). It is evident that, however valued some may think diversity and inclusion efforts are, there is also a risk that it will continue to perpetuate white normativity, racist practices and policies, and anti-justice oriented climates. Walcott, as others have suggested, is critical of the ability of diversity and inclusion efforts to create and sustain work environments that are equitable and socially just. He ultimately argues that this is not possible with such efforts as the default position is to sustain current institutional practices that have prevented minoritized individuals from entering in the first place.

Aviation Education

The focus on changing the representation to attract and retain more minoritized individuals can also be found at the collegiate level within aviation higher education, and STEM (science, engineering, technology, and math) fields more broadly. Halleran (2019) recognizes the low numbers of women represented throughout the industry and argues for continued efforts in outreach and mentoring programs that encourage young women to pursue careers in the aviation industry. This is a position that most in STEM academic fields take when it comes to increasing the numbers of students who have been underrepresented by the field. What is most common within higher education institutions are the efforts to increase the programming in support of marginalized or underrepresented students, underscoring questions as to why they are not being represented in the research that is being conducted within STEM fields. Tomasko, Ridgway, Waller, and Olesik (2016) looked at the participation of underrepresented minorities (specifically Hispanic, African American, and Native American), first-generation students, and females in a six-week bridge program that occurred prior to their enrollment in a land-grant, research institution. What the study found was that participation in this program was statistically significant for retention to major (out to the students' third year) for African Americans, Hispanics, Native Americans, and females. The findings were, on the other hand, not statistically significant for first-generation students. The primary finding from this study was that students needed both a sense of belonging and academic support structures in order to persist in STEM. Their conclusion was that programming directed at underrepresented groups needed to address the student holistically, and not just provide academic support structures. What this study unknowingly identified was the need for academic programs to reflect more critically on the underlying reasons why their programs may not have historically fostered inclusive environments. This kind of analysis transitions efforts from being solely about representation into ones that evaluate institutional structures that have maintained barriers to entry.

Kim and Albelo (2020) conducted a qualitative study that gathered information on the experiences of female aviation students in order to better understand their barriers to success. Their findings suggest that female collegiate students looked for communication, community, and positive relationships with faculty. Their work begins to move the conversation around simply questions of increasing numbers and into an evaluation of the experiences of women. In fact, their recommendations did not rely on programming for recruitment, so much as they were designed to address the concerns that were raised by the women's experiences. This is what Pawley (2017) argues creates an inclusive practice. Moving past programming, for Pawley, means questioning the degree to which researchers still rely on white male students for subjects, and feel obligated to defend the inclusion of underrepresented students. Her calls to reimagine research in engineering education resonate with the work of Kim and Albelo (2020) where more work needs to be done to better understand the experiences of minoritized individuals in order to create and promote solutions to the problems of representation.

Some researchers are beginning to rethink their methodologies when it comes to evaluating and analyzing the experiences of minoritized students. Secules, Gupta, Elby and Tanu (2018) demonstrated how an innovative approach to research might be fruitful. The authors relied on black feminist scholar and educator bell hooks to provide a way of theorizing and articulating the experiences of a marginalized student. The stated purpose of their research is to apply "scholarship from critical theory and narrative as a new resource for approaching and understanding the process of supporting marginalized student agency" (p. 186). The authors understood that their particular research into underrepresented students necessitated a different approach to theorizing about the connections between student experiences in engineering and mentorship programs. In other words, there was a sense that the work they were doing was in consideration of the students and not merely that they represented a marginalized group.

However, while Secules, Gupta, Elby and Tanu (2018) used black feminist scholar bell hooks to create space and opportunity for students who have traditionally been marginalized by the field of engineering education to share their experiences, they were still unable to move beyond their primary argument that representation is imperative to changing the ways in which research is conducted in the field. Their research took the step of finding innovative ways of conducting research with individuals who have been underrepresented, but it didn't take the step of translating how those experiences reflect the current climate and culture of STEM fields that maintains white normativity. It never moves beyond mere bodies and into more challenging conversations about how and why minoritized individuals fail to show up in research practices or in STEM-based academic programs and careers.

Dismantling the Status Quo: Black Feminism and Anti-Racist Discourse

If, as Ahmed, Walcott, and others suggest, diversity and inclusion efforts are tied to maintaining and sustaining 'white normativity,' is there a way of moving forward that achieves the kind of transformation that is sought? What kind of possibility and solutions are there if we begin to move away from representation as being an indicator for success?

One of the places that we might turn to is the research and literature around anti-racism and Black feminist scholarship. In both instances there is a focus on the individual and the value of experience as important to knowledge creation, discourse, and policymaking. In particular, diversity and inclusion advocates and practitioners must understand that not all minoritized individuals experience disadvantage, created by the aviation industry, in the same way. Black feminists have described this as an 'intersectional approach' to understanding and articulating the experiences of discrimination experienced by Black women. Crenshaw (1989) writes, "With Black women as the starting point, it becomes more apparent how dominant conceptions of discrimination condition us to think about subordination as disadvantage occurring along a single categorical axis" (p. 140). Crenshaw was theorizing about the law and the legal profession in the United States and how Black women are often marginalized in multiple ways because of their identities as both Black and women. She argues that one cannot fully understand or theorize about the lives of marginalized groups without consideration for the intersectional experience. "Because the intersectional experience is greater than the sum of racism and sexism, any analysis that does not take intersectionality into account cannot sufficiently address the particular manner in which Black women are subordinated" (pg. 40). While Crenshaw was speaking from the legal field, Evans (2013) is able to directly connect this theory on intersectionality back to the aviation industry. Her conversations with African American flight attendants demonstrates the ways in which they experience both racism and sexism as a regular part of their work environment from both passengers and colleagues. Evans (2013) writes:

> Arguably, most other works on emotional labor often fail to incorporate the multiple ways it is performed throughout the workday. By specifically examining African American pilots and flight attendants, occupations that remain understudied, the more explicit connections between emotional labor performance, and race and gender identity and ideologies clearly show that much emotional labor takes place within complex systems of interaction. (p. 10)

Both scholars stress the importance of articulating and understanding how these experiences impact the ways in which Black women and other women of color experience traditionally white spaces. This kind of (intersectional) understanding of experience is not articulated in articles and pictures that tout the 'first all-Black flight crew," or the first Black female captain at an organization.

While Crenshaw was theorizing specifically about Black women, we can imagine how an intersectional approach might be useful to understanding and articulating the experiences of a variety of underrepresented groups (e.g. LGBTQIA, Latinx, individuals with disabilities, and Indigenous people). Key to using an intersectional approach is the recognition that the experiences of marginalized and underrepresented students are complex and not just the sum of their identities (for example, being queer and Black), but the ways in which individuals can be subjected to what Crenshaw (1989) calls "double-discrimination" (p. 149). Intersectionality is not meant to be an 'additive' approach to understanding racism, sexism, discrimination, etc. It is mean to create an opportunity to more fully understand the ways in which, those who have historically been marginalized within an industry, continue to be.

The Role of Controlling Images in Maintaining White Normativity

One of the ways in which we can better understand the experiences of Black women, women of color, and other minoritized individuals, is to better understand how images are used as a controlling force. Ahmed (2012) describes the ways in which institutions have relied on imagery as a means for maintaining the status quo. It creates an opportunity to appear supportive of diversity and inclusion, but does little to make any transformative change that would enable more individuals to have access.

Imagery has long been used as a means of controlling different groups of people. Brooks and Hébert (2006) write, "The racial categories we use to differentiate human difference have been created and changed to meet the dynamic social, political, and economic needs of our society" (pg. 297). In other words, the ways in which we depict and articulate the categories of individuals who are racially different from ourselves, are deeply connected to our political, social, and economic interests. Simms (2001) indicates that there are three specific images of Black women (mammy, Jezebel, and mule) which became an integral part of the discourse which justified the enslavement of Black women and ultimately "contributed substantially to the construction of African women's gender" (pg. 880).

Collins (2009) furthers the argument that imagery has a long history of being used to control Black women, in what she calls 'controlling images.' Collins (2009) writes, "Portraying African-American women as stereotypical mammies, matriarchs, welfare recipients, and hot mammas helps justify U.S. Black women's oppression. Challenging these controlling images has long been a core theme in Black feminist thought" (pg. 76). Collins articulates the ways in which images often become a narrative which is then used as the basis for which Black women are oppressed. Lindsey (2012) reinforces this narrative by writing "Systems of domination such as American slavery, colonialism, cultural imperialism, and global capitalism produced contexts in which black female bodies became instrumental to configurations of racialized sexual stereotypes. Popular culture and mass media circulation of images of popular culture artists are preeminent sites for the reification of the power of the systems of domination" (pg. 1). While Lindsey may be speaking specifically about what happens with pop culture symbols (Beyoncé, Cardi B, etc.) her argument is applicable to the imagery that the aviation industry leverages in the form of articles like the one Delta produced about its first Black female captain. The end goal of the reaction those images produce may be a little different, but in both situations, Black women and women of color are being made visible, often with little to no reflection on their personal experiences, and frequently leading to situations where the status quo is being maintained.

Ultimately the arguments of Collins, Simms, and others suggest that diversity efforts which focus on representation through imagery ignore the long history, and the ways in which images have been used as a controlling force against Black women and other minoritized individuals. A diversity and inclusion strategy that is based on representation alone, is less likely to encourage and support the kind of conversations and reflection that would produce transformational change within organizations. By failing to have these challenging conversations, the industry may face the consequence that 'whiteness' is reinforced and sustained.

Black feminist scholarship lends itself to the practice of anti-racism. Kendi (2019) writes, "An antiracist idea is any idea that suggests the racial groups are equals in all their apparent differences – that there is nothing right or wrong with any racial group. Antiracist ideas argue that racist policies are the cause of racial inequities" (pg. 21). Kendi makes the case that difference itself is not the problem. The problem is when that translates into what he calls 'racist policies,' or systems and structures designed to oppress people. He further writes "Like fighting an addiction, being an antiracist requires persistent self-awareness, constant self-criticism, and regular self-examination" (pg. 23). This is where the aviation industry continues to struggle. It rarely seems to challenge itself, to rethink why there is a history of marginalized people in the industry and the ways in which it sustains policies and procedures which prevent minoritized individuals from accessing space.

Conclusions

Suggested here, is not to ignore the reality that there are still groups of individuals who are being underrepresented in the aviation industry, and the importance of representation to the outreach and recruitment of those groups. These efforts are critical to creating a more diverse, inclusive, and equitable aviation industry. However, these efforts alone are not enough to create the kind of change the industry is seeking with its diversity and inclusion efforts. As Evans (2013) suggests:

> As people of color and women move into specific industries, their experiences of engaging in emotional labor, arguably based on their racial and gender identity, should be the primary focus of gauging the overall change, or lack thereof, of the general racial and sexist climate. (pg. 11)

For Evans, the solution is clear, more effort needs to be put towards understanding the experiences of Black, Indigenous, and other people of color, if we hope to create lasting change. Building on the research done by Evans, Ahmed, and others, I argue that focusing on representation alone ignores the important conversations that need to be had around why the aviation industry has been traditionally coded as white and male. The current thinking of diversity and inclusion efforts as a solution to the reasons why the industry remains underrepresented ignores the experiences that are being had by minoritized people in aviation. Focusing on building representation alone does not directly address the challenges that are faced by these groups. Instead, what it does is bring additional individuals into a system that is still struggling to understandi how it can become more inclusive and equitable.

As Crenshaw and others have suggested, looking to the experiences of those who have historically been minoritized in the industry, is critical to the industry successfully moving forward in its efforts to diversify and become more inclusive. These experiences can help us further understand how and why whiteness continues to be normalized, and the ways in which this prevents the industry from creating and sustaining a transformational culture of equity and inclusion.

Recognizing the importance and value of representation in changing the industry is only the first step in creating a more equitable work environment. Until we are able to have those challenging conversations that are in direct response to the experiences of minoritized individuals, then the industry will continue to struggle with attracting and retaining diverse talent. Part of the solution is the recognition that diversity efforts focused on representation fail to account for the experiences which suggest that whiteness and maleness are still the predominant feature of the industry. Once we realize the ways in which this maintains barriers to entry and success, then we can then begin to think about the kinds of solutions that would be necessary in order to create a culture and climate that not only recruits, retains, and sustains, but values minoritized individuals.

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The Use of Aviation Safety Practices in UAS Operations: A Review

William Theodore Weldon
Purdue University

Damon Lercel
Purdue University

Joseph Hupy
Purdue University

Kaleb Gould
Purdue University

Unmanned Aerial Systems, UAS, have rapidly become a part of the US National Airspace System (NAS) with more than 1.6 million registered between 2015 and 2020. As the number of UAS has increased so has the number of sightings by manned aircraft and airport operators. This increase in sightings has raised concerns about the safety of UAS operations, a concern validated by the experiences of the US military. Following high accident/incident rates during UAS operation the US military discovered that UAS, despite having no pilot onboard, are subject to human error. The research and methods to minimize human error are mature, widely integrated, and successful in manned aviation. This paper presents a literature review of three aviation safety practices and their use in UAS operations. Science Direct and the Web of Science Core Collection databases were reviewed for articles with the keywords "Crew Resource Management", "Safety Management Systems", or "Standard Operating Procedures" and "Unmanned Aerial System" or "Unmanned Aerial Vehicle." One hundred and sixteen articles containing these keywords were published between 2000-2020. Each of the discovered articles were downloaded and reviewed by two researchers. This review discovered that six articles discuss the use of either CRM, SMS, or SOPs in UAS operations, which suggests a need for a greater body of UAS research in these areas. This void in research mirrors the early integration approach taken by the US military, and the consequence of the knowledge gap was an increased accident rate. Additional research must be conducted to understand the effect of human error on civilian UAS operations to allow for the safe operation of UAS in the US NAS.

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The unprecedented growth of Unmanned Aerial Systems (UAS) in the United States has seen over 1.6 million UAS enter the National Airspace System (NAS) between 2015 and 2020 (FAA, 2020a; Valavanis, 2008). Due to the dramatic increase of UAS in the NAS, concerns have been raised regarding the risk associated with UAS operations (Dalamagkidis, Valavanis, & Piegl, 2008). Of large concern is the risk of mid-air collisions between manned and unmanned aircraft (O'Donnell, 2017; Russell, 2010; Zhang et al., 2018). Showcasing the potential danger are the numerous reports of UAS sightings near manned aircraft or airports, over 100 per month, and the two confirmed mid-air collisions between manned and unmanned aircraft (FAA, 2020b; NTSB, 2017, 2019). One well researched solution to the dramatic potential of manned-unmanned mid-air collisions is the development of "sense and avoid" technology for UAS (Haessig, Ogan, & Olive, 2016; Karhoff, Limb, Oravsky, & Shephard, 2006; Stark, Stevenson, & Chen, 2013). While on-board airborne collision avoidance systems (ACAS) are vital to safe air traffic management, they do not entirely prevent mid-air collisions (Brooker, 2005). Human error in the cockpit has been responsible for aircraft accidents, including midair collisions, even with robust technological solutions that may have prevented the accident (German Federal Bureau of Aircraft Accidents Investigation, 2004; Papadimitriou et al., 2020).

Human error, active and latent, plays a major role in aviation accidents and incidents (C.-C. Chen, Chen, & Lin, 2009; Chiu & Hsieh, 2016; McFadden & Towell, 1999). While human error cannot be completely eliminated from a system, it can be anticipated and mitigated (Tullo, 2019). Manned aviation provides a significant history regarding methods to reduce the negative impact of human error. Multiple complimentary and overlapping processes or systems have been implemented in traditional manned aviation aimed at mitigating human error in the cockpit (Salas, Maurino, & Curtis, 2010). Crew Resource Management (CRM) reduces error by allowing a cockpit crew to function as a multi-person unit taking advantage of the skills, knowledge, and capabilities of all members of the crew (Ginnett, 2019). Safety Management Systems (SMS) are a formal method by which organizations define how they will mitigate risk within their operations that is followed by all levels of the organization (Roughton, Crutchfield, & Waite, 2019). Standard Operating Procedures (SOPs) ensure that all flight crews reliably complete tasks in the correct manner (FAA, 2017). These three systems have reduced human error and increased safety in manned aviation (Davies & Delaney, 2017).

Early UAS integration into the US military relied on software modification, instead of a robust system of traditional aviation safety practices, to "reduce human-error induced losses to near zero" (DOD, 2001, p. 54). The need for these aviation safety practices can be seen in the Predator program (A. Tvaryanas, Thompson, & Constable, 2005). While not the first UAS used by the US Military, the Predator was the first to be widely integrated in military service (Nullmeyer, Herz, & Montijo, 2009). During this integration it became clear that removing the pilot from within the aircraft does not eliminate human error as the Predator's mishap rate was 10 to 100 times higher than manned aviation, with 68% involving human error (DOD, 2001; A. P. Tvaryanas, Thompson, & Constable, 2006). It was also discovered that in some cases an increase of automation proved detrimental. For example the RQ-4 Global Hawk, the US Air

Force's High Altitude Long Endurance (HALE) platform, complex mission planning processes led to taxi speed of 155 knots into a turn causing major damage to the aircraft (Williams, 2004). The human factors challenge with UAS can in part be explained by the rapid deployment of the technology which outpaced the research and development of SOPs, CRM training, and adequate SMS for operations (Johnson, 2009; Moorkamp, Kramer, van Gulijk, & Ale, 2014b). Given the current safety expectations of the aviation industry, UAS safety processes and support systems cannot take years to develop or rely upon lessons learned strictly from UAS accidents and mishaps. Human factors guidelines must instead be developed from early operational experiences with UAS and the lessons learned in manned aviation and adopt a greater proactive approach to safety (Hobbs & Shively, 2013).

Use of Safety Standards in Scientific Research Literature

In order to understand the current state of literature concerning the use of human factors practices in UAS operations, predominantly using UAS as scientific data collection tool, a scoping literature review was performed, using the ISI Web of Science core collection and Science Direct. The first article to mention UAS in either database appeared in 1988 (Draper, 1988) and increased rapidly to 126 in the 1990s, 2,075 in the 2000s, and 20,732 in the 2010s. This exponential rise in UAS related publications leaves no doubt that technology is being rapidly adopted in many fields and adapted to many uses. This literature was reviewed using the methods described by (Arksey & O'Malley, 2005) with the goal of determining the current state of UAS literature regarding human factors practices. Human factors in aviation is an extensive field of study that bridges into many other fields; such as psychology, computer science, and engineering (FAA, 2008). Given the broad nature of aviation human factors research the scope had to be set so that a large portion of human factors based research would be discovered, but limited enough that it could be completed in a reasonable timeframe. In order to accomplish this FAA regulations, 14 CFR and Advisory Circulars, were reviewed to determine the practices required for operation. In parallel the application of aviation human factors practices to other industries was reviewed to determine which practices were the most used outside of aviation; with the idea that these would be the most likely to be used without aviation knowledge as our focus is the use of UAS as a scientific data collection tool. These two lists were compared and the three practices chosen were CRM, SOPs, and SMS. Each database, ISI Web of Science core collection and Science Direct, were queried in the following way ("Unmanned Aerial System" OR "Unmanned Aerial Vehicle") AND ("Crew Resource Management") with "Crew Resource Management" being changed for each human factors practice, Table 1. The first article that contained the required verbiage appeared in the year 2000 and this year was chosen as the start year for the literature review with 2020 set as the end year. Each returned article was retrieved and reviewed by two separate reviewers who each recorded: year, author, title, primary topic, role of UAS, role of the human factors practice, and the relevance of human factors to UAS operations within the article. Articles were marked if human factors practices were applied in operation and the effect of the practice was discussed, or if the effect of human factors practices applied to UAS operations in general were discussed. Once each article had been independently reviewed, the reviewers convened and compared their assessments. During this comparison there were articles where the reviewers disagreed. Where there was a disagreement the articles were re-reviewed against the inclusion criteria. The initial search of Science Direct and the ISI Web of Science core collection returned 116 sources containing relevant text based upon database queries, table 1. All 116 sources were retrieved and reviewed by two reviewers. Of these 116 sources only six were found to discuss the use of human factors practices within UAS operations. While each of the three human factors practices is represented safety management systems had the most relevant articles, followed by crew resource management, Table 2.

Table 1.
Count of articles containing both "Unmanned Aerial Systems" OR "Unmanned Aerial Vehicles) and one of the human factors terms

Year	Crew Resource Management	Standard operating Procedures
2000-2010	5	6
2010-2020	15	56
	Safety Management System	Total Articles
2000-2010	3	14
2010-2020	31	102

Table 2.
Articles found during the literature review which positively discussed the use of one of the three human factors practices within UAS operations.

Citation	Title	CRM	SMS	SOP
(Ren, Cheng, & Huang, 2015)	Exploration of Crew Resource Management Concept Based on UAV System	x		
(O'Connor, Hahn, Nullmeyer, & Montijo, 2019)	Chapter 19 The Military Perspective	x		
(Moorkamp, Kramer, van Gulijk, & Ale, 2014a)	Safety management theory and the expeditionary organization: A critical theoretical reflection		x	
(Moorkamp, Wybo, & Kramer, 2016)	Pioneering with UAVs at the battlefield: The influence of organizational design on self-organization and the emergence of safety		x	
(Clothier, Williams, & Hayhurst, 2018)	Modelling the risks remotely piloted aircraft pose to people on the ground		x	
(Zmarz et al., 2018)	Application of UAV BVLOS remote sensing data for multi-faceted analysis of Antarctic ecosystem			x

Discussion of Literature Review Human Factor Practices

Current literature is sparse, but what has been published describes the benefits of human factors practices in UAS operations. “The Military Perspective”, the nineteenth chapter of *Crew Resource Management (Third Edition)*, O’Connor, Hahn, Nullmeyer, & Montijo (2019) describe the use of CRM in global military training programs and explicitly discuss the implications of human error in UAS programs, as well as the positive impact of CRM training on mishap rates. “Exploration of Crew Resource Management Concept Based on UAS System” focuses on the use of CRM training to decrease UAS mishap rates within UAS operations and presents multiple suggestions for implementation (Ren, Cheng, & Huang, 2015). Moorkamp reports on the experience of Task Force Uruzgan, describing the challenges and considerations that must be taken when implementing SMS in a rapidly changing and unpredictable environment, such as a combat zone (Moorkamp et al., 2014a; Moorkamp et al., 2016). While UAS may require a specialized SMS when operating in unpredictable environments a proactive SMS allows the operator to recognize factors that endanger flight and lead to an accident (Clothier, Williams, & Hayhurst, 2018). In *Application of UAV BVLOS remote sensing data for multi-faceted analysis of Antarctic ecosystem* Zmarz et al describe the steps taken to create SOPs for regular data collection flights in a hostile environment, and how those SOPs were integrated into a living handbook for UAS operations. The use of aviation based human factors practices when UAS are used as a scientific data collection tool are still in their infancy (Lercel & Hupy, 2020). Developing and integrating human factors practice for UAS operations will require an assessment of how these practices are integrated into manned aviation. The following sections describe how each of the discussed human factors practices, CRM, SMS, and SOPs are currently used in manned aviation and the effect they have had on flight safety.

Crew Resource Management

Crew Resource Management is the process by which an aircraft crew makes “effective use of all available resources: human resources, hardware, and information” (FAA, 2004, p. 2). The concept of CRM was developed during a 1979 NASA workshop in the wake of multiple fatal aircraft accidents resulting from pilot error, most notably the collision of two 747 airliners at the Tenerife airport (Cooper, White, & Lauber, 1980; Helmreich & Foushee, 2010; Netherland Aviation Safety Board, 1978). Early CRM programs were focused on increasing the managerial effectiveness of pilots, and providing general information on interpersonal interactions in the cockpit (Helmreich, Merritt, & Wilhelm, 1999). Unfortunately, this information provided little in the way of specific guidance and the cockpit became a group of highly skilled individuals working simultaneously towards the same goal, instead of a cohesive team (Ginnett, 1987). A second CRM workshop was held in 1986, focusing on methods to improve team interactions and synergy; with Line Oriented Flight Training (LOFT) proving effective (Hamman, 2010; Orlady & Foushee, 1987). The improvement of aircraft simulators has allowed LOFT to include realistic scenarios and evaluate the performance of the flight crew instead of an individual crewmember (Koteskey, Hagan, & Lish, 2019). Simulator based LOFT has been credited with the near miraculous survivable crash landing of United Airlines Flight 232 (Brookes, 1992). After losing hydraulic power to the aircraft’s control surfaces the flight crew was able to use differential engine power to guide the aircraft to the Sioux City airport. This method of control required complex crew coordination and simulator based reenactments determined that the crew “greatly exceeded reasonable expectations” (National Transportation Safety Board, 1989, p. 76)

Crew Resource Management (CRM) is credited as an essential factor in reducing aviation accidents and increasing the safe return of critically damaged aircraft (Ford, Henderson, & O'Hare, 2014; Wakeman & Langham, 2018). These high-profile successes have drawn the attention of high consequence industries looking to emulate aviation's safety successes (Malcom, Pate, & Rowe, 2020). Medicine is one such industry taking notes from aviation's successes with a focus on CRM and simulation-based training (Hughes et al., 2016; Schulz, Endsley, Kochs, Gelb, & Wagner, 2013). Introducing CRM into trauma care has had "an overwhelmingly positive impact on confidence, preparedness, and teamwork in trauma personnel," (Ashcroft, Wilkinson, & Khan, 2020, p. 17) In addition to increasing the confidence of trauma, personnel CRM was found to enhance their non-technical skills and reduce surgical mortality rates (Neily et al., 2010; Wakeman & Langham, 2018). The benefits of CRM have been recognized throughout manned aviation and other high consequence industries, such as the medical industry. Despite their similarities additional research will be required to adequately adapt CRM practices from manned to unmanned aviation (Lim et al., 2018).

Safety Management Systems

Safety Management is the "systematic control over worker performance, machine performance, and the physical environment," and a safety management system (SMS) is an organized collection of all used safety management practices within an organization (Heinrich, Petersen, Roos, Brown, & Hazlett, 1980, p. 4; Li & Guldenmund, 2018). SMS began integration into aviation after a series of aircraft accidents were attributed to latent failures (McDonald, Corrigan, Daly, & Cromie, 2000). Latent failures are a failure in an organizations structure, and are frequently revealed by active failures (Maurino, Reason, Johnston, & Lee, 2017). Active failures are discreet events in the human-machine interface with unintended and often un-desired consequences (Reason, 1998). SMS not only allows an organization to account for active and latent errors, but can assist in the development of a safety culture within the organization (Rundmo & Hale, 2003). While safety culture has many definitions (International Nuclear Safety Advisory, 1991; Turner, Pidgeon, Blockley, & Toft, 1989; Uttal, 1983) the goal is to create a culture which values safety and adopts practices which reduce accidents (Cooper Ph.D, 2000). As a safety culture is developed SMS programs further mature and become more effective which in turn strengthens the organization's safety culture (Cooper Ph.D, 2000; Hurst, Young, Donald, Gibson, & Muyselaar, 1996; Patankar & Sabin, 2010).

Standard Operating Procedures

Standard Operating Procedures (SOPs) are a series of written procedures containing important information regarding task completion that each member of an organization follows (Bains, Bhandari, & Hanson, 2009). In aviation, SOPs are required for all stages of flight to ensure correct task completion throughout the flight, increasing the safety of flight operations (Moriarty, 2015). SOPs are an important part of increasing the safety and reliability of task completion, but increase in effectiveness when checklists are implemented in parallel (C. Chen, Kan, Li, Qiu, & Gui, 2016). Checklists developed in the wake of the Boing B-17 test flight crash and came to prominence after their integration proved effective in improving flight safety for that aircraft (O'Connor, Gordon, & Mendenhall, 2013; Schamel, 2012). Since this successful demonstration, checklists have become one of the core methods of standardization within aviation operations (Degani & Wiener, 1993). Deviation from SOPs in a high consequence and high complexity industry has potentially dire consequences; between 2001 and 2010 the National Transportation Safety Board (NTSB) identified 86 accidents, amounting to 149 fatalities, involving lack of adherence to or lack of adequate SOPs or checklists (Sumwalt, 2013).

While UAS operations are a lower consequence endeavor, in terms of potential fatalities, when compared to manned flight, there are many parallels in operation. In a 2013 presentation Robert Sumwalt of the NTSB gave a presentation concerning SOPs; the presentation contained the following quote concerning an aircraft crash in Atlanta, Georgia on September 14, 2007:

> When asked about the flight department's standard operating procedures (SOPs), the chief pilot advised that they did not have any… the flight department had started out as just one pilot and one airplane, and that they now had five pilots and two airplanes…(Sumwalt, 2013, p. 10)

While this quote is describing a corporate flight department it could easily be describing a UAS department. Small departments with little to no aviation experience are very prevalent in emergency response, where most UAS operations are undertaken by individuals as a collateral duty (Todd, Werner, & Hollingshead, 2019).

Conclusions

With an average of 876 UAS registered per day since 2015 (FAA, 2020a) it would be impossible to remove UAS from the NAS. The meteoric rise of UAS in the United States has outpaced the development of traditional aviation safety practices within the UAS industry, just as it did in the US Military. When reviewing the experiences of the US military, in regards to UAS integration, the effect of rapid integration is easily seen in an accident rate 10 to 100 times higher than manned operations (DOD, 2001). In spite of the high accident rate UAS were used extensively in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) with the Army flying 867,566.6 hours between October 7th, 2001 and December 2009, an average of 288 hours per day (Dempsey & Rasmussen, 2010). During this operational period, multiple articles and assessments were written by the US military to decrease the accident rate to acceptable levels.

Integration of consumer UAS into the NAS has the benefit of hindsight, through both manned aviation and the integration experiences of the US military. However, a review of the literature does not provide compelling evidence that these lessons are being applied. Of the 22,934 UAS based articles reviewed, 116 mention UAS and one of the three discussed human factors practices in the same article, and six discuss the use of the practices within UAS operations. Of these six: three discuss SMS, two discuss CRM, and one discusses SOPs. Two of the SMS related articles discuss the experiences of a Dutch Expeditionary Force operating a UAS in a complex environment, and the third states that a robust SMS can assist in early detection of errors. While one of the CRM articles focuses entirely on the use of CRM in UAS operations it appears poorly translated and contains few sources. The second CRM article highlights the challenges faced by the US military when first integrating and operating UAS platforms. This single article concerning SOPs discusses the experiences of an Antarctic research team and the steps they took to safely operate a UAS for wildlife monitoring.

In the same timeframe, 2000-2020, over 3,000 articles mentioning CRM/SMS/SOPs and Aviation/Airline were published concerning manned aviation; many of which were included as citations in this paper. The dramatic difference in published literature suggests a severe knowledge gap in the management of human error in UAS operations. This knowledge gap is particularly concerning as human error has been reported as the leading cause of aircraft accidents, both manned and unmanned (Harris & Li, 2011; A. P. Tvaryanas et al., 2006). Over the last 20 years research concerning human error and human factors has made up 3% of all research discussing manned aviation, in contrast human factors makes up 0.026% of all research discussing UAS. The current state of literature suggests that there is a lack of research being performed on the human factors component of UAS operations. This knowledge gap exists in opposition to an industry where safety is the highest desired competency and the proven problematic results from military integration (Lercel & Hupy, 2020; A. P. Tvaryanas et al., 2006). Civilian UAS integration must learn from these experiences, as decades of incidents and accidents are no longer tolerated (Hobbs & Shively, 2013).

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University Aviation Association
8092 Memphis Ave
Millington, TN 38053
(901) 563-0505
hello@uaa.aero