DATA-DRIVEN IMPROVEMENT OF FLIGHT TRAINING SAFETY AT PURDUE UNIVERSITY

Matthew C. Chow
Purdue University
West Lafayette, Indiana
Shantanu Gupta
Purdue University
West Lafayette, Indiana
Celeste D. Torrez
Purdue University
West Lafayette, Indiana
Suvarna Veeravalli
Purdue University
West Lafayette, Indian
John H. Mott
Purdue University
West Lafayette, Indiana
Jack J. Green
Purdue University
West Lafayette, Indiana
Nikolas A. Sambado
Purdue University
West Lafayette, Indiana

The School of Aviation and Transportation Technology at Purdue University utilizes a wide range of resources to train aspiring pilots, technicians, and managers. Aircraft operate in one of four practice areas located within a 30 nautical mile radius of the Purdue University Airport. Due to factors such as poor weather conditions, inexperience of student pilots, and proximity misjudgment, one aircraft could operate in close proximity to another in the same practice area, compromising the safety of both aircraft and causing a Near Midair Collision (NMAC) event due to miscommunication, misinterpretation, or failure to act on the part of the pilots involved. The objective of the research reported herein is to develop a diverse student team to evaluate and address flight training safety at Purdue University. The team comprises the research arm of the Purdue Flight Operations Center, aggregating data from sources such as weather monitoring systems, aircraft maintenance systems, ADS-B transponders, real-time dispatch systems, and air traffic systems. The collected data will be used to target common operational errors and study their frequency and nature, and to measure aircraft separation in order to develop and improve parameters for the identification and reporting of NMAC events. Techniques developed by this team will be used by the Purdue safety team to analyze each instance where an NMAC event has occurred and develop strategies to mitigate these events. The research team will, in addition, develop data dashboards and provide suggestions to help improve the overall safety of the Purdue flight program.

The Flight Operations Research Center (FORC) is an initiative to improve training operations involving the student pilots at Purdue University. Data-driven improvement of flight training safety, one of the research areas of the FORC, aims to mitigate the risk associated with training student pilots by analyzing data from ADS-B transponders installed on the training aircraft. Traditionally, collision avoidance in General Aviation (GA) flying has been accomplished by pilots utilizing visual scanning techniques. Wide adoption of new transponder technology has improved pilot situational awareness by displaying electronically the location of nearby aircraft. This ADS-B data can also be collected by ground stations to be analyzed by researchers. To assist pilots and improve training conditions, the FORC aims to develop a diverse student team to analyze the ADS-B data, identify the common operational errors, study the trend patterns, and estimate aircraft proximity to assist the Safety Committee in improving the overall safety of the program.

The research herein describes the data-driven safety improvement process of estimating aircraft proximity and identifying Near Midair Collisions (NMAC) of the training fleet. Accurate identification of these events, both from the data and from pilot safety reports, is of high importance in order to determine their causes and explore safety improvement opportunities. The analysis can further be extended to optimize the assignment of aircraft to practice areas in order to reduce congestion, hence providing safer airspace for practice. Additionally, this article discusses the student development and learning outcome aspect of the FORC. Through its involvement with this research center, a diverse team of student participants is acquiring essential skills to solve real-world problems.

Literature Review

A 2011 research study from the Massachusetts Institute of Technology (MIT) found that ADS-B is becoming the foundation for aircraft surveillance in the United States. One solution that was presented to encourage the implementation of ADS-B technology in the existing general aviation fleet is to incentivize users with high-value information. Airborne traffic alerts are one such application. The MIT researchers also found that the airport environment, which is also where a high volume of flight training occurs, is where the most NMAC reports arise (Kunzi & Hansman, 2011). NMACs resemble the concept of a "near miss", which is an event where a potentially disastrous consequence is narrowly avoided (Dillon & Tinsley, 2008). In their research, Dillon and Tinsley (2008) argue that a near-miss event tends to lower the perceived risk of a situation in the mind of the individual who experienced the event, which then leads that individual to make riskier decisions. Thus, it is imperative for organizations to reduce the number of these events, and to use them to improve awareness of perceived risk.

Introducing research opportunities in undergraduate school is said to strengthen students' interest in research while providing guidance from mentors, which can serve as a benefit for students (Russell, Hancock, & McCullough, 2007). While grade point average (GPA) is not a comprehensive measure of success, it has been shown that students who participate in a long-term research project tend to have higher GPAs than those who do not (Fechheimer, Webber, & Kleiber, 2011). It has also been found that teams can benefit from diversity if team members are encouraged to learn from one another and share differing viewpoints. An example of this occurs when team members are encouraged to work on their area of expertise, then present findings to the rest of the group to foster discussion and feedback (Post, De Lia, DiTomaso, Tirpak, & Borwankar, 2009).

Methodology

An initiative to improve flight training safety was taken by the Purdue University School of Aviation and Transportation Technology (SATT) through the establishment of the FORC. This student research team was formed in August 2018 to analyze data from multiple sources, including weather monitoring systems, aircraft maintenance systems, ADS-B transponders, real-time dispatch systems, and air traffic systems. The research team is comprised of students from multiple areas of study at the university. The team is comprised primarily of students enrolled in programs within the SATT, and includes undergraduate students studying Aviation Management, Aeronautical Engineering Technology, and Professional Flight Technology as well as graduate students pursuing a Master of Science in Aviation and Aerospace Management. Some of these graduate students have been through the undergraduate program at Purdue and others are new to the university, thus incorporating diverse perspectives. In addition to the SATT students, the team also has student members from other departments on campus, such as Computer Science, Data Science, Industrial Engineering, and Aeronautics and Astronautics Engineering (AAE). Including students with different skills has been a goal for this team, since each phase of the research requires different specializations.

Students are carefully recruited to the FORC in several ways. Initially, the faculty advisor selected students to form the preliminary research team. Once operational, existing members identified other students possessing skills needed by the team. By cultivating students with such diverse backgrounds, the research team can leverage its strengths where applicable in various stages of the projects. For example, team members with a background in coding wrote a Java program that filters out extraneous data and computes distances between two aircraft. Throughout this process, students in the Professional Flight program provided context and information about how the aircraft are operated and how the fleet is organized. Additionally, Aviation Management students compared data from multiple sources by drawing on experience from projects in previous classes in which they analyzed fleet data. Graduate students and those with user experience skills then created dashboards to present the results to the Safety Committee.

The primary objective of the team thus far has been to use ADS-B data collected from the aircraft to identify proximity incursions. The team has chosen this term to describe events in which one aircraft operates within a certain distance of another aircraft. While the Federal Aviation Administration (FAA) already uses the term NMAC to refer to cases where aircraft operates within 500 feet of one another, the research team has decided to use the broader term proximity incursion. This decision has been made as a result of a Safety Committee request for data related to any instances where aircraft are in close enough proximity to present a safety hazard. This includes situations where aircraft are not within 500 feet of one another, but were still close enough to warrant concern.

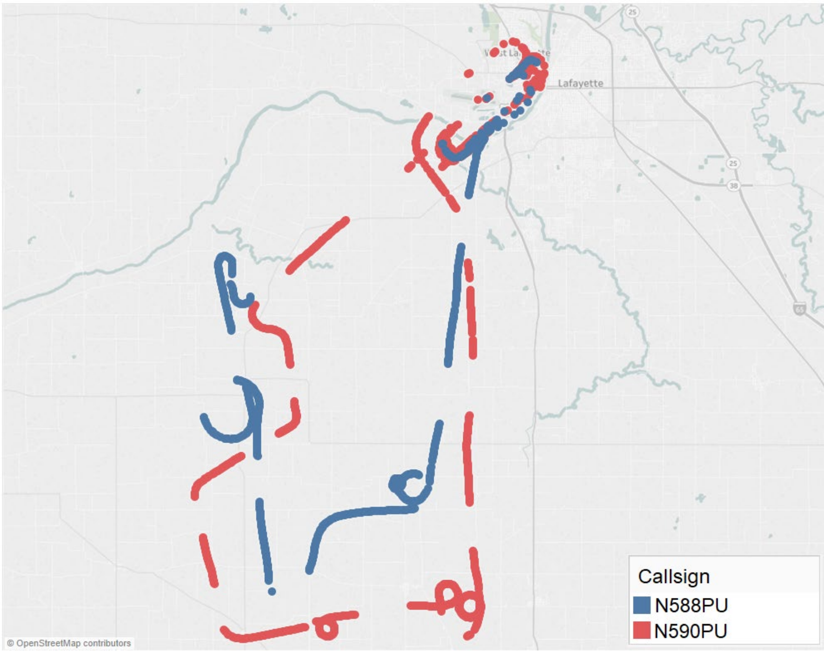

Figure 1. An example of aircraft position data recorded by the ADS-B receiver

To identify proximity incursions around the Purdue University Airport, an ADS-B data analysis program was coded in Java. This code filters the data to include only aircraft within a 30-nautical mile radius of the airport and between 300 and 10,000 feet MSL. The filtering process serves to reduce the number of calculations performed by the code. This particular airspace volume was selected because student pilots practice training maneuvers within 30 nautical miles of the airport. The altitude restrictions serve to filter out surface operations below 300 feet and commercial aircraft that typically operate above 10,000 feet. Once extraneous data has been eliminated, the code divides aircraft into altitude blocks depending on the desired sensitivity. Additionally, a Kalman filter was used to develop a predictive model to fill in missing data points due to intermittent ADS-B reception. Figure 1 shows an example of data from the ADS-B receiver before Kalman filtering. Finally, the code calculates the distance between aircraft in each altitude block and records the distance if it is less than the proximity incursion threshold.

Using the results from the algorithm, the team created dashboards that summarize safety trends for the Safety Committee. For example, the number of proximity incursions can be compared from one month to the next, from a month in the previous year to that of the current year, or year to date. The specific periods and intervals can be customized according to the needs of the Safety Committee. By analyzing these trends and correlating them with current flight operations procedures, the student team can make recommendations to the Safety Committee. Members of the committee can use the results to determine if or when there is an increased hazard level and take appropriate steps to mitigate risks.

Impact

At Purdue University, the Safety Committee strives to mitigate risks associated with the flight training program. With student lives at stake, continuous efforts to ensure safe flight operations is of paramount importance. The FORC supports these efforts by providing recommendations through data analyses that quantify relative aircraft distances, identify proximity incursions, and study trends which could lead to hazardous situations.

The FORC has a tremendous impact on the involved students as well. In addition to improving individual research capabilities, students on this research team also develop critical thinking and problem-solving abilities and realize academic benefits. For example, students with a statistical background develop their data analysis skills through this real-world project. Additionally, AAE students might utilize the experience of implementing the Kalman Filter, since the algorithm was originally developed for use in guidance and control of spacecraft. With the practical application and practice of skills, engineering students can better understand materials taught in classes such as Dynamics and Vibrations; this class teaches the principles behind mathematically modeling the movement of relative bodies, which is the concept behind the Kalman filter. Data Science students also benefit in a similar way. Writing programs in Java while taking a course focused on object-oriented programming reinforces their learning. Beyond coursework, students learn new tools and software such as Tableau and R (a statistical programming language) that could benefit them in the future.

The FORC also prepares students for their industry careers by developing teamwork and leadership skills. Students work in a collaborative group environment to accomplish common goals while working under such pressures as deadlines, setbacks, and a result-oriented organization. Student researchers develop professional skills including time management, prioritization, problem-solving, and decision-making. Additionally, students with leadership roles in the FORC learn project management, work-load distribution, and organizational leadership skills.

Beyond collaborative work and team leadership, team members also develop essential communication skills for time-sensitive work environments. Weekly updates to the operations center improve short impromptu summarization, while formal presentations provide opportunities for students to practice public speaking. In addition to presentations, team members also work on academic publications and gain an understanding of the process from an author's perspective. This process is valuable for students since strong written communication skills are required in almost every workplace. Apart from providing better job opportunities, work on academic publications is of high importance for graduate students with plans in academia. Participation in this research project provides team members with the valuable skills and experiences discussed above and strengthens their résumés to better equip them for industry exposure.

Limitations and Future Work

Although cultivating a diverse team of student researchers is a stated goal of the FORC, there are several limitations associated with doing so. Graduation of students and study abroad programs interrupt the growth of technical expertise, and results in a lack of consistency in the composition of the team. To overcome this, the team management needs to identify and recruit new members regularly, which is a time-consuming process due to the technical nature of the project. Similarly, with team members volunteering for the project, it is sometimes difficult to maintain motivation. Another limitation of the project is the difficulty in validation of the results. Because implementation of the recommendations made by the FORC is at the discretion of the Safety Committee, hypothesis testing and validation can be problematic. Further, since the NMAC calculations are based on ADS-B data, irregularity in the recording of data can also make validation difficult. ADS-B systems aboard aircraft only broadcast position data every few seconds, and data gaps can result from aircraft orientation issues with respect to the receiving antenna. If a proximity event were to occur during such intervals, the algorithm may inaccurately measure the distance between two aircraft or miss the event in its entirety. Pilot feedback can be used to validate some events; however, these do not result in accurate reporting of all such events.

The next steps for the FORC are to refine the accuracy of recorded data using the Kalman filtering algorithm, validate relative aircraft distances, and verify pilot-reported proximity events. Another goal is the automation of the algorithm to provide real-time results and live dashboards. These dashboards can be used to determine the average frequency of proximity incursions or to compare the frequency of proximity incursions between aircraft types. Access to live dashboards can also be used by dispatchers to distribute aircraft more evenly between practice areas, improving temporal or spatial utilization. These dashboards can increase the ability of the flight program to safely train a greater number of students, thereby providing increased flight opportunities for flight instructors. Improved safety and efficient fleet utilization enable the program to train more students, which will reduce student flight fees by decreasing the overall cost of the program.

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