Project Description

The purpose of this project is to build a low cost, long endurance, vertical takeoff and landing (VTOL) aircraft that will allow a variety of first responders to react quickly in emergency situations. Building an aircraft with a 6-hour or greater useable flight time is an attainable goal given the skill set of our team. The team plan is to adapt an existing, proven, manned airframe to the specific requirements outlined for this competition. The final design will be based on the V-173 Flying Pancake, built by the Vought Aircraft Company in 1938. The application of an existing design is beneficial because a significant portion of the engineering work is complete. The V-173 Flying Pancake will fly because it is a proven Prototype. It was so successful that the US Navy contracted Vought to produce a fighter version, the XF5U. Although a low aspect ratio design for this aircraft may not appear practical, it is perfect for this application due to the location of the propellers. Typically, high aspect ratio wings are used for long endurance flight because the long, thin wing has lift and drag characteristics that are ideal for this flight regime. Low aspect ratio wings typically suffer from drag induced by air spiraling off the lifting surface creating wing tip vortices. The V-173 Flying Pancake design is unique in this regard because it counteracts these vortices by locating the counter-rotating propellers at the end of the wing, effectively cancelling the vortices. By reducing the vortex drag and restoring the aerodynamic efficiency, all of the benefits of using a low aspect ratio wing design apply: favorable maneuverability, high dash speed, low stall speed, and high payload capacity.

Charles Zimmerman, the designer of the aircraft, originally designed the V-173 Flying Pancake as a VTOL aircraft. This capability was demonstrated in test videos of small scale drones conducted in 1938. The build team conducted further research into this capability at the beginning of 2018. The build team flew to Dallas to meet with the Vought Aircraft Heritage Foundation, a group of former Vought Aircraft employees that restored the original V-173 Flying Pancake., The team was able to meet with Vought engineers to discuss downsizing the V-173, and gained valuable insight on how to adapt the design to the requirements of this competition. The meeting was enlightening, and the team came away encouraged that their adaptive design concepts were feasible.

The potential of the V-173 Flying Pancake has been expanded and reimagined due in part to the use of modern power systems and materials. Our team at Middle Tennessee State University (MTSU) have the resources and the facilities necessary to redesign the V-173 Flying Pancake as a small, unmanned aircraft system (UAS). The MTSU Aerospace Department is equipped with a modern UAS lab specializing in building and operating small UAS. Laser cutters, 3D printers, Computer Aided Design (CAD), and exotic materials are all currently utilized in the production of high quality unmanned aircraft. A wind tunnel in the same building is ideal for testing the unmanned V-173 Flying Pancake design. Not only is the University fully insured, MTSU features a 440-acre research farm with a large flight test area. The test facility is also registered as an Academy of Model Aeronautics flight field. Safety is the first priority. Our

team's ability to conduct test flights at a private, safe, secure flight test location near campus is an invaluable asset.

Our substantial experience in building small, inexpensive UAS is a major advantage. Our team at MTSU has built several high quality and reasonably priced UAS for companies and government. Many of these companies have been guided to believe that they need very expensive, highly advanced UAS to complete relatively basic missions. The plan for the unmanned Flying Pancake (uP) conceptualizes testing with a small scale model. We will use the latest 3D-printing technology to create a 12" (1/4 scale of final model) shell. This shell will be used specifically in testing the aerodynamic characteristics of the uP with the canopy and engine intakes removed from the original Vought Design. This is the point in the test program where the uP will receive electronics. The team has chosen the Pixhawk 2 open source flight controller. The build team has gained substantial experience with this flight controller and with the supporting ground station (Mission Planner). The Pixhawk 2 has fully autonomous flight capabilities as well as accurate GPS and RTK navigation options. The software is compatible with VTOL designs and does not represent the recent security risk associated with DJI UAS. Both Pixhawk and Mission Planner are widely used by the industry, and the components have excellent community support.

The team plans to power the ¼ scale model with two three-phase brushless electric motors turning 7.5-inch propellers. The team will conduct tests to determine the optimal blade number and design. The power source for the design will be lithium-ion batteries. The design for the power source represents the greatest challenge. Batteries are heavy for long endurance and the power produced frequently does not meet the power demand. The team solution will be to increase capacity, decrease power draw, and decrease weight. The build team has gained experience building lithium-ion cells, which will be used in both the small-scale and full-sized uP. They are significantly lighter than the lithium-polymer batteries that are widely used in commercial UAS platforms. Because of these weight savings, the team anticipates that battery capacity can be greatly increased. To overcome battery capacity limitations, the design will incorporate the use of solar cells and an energy recovery system. The top surface of the uP has over a square yard of surface area to effectively capture solar radiation. This is a proven way to extend the flight time for a UAS system.

After completion of the small-scale concept, the team will construct a full-size aircraft that will comply with size limitation. The frame will be foam based, with laser-cut birch ribs providing the shape for the airfoil. The team will use a hotwire to cut foam to fit in-between the ribs. This design feature combination will be easily repaired in the field. This feature is a key element of maintainability in a first responder environment. The foam will house compartments for payload, the flight controller, and battery system. This technique is chosen because of its low cost of manufacturing and the availability of the materials.

Operator mission flexibility will be a byproduct of this wing shape because of the large amount of payload space available. A multitude of sensors and optics can be fitted simultaneously. This feature makes the uP multi-mission capable and will provide the first responder with a wide range of available response options.

Flight tests will be conducted at the MTSU research farm facility after the conclusion of final construction. The MTSU test facility is ideally suited to conduct endurance and speed testing. The flight-test goals will be to attain 6 hours of flight endurance and to determine a top-

end speed. The low aspect ratio has an advantage of a high dash speed (i.e., the ability to move from one area of interest to the next). This is a desired flight characteristic to allow first responders greater flexibility in repositioning the uP based on situational needs.

The build process will be meticulously documented in order to facilitate future manufacturing. The build team will prioritize processes that are simple and inexpensive without sacrificing quality or mission capability.

Ample time has been set aside each week to complete this project. The build team consists of highly motivated students that creates a necessity for efficient time management. Completion of the primary building tasks will occur throughout the week. Makeup time will be available on the weekends. Team members have unlimited access to the facility.

In addition to the eight build team members, three advisors will be contributing their knowledge in a supporting role. Each advisor has provided their bios and bring a unique background and skill set including backgrounds in the FAA, Military, Physics, Electronics, and Regulations. They will not be contributing to the build directly; rather they will only offer support and expertise as necessary.

Resume Information

James A Manni

A senior from Louisville, Kentucky, James has been involved in the field of aviation since 2011. He holds 2 FAA licenses: Private Pilot (142 hours) and Remote Pilot (30 hours), and exhibits a deep passion for UAS. James has built several custom frames and full systems, and has years of experience working with DJI, Tarot, and Pixhawk flight systems. He is ICS-100 certified, and worked with Tennessee firemen during a demonstration of UAS in Support of Fighting Wildfires, an event that took place in spring of 2017. James' education has focused on supporting areas of UAS as well, specifically manufacturing, remote sensing, and GIS. He will graduate in the spring of 2018 with a bachelor's of science in aerospace with a concentration in Unmanned Aircraft System Operations.

Rory J Johnson

Rory is a current undergraduate student in the Aerospace Program focusing on Unmanned Aircraft Systems Operations. He transferred to Middle Tennessee State University in 2015 to be part of the new UAS program. His aviation career began in 2015 and has continued to progress. Rory holds a Private Pilot License, Part 107 Unmanned Aerial License, and an ICS-100 certification. He has over 25+ hours in fixed wing and multi-rotor flight time. His extensive knowledge base consisting of UAS ground mapping (PIX4D/DroneDeploy), GIS, cinematography, and multispectral camera use is an asset to this project. After graduating, Rory hopes to step into military contracting or find a job working in the United States with a privately owned business.

TJ Caldwell

Ever since he can remember, TJ has exhibited a passion for small electronics. No device was safe from him and his trusty screwdriver. Little has changed since then except now he can put the remote back together. His childhood led TJ to seek an education in mechanical engineering and now UAS operations. He has been building and flying model airplanes since he was 10 years old. His multi-rotor experience can be traced from the days when individual gyros were a brand new concept. TJ has 5 years of mechanical drafting and modeling experience, 3 years at Bridgestone USA, and a semester of teaching science and 3D printing at a middle school under his belt. He also has a patent pending aerodynamic trailer design, custom built 3d printers, experience designing and building complex custom circuitry, and has restored every manner of antique vehicle. Now a Lab Assistant at MTSU, TJ is excited to be a part of this winning team.

Jud McCracken

With the close of 2017, Jud completed an educational goal of finishing a series of Unmanned Aircraft Systems (UAS) classes at Middle Tennessee State University. Aviation has been a passion for Jud since the age of nine. He sees UAS to be a continuation of this passion and its use to grow exponentially for disaster relief. Self-study in electronics technology resulted in diplomas in electronics technology and electronics engineering technology from Cleveland Institute of Electronics. He holds Federal Communication Commission (FCC) certificates in General Radiotelephone Operator License with Ship RADAR endorsement and Amateur Extra Class. The appeal of commercial aviation resulted in a decade of avionics work with Trans

World Airlines and Western Airlines. However, the airlines did not have the rapid technology advances of the military and he returned to the US Air Force. Project management, training, and supervisory skills were developed in addition to technical skills during his time in the Air Force.

Upon retirement in 2006, Jud completed the diploma program in airframe and powerplant mechanic from Tennessee Technology Center at Memphis. Graduation permitted him to obtain the FAA airframe and powerplant mechanic certificate. In addition, he graduated from Eastern New Mexico University, Roswell in 2006 with an Associate of Applied Science in Aircraft Maintenance Technology. Jud followed this formal education with a Bachelor of Science in Aerospace Technology and a secondary major in Flight Dispatch and Scheduling in 2009. A Master of Science in Aviation Systems from the University of Tennessee at Knoxville (UTK) was earned in 2012 with a graduate certificate in Engineering Management. Currently, he is a PhD student in Industrial Engineering at UTK. The development of an extended endurance UAV at MTSU this year as a member of the "Pancake Airplane" Team will permit him to add his knowledge in lean manufacturing, avionics, and optimization to the success of the project. The team has as one of its goals to add to the UAV body of knowledge and publish a paper. He considers it a privilege to have this opportunity to work with a group that shares my passion with aviation.

Lance D Parker

An undergraduate student at Middle Tennessee State University, Lance has a broad aviation background. He has experience working for the University as a UAS lab assistant, and the Shelbyville Municipal Airport, where he served as a lineman and Manager. A tireless worker, Lance has studied advanced aerodynamics and electronics during his time at MTSU. He has amassed over 50 hours of unmanned flight time, and has participated in search and rescue missions for the Bedford County Police Department. Lance is ICS-100 certified and is working towards his private pilot license.

Kevin Corns Ph.D.

Dr. Kevin Corns is an Assistant Professor of Aerospace teaching Unmanned Aircraft Systems at Middle Tennessee State University. Prior to moving to Tennessee, he developed and taught Unmanned Aircraft Systems at Arizona State University. Kevin retired from the military after serving 24 years in the US Marine Corps Scout and the Colorado Air National Guard as a Crew Chief on A-7D, F-16, and as a mechanic and Flight Engineer on T-43A aircraft. Kevin is a former Boeing ScanEagle operator and instructor and was part of the initial cadre at Boeing's ScanEagle Training Center in Clovis, NM. He has received an Associate's Degree in Aircraft Maintenance from the Community College of the Air Force, a Bachelor of Science degree in Aviation Science from Metropolitan State University of Denver, a Master's in Business Administration Aviation from Embry Riddle Aeronautical University, and Ph.D. in Education specializing in Instructional Design for Online Learning from Capella University. His current focus is in developing low-cost UAS for first responders, unmanned aircraft pilot training, eLearning in high reliability professions, adaptive curriculum, and experiential learning. Kevin holds the following FAA licenses/certificates: single engine land, multiengine land, instrument SEL, remote pilot, advanced ground instructor, and airframe and powerplant mechanic.

Adviser Information

Dr. Charles Perry

Dr. Perry attended MTSU from 1962 through 1968 receiving his Bachelor's and Master's Degrees in Chemistry in 1966 and 1969 respectively. Upon completing the advanced ROTC program in January of 1969, he served in the U.S. Army for two years as a Lieutenant in the Signal Corps. After his military service, he attended Vanderbilt University and graduated in May, 1976 with a Ph.D. in Electrical Engineering.

Dr. Perry began his IBM career in Kingston, NY working on flat panel plasma display technology. He quickly established the reputation for innovation and "out of the box" problem solving. He was awarded an IBM Outstanding Contribution Award in January, 1978 for solving a technical problem in flat panel displays. A major aspect of the award was recognition for his contributions in making the new technology work in high volume manufacturing. Dr. Perry continued to make major contributions to IBM technology and manufacturing for the 28 years of his career. During his career in research, development and manufacturing, he held various engineering and management positions eventually becoming an IBM Distinguished Engineer. He holds 40 U.S. Patents for inventions in materials, manufacturing processes and tools, and hardware as well as numerous IBM awards for outstanding technical contributions and innovations. Dr. Perry was also recognized by receiving the IBM Market Driven Quality Leadership Award.

Mark N. Callender

Mark “Nate” Callender joined the Aerospace Department at MTSU in 2005. He earned an M.S. in Aviation Systems and a Ph.D. in Engineering Science from the University of Tennessee Space Institute. His courses taught at MTSU include: Introduction to Aerospace, Theory of Flight, Aviation Laws and Regulations, Fundamentals of Aerodynamics, Problems in Aerospace, Aircraft Performance, and Applied Statistics in Aviation Research. He coordinates the Aerospace Technology concentration, supervises the Aerospace Technology Laboratory, mentors undergraduate and graduate researchers (Aerospace Technology seniors, URECA Scholars, Honors students, and Masters students), chairs departmental and university committees, and is a member of the EXL, Honors, and Graduate faculty. His area of specialization is in low Reynolds number aerodynamics, propeller/rotor noise reduction, and fixed-wing flight testing. Dr. Callender tries to inspire his students in the “pursuit of wisdom” by pursuing it himself. He wants his students to discover the truth of the proverb “blessed is the one who finds wisdom, and the one who gets understanding” (Proverbs 3:13). He hopes to exemplify calmness of temper and judgment inside and outside of the classroom. Dr. Callender has incorporated glider design competitions, flight testing (simulated and actual), and wind tunnel usage (actual and virtual) into AERO 1020, 3440, and 4440. He has also used a robot in the classroom for recording lectures that can then be provided to students upon request. Dr. Callender was recognized for Outstanding EXL Collaborations, an influential faculty member, and as a professor who makes a difference. He has received the Excellence in Teaching Award and the Most Challenging Class Award. He was awarded MTSU’s Outstanding Teacher

Dr. Peter Neff

Education

Ph.D. in Public Policy and Administration, Walden University, 2016

Master of Aeronautical Science, Embry-Riddle Aeronautical University, 2004

Bachelor of Science, Engineering, Trinity College (Hartford, CT), 1968

Professional

Assistant Professor of Aerospace, Middle Tennessee State University

Federal Aviation Administration, Aviation Safety Inspector

Manager of the Long Beach Aircraft Evaluation Group, FAA Flight Standards Service

Deputy Assistant Manager, Air Transportation Division, FAA Headquarters, Washington, DC

Airline Pilot, 32 years 6 months, 22,000 Flight Hours

Airline Transport Pilot, Nine pilot type ratings

Captain on five 14 CFR part 25 air carrier aircraft

Lead pilot negotiator ALPA local Council

United States Air Force, 29 years, 3,900 Flight Hours

Chief Pilot C-141 Squadron, in-flight air refueling qualified

Vice-Group Commander

Retired Lt. Col.

General Aviation, 900 Flight Hours

CFI, CFII, MEI certificates