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Unmanned Aerial Systems Research, Development, Education and Training at Embry-Riddle Aeronautical University

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Michael P. Hickey, Editor

University Dean of Research and Graduate Studies
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Foreword

With technological breakthroughs in miniaturized aircraft-related components, including but not limited to communications, computer systems and sensors and, state-of-the-art unmanned aerial systems (UAS) have become a reality. This fast growing industry is anticipating and responding to a myriad of societal applications that will provide either new or more cost effective solutions that previous technologies could not, or will replace activities that involved humans in flight with associated risks.

Embry-Riddle Aeronautical University has a long history of aviation related research and education, and is heavily engaged in UAS activities. This document provides a summary of these activities. The document is divided into two parts. The first part provides a brief summary of each of the various activities while the second part lists the faculty associated with those activities. Within the first part of this document we have separated the UAS activities into two broad areas: *Engineering* and *Applications*. Each of these broad areas is then further broken down into six sub-areas, which are listed in the Table of Contents. The second part lists the faculty, sorted by campus (Daytona Beach---D, Prescott---P and Worldwide--W) associated with the UAS activities. The UAS activities and the corresponding faculty are cross-referenced.

We have chosen to provide very short summaries of the UAS activities rather than lengthy descriptions. Should more information be desired, please contact me directly or alternatively visit our research web pages (http://research.erau.edu) and contact the appropriate faculty member directly.

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Acknowledgements

A number of people have worked to produce this UAS document. Clearly, the faculty providing information related to their involvement in UAS research and/or teaching is greatly appreciated, and without their contributions this document would not exist. Their names appear in the appendix. Teresa Ochoa helped collect information from the contributing faculty. Teri Gabriel worked tirelessly with the provided information, sorting, editing and formatting to produce the final document. The help and advice of some of our faculty having UAS expertize was critical, and for that I'd like to thank Mr. Alex Mirot, Drs. Brent Terwilliger, Ken Witcher, Stephen Bruder, Brian Davis, Massoud Bazargan, Dahai Liu and Richard Stansbury. I would also like to thank the University Research Council for their help: Drs. Susan Allen, Quentin Bailey, Massoud Bazargan, Alan Bender, Sergey Drakunov, Thomas Field, Soumia Ichoua, Mark Sinclair, Ahmad Sleiti, Todd Smith, and Alan Stolzer.

Last, but not least, I would like to also thank Dr. Richard Heist, Senior Vice President for Academic Affairs and Research, Dr. Richard Bloom, Chief Academic Officer at Prescott and Dr. Brad L. Sims, Chancellor of Worldwide, for their continued support of UAS related activities across our university.

Cover picture: A fully 3-D printed UAV developed for Boeing in 2011.

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Embry-Riddle Aeronautical University
Unmanned Aircraft System
Capabilities

Engineering

E1. Design, Development, and Validation

(Inclusive of the entire system including vehicle, control stations and payload)

Figure 1: Optionally piloted aircraft in the Eagle Flight Research Center.

Advanced Verification Techniques

The project, sponsored by the FAA, dealt with advanced verification techniques for safety-critical airborne hardware complying with DO-254. (D20)

Aerobiological Sampling using UAVs

This project involves collecting biological samples in the planetary boundary layer above agricultural fields. The goals were to find optimal autonomous flight patterns and to track the transport of plant pathogens in the planetary boundary layer. (D29)

Aerodynamic Design Considerations for UAS during Refueling Operations

This research investigates the aerodynamics associated with Unmanned Aerial Systems during refueling operations. (W05 & W06)

An Optionally Piloted Unmanned Aircraft System

A team of faculty and students are developing an unmanned (surrogate) aircraft that will autonomously fly a series of waypoints and avoid local air traffic (both cooperative and non-cooperative aircraft.) (D14, D16, D17, D22, & D23)

CFD Analysis of Aerodynamic Surface Finishes

This project involves CFD modeling of low speed boundary layer airflow on various UAS surface finishes. (W05 & W13)

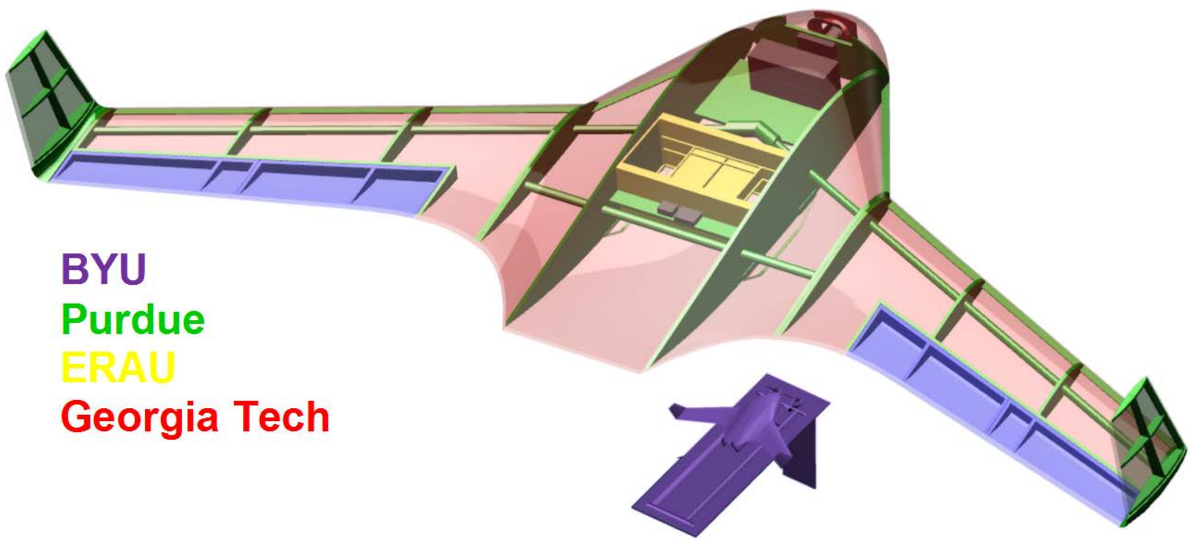

Figure 2: Boeing AerosPACE (Aerospace Partners for Advancement of Collaborative Engineering) 2013-14 Program. Blended Wing Body (BWB) UAS for Agricultural Surveillance Missions. Designed & Built by a Multi-University Team, including ERAU Prescott

Design of Hunter-Killer UAV's using Morphing Aircraft Technology

This project investigated the initial requirements for the USAF second generation of Hunter-Killer UAV's as follow-on systems to the Predator and Reaper UAV's. (W07)

Development of a Fully 3-D Printed Fixed-Wing UAV

Boeing sponsored project involving developing tools and techniques for rapid parametric-based design and manufacture of UAV using 3-D printing technology. (D19, D28, D29 & D30)

High-Fidelity Modeling of Gust-Airfoil Interactions for UAVs

The project conducted in collaboration with WPAFB and Eglin AFB AFRL scientists over the past eight years employs DOD HPC and ERAU computer facilities to conduct high-fidelity, low-Reynolds, aeroelastic gust-airfoil interaction studies to model unsteady responses and their control for small UAVs operating in highly unsteady urban canyons. The focus is on modeling airfoil interactions with canonical upstream flow configurations including time-harmonic and sharp-edge gusts, vortices and synthetic turbulence with prescribed characteristics tailored to a specified unsteady flight-path environment. (D15)

Hypersonic Flight of UAV as a Cargo Vessel

This project involved the computational fluid mechanics analysis of hypersonic flight parameters. (W02, W05, W13)

NOAA Gale: An Unmanned Aircraft for In-Situ Study of Tropical Cyclones

ERAU has developed an unmanned aircraft for NOAA, which deploys from a WP-3D Orion hurricane hunting aircraft. It is designed to provide real-time meteorological sampling from within tropical cyclones. (D23 & D24)

Pelican Water-Deployable UAV

This is a project to develop a water-deployable UAV for maritime operations for use in remote sensing applications such as wildlife monitoring. A system originally developed for sUAS was redesigned to allow for launching from boats and recovery by water landing. A design was created and testing was performed to determine the optimum landing profile of a flying wing in a water recovery. (D28)

Figure 3: UAS of various classes and types each must be evaluated as part of the development and testing process.

Qualification of Verification Tools

The project, sponsored by the FAA, dealt with the qualification of verification tools for airborne safety-critical software complying with DO-178. (D20 & D21)

Robust Nonlinear Aircraft Tracking Control using Synthetic Jet Actuators

A robust, nonlinear tracking control strategy was developed for an aircraft equipped with synthetic jet actuators (SJA). The control law was shown to yield zero steady-state error trajectory tracking in the presence of dynamic system uncertainty, actuator nonlinearity, and unknown, nonlinear external disturbances (e.g., wind gusts). (D12)

Software Engineering Process

This project involved the evaluation of software engineering processes, software development tools with automatic code generation, software intensive system/software safety assessment, the testing of flight data processing software, and airborne systems certification with DO-178C and related guidance, software tools qualification. (D21)

TeamAIR

This project involved the design and building of a fixed-wing UAS for the Association of Unmanned Vehicle Systems International (AUVSI) Small UAS engineering competition. These UAS must be capable of autonomously searching a military airfield for static targets. (P02)

The use of Orthogonal Arrays in Optimum Conditions for Drogue Re-fueling of Unmanned Aerial Vehicles

Using statistical and mathematical analysis methods, drogue movement during low speed flight of refueling UAVs is being studied. (W05, W11 & W13)

UAS Clusters as a Source of Competitive Advantage

As UASs continue to evolve, it is important to remember that clusters have played an important role in the history of aerospace manufacturing. Although we don't know exact numbers, we know the UAS industry will be huge, and we also know it will continue to play a crucial role in national defense. Given the enormous impact UAS could have on our country, the focus of this project is on leveraging innovative best practices that can accelerate our competitive advantage in UAS design, manufacturing, and lifecycle support. (W15)

E2. Communications and Security

A Technology Survey and Regulatory Gap Analysis of Command, Control, and Communication (C3)

A survey of technologies for UAS command, control, and communication was performed. Given these technologies, the federal aviation regulations were assessed to determine which applications were applicable, needed re-interpretation, needed revision, or were missing. (D23 & D25)

Unmanned Aviation Systems (UAS) and Integration with National Air Space (NAS)

This project involves the role of secure communications in the deployment of ADS-B for both manned and unmanned flight. What are the similarities and differences for secure communication – ground to air, air to satellite, ground to satellite, air to air. (P01)

E3. Modeling and Simulation (M&S)

Aerobiological Sampling Using UAVs

The details of this research are described under *E1. Design, Development, and Validation.* (D29)

Capability Analysis and Effectiveness Response for Unmanned Systems (CAERUS) Framework

The CAERUS framework was developed to support detailed examination of performance and suitability of unmanned system configurations, including UAS, to perform envisioned applications. The framework features use of M&S concepts and techniques to gain insight regarding identifying design issues, configuration considerations, or system performance. (W01, W03, W08, W09, W10, & W11)

Figure 4: Visual depiction of UAS in orbit over stationary object of interest (target), generated using CAERUS Framework.

Development of a Fully 3-D Printed Fixed-Wing UAV

The details of this research are described under *E1. Design, Development, and Validation.* (D19, D28, D29 & D30)

Effects of Visual Interaction on Unmanned Aircraft Operator Situational Awareness in a Dynamic Simulated Environment

This study represents a longitudinal study to further the findings of an earlier study examining UAS operator situational awareness. It is hypothesized that increased situational awareness can be achieved for UAS operators through incorporation of operational reference cues (e.g., aural vibrational, visual cueing) into the human-machine-interface (HMI) of the UAS ground control station (GCS). (W03, W09 & W10)

Guidance, Navigation, and Control (GNC) for Autonomous UAVs in Urban Environments

This project entails development, simulation, and testing of GNC algorithms to enable small UAVs to operate autonomously in complex urban environments. These GNC algorithms include mapping unknown environments using processed vision and LIDAR sensor data, optimal path planning with obstacle avoidance, and vision-aided navigation. (D17)

High-Fidelity Modeling of Gust-Airfoil Interactions for UAVs

The details of this research are described under *E1. Design, Development, and Validation.* (D15)

Human Computer Interfaces for Supervisory Control of Multi-mission, Multi-agent Autonomy (OSD12-HS1)

Interface for Supervisory Adaptive Autonomous Control (ISAAC) was developed, providing a Decision Support System and intuitive Graphical User Interface with the goal of enabling supervisory control and ameliorating the problems of system complexity and workload facing operators of multiple unmanned/autonomous assets. (D09)

Modeling and Simulation

This project involves the modeling of the air traffic control environment, and human-in-the-loop simulation for NextGen. (D21)

Pilot-in-the-Loop Mobil Research Test Bed

In this project a Mobil UAV Ground Control Station (GCS) will be developed and implemented. The system will support aviation safety research with pilot-in-the-loop capabilities using unmanned aerial systems platforms and where adverse flight conditions, such as subsystems failures, could be simulated in real-time to characterize pilot response, control laws performance, and human-machine interactions. (D16)

Reinforcement Learning of Imperfect Sensor for Autonomous Aerial Vehicles

This study utilized the Signal Detection Theory (SDT) to model the sensor sensitivity on autonomous aerial vehicles, investigated the interaction between sensor sensitivity and Reinforcement Learning algorithm on agent performance for target search and identification. (D09)

UAS-Aircraft Rescue Fire Fighting Response Conceptual and Application Analysis

The application of UAS to support ARFF response was selected to serve as an initial test case for the use of category representative UAS attribute performance models (APMs) and the Capability Analysis and Effectiveness Response for Unmanned Systems (CAERUS) M&S framework to investigate and analyze potential effectiveness. The intent was to ascertain the utility of employing UAS to support ARFF response efforts. (W01, W03, W08, W09, W10 & W11)

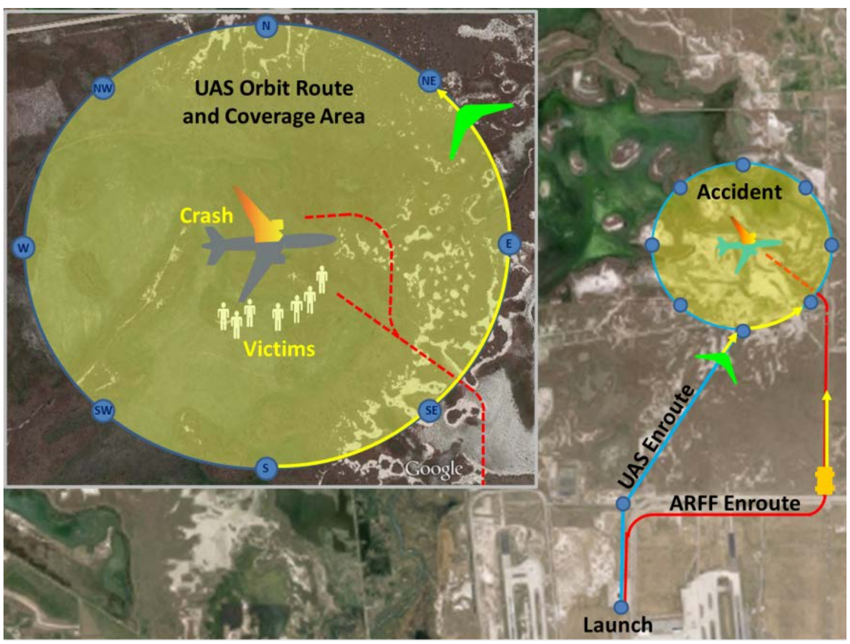

Figure 5: UAS Application Analysis – UAS ARFF Theory of Operation

UAV Flight Control with Macro-fiber Composite Actuators

In this project macro-fiber composite (MFC) aileron actuators are designed for implementation on a medium-scale, fixed-wing UAV in order to achieve roll control. Several MFC aileron actuator designs are evaluated through a combination of theoretical and experimental analysis. (D16, D17 & D18)

Unmanned System Attribute Performance Model Development

Our team of researchers has been actively compiling published performance data associated with commercially-off-the-shelf (COTS) group 1 to 3 fixed-wing and vertical takeoff and landing (VTOL) UAS in an effort to develop statistical models of each category (282 unique platform configurations captured, to date). (W03, W09 & W10)

E4. Autonomy and Control

A Technology Survey and Regulatory Gap Analysis of Emergency Recovery and Flight Termination (ERFT) Systems for UAS

A survey of technologies for UAS emergency recovery systems and flight termination systems was performed. Given these technologies, the federal aviation regulations were assessed to determine which applications were applicable, needed re-interpretation, needed revision, or were missing. (D23 & D25)

Aerobiological Sampling using UAVs

The details of this research are described under *E1. Design, Development, and Validation.* (D29)

Android Autopilot System

In this project a flexible, cross-platform autopilot system capable of integrating advanced autonomy behaviors including obstacle avoidance, motion planning, and automatic task allocation is being developed. The system is designed to run on Android on Linux operating systems and will be demonstrated using an Android smartphone as a complete autopilot solution including sensors, processing, and payload capability. (D28)

Application of Autonomous Soaring

The project, performed in collaboration with the Management Center Innsbruck (MCI), studied the application of autonomous soaring in order to extend the flight time of autonomous surveillance aircraft. (D20)

Development of a Fully 3-D Printed Fixed-Wing UAV

The details of this research are described under *E1. Design, Development, and Validation.* (D19, D28, D29 & D30)

Guidance, Navigation and Control (GNC) for Autonomous UAVs in Urban Environments

The details of this research are described under *E3. Modeling and Simulation (M&S).* (D17)

Image Processing In Support of "Sense-and-Avoid" for UAS Operations

Our UAV is designed to be able to see – to determine the distances, azimuth and elevation angles of – other flying objects. To do this, we use an integrated radar and image processing system, where the radar is used to provide distance information and rough angle information and image processing is used to acquire accurate angle information. (D17, D19, D22, D23, & D27)

Implementing Low Cost Two-person Supervisory Control for Small Unmanned Aerial Systems

The purpose of this research was to examine literature, guidance, regulations, and other influencing factors to assess the necessity of redundancy management practices to identify recommended control stratagem, processes and procedures, operational criteria, and design of a proof of concept system to operate sUAS with optimal safety and operational benefits within recommended and legislated boundaries. (W03 & W09)

Lyapunov-based Adaptive Regulation of Limit Cycle Oscillations in Aircraft Wings using Synthetic Jet Actuators

A Synthetic Jet Actuator-based nonlinear adaptive controller is developed, which is capable of completely suppressing Limit Cycle Oscillations in UAV systems with uncertain actuator dynamics. A rigorous Lyapunov-based stability analysis is utilized to provide asymptotic (zero steady–state error) plunging regulation, considering a detailed dynamic model of the pitching and plunging dynamics; and numerical simulation results are provided to demonstrate that simultaneous pitching and plunging suppression is achieved using the proposed control law. (D12 & D15)

Multi-Rotor Vector Control User Interface

This research represents the conceptual design of a multi-rotor control methodology to support observing areas outside direct line-of-sight (LOS) to locate objects of interest in tactical environments. It is hypothesized that the design of an interface featuring vector/autopilot control would reduce operator attentional allocation, supporting the maintenance of localized situational awareness. (W09 & W10)

Pilot-in-the-Loop Mobil Research Test Bed

The details of this research are described under *E3. Modeling and Simulation (M&S).* (D16)

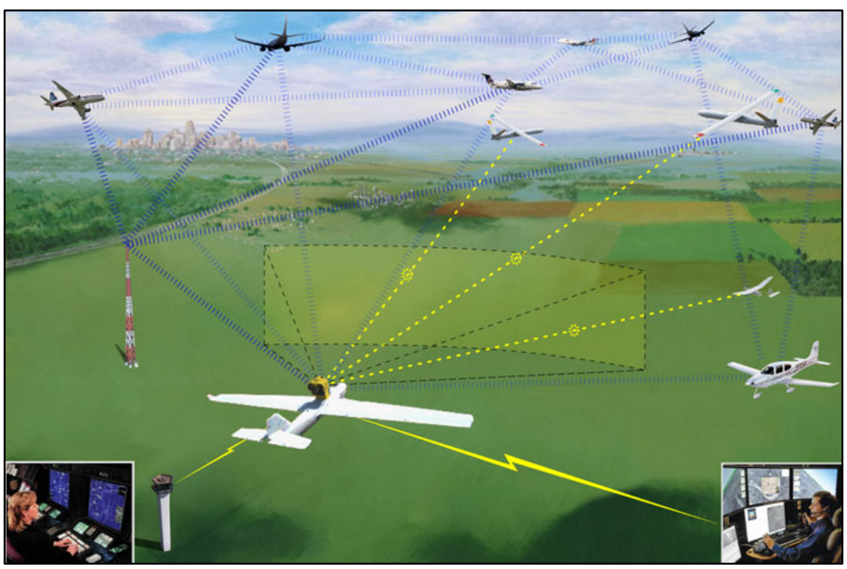

Figure 6: Simulation for sense and avoid studies.

Smart Materials for UAV Flight Control and Morphing

This study involves the development of smart material actuators for UAV flight control and wing morphing. (D16, D17 & D18)

UAS Sense and Avoid

This project involves the development of vision-based algorithms for identifying and estimating the location of uncooperative air traffic in support of sense and avoid operations. (D14, D16, D17, D22, D23 & the Eagle Flight Research Center)

UAV Autopilot Design Project

In this project an autopilot will be designed for autonomous UAVs that will allow its use in the presence of unpredictable atmospheric disturbances while minimizing energy expenditures and thereby extending the range of UAVs. (D11)

UAV Flight Control with Macro-Fiber Composite Actuators

The details of this research are described under *E3. Modeling and Simulation (M&S).* (D16, D17 & D18)

Vision-Aided Navigation

This research includes identifying known landmarks or tracking visual features in order to provide inertial measurements when GPS is not available. (D17)

E5. Propulsion and Power

Development of a Fully 3-D Printed Fixed-Wing UAV

The details of this research are described under *E1. Design, Development, and Validation.* (D19, D28, D29 & D30)

High-Fidelity Modeling of Gust-Airfoil Interactions for UAVs

The details of this research are described under *E1. Design, Development, and Validation.* (D15)

Unmanned System Attribute Performance Model Development

The details of this research are described under *E3. Modeling and Simulation.* (W03, W09 & W10)

E6. Operational Environment

Emergency Response using UAS

The purpose of this research was to examine past uses, current and potential opportunities, and influencing factors associated with the use of UAS technology to support aviation accident and emergency response. (D09, W03, W04, W08, W09, W10 & W11)

Image Processing In Support of "Sense-and-Avoid" Operations

The details of this research are described under *E4. Autonomy and Control.* (D17, D19, D22, D23, & D27)

Implementing Low Cost Two-Person Supervisory Control for Small Unmanned Aerial Systems

The details of this research are described under *E4. Autonomy and Control.* (W03 & W09)

Figure 7: UAS Competition and Demonstration at Wings over Houston

<u>Integrating Unmanned Aircraft Systems into Airport Operations and Master Plans</u>

The purpose of this research was to identify and establish best practices for development of a model supporting integration of UAS operations into airport master plans. This qualitative, observational, and multiple-case study incorporated the evaluation of airport master plan development (Fallen, NV), UAS operations and specific UAS airport integration issues. (W03, W09, W11, W12)

<u>Operational Environment</u>

This project provides a decision support system for air traffic system management, analysis and validation of the national airspace simulation models. (D21)

<u>Public Perception of Unmanned Aerial Systems (UAS): A Survey of Public Knowledge Regarding Roles, Capabilities, and Safety While Operating Within the National Airspace System (NAS)</u>

This research explores the perception and depth of knowledge possessed by the public-at-large concerning safety issues surrounding the integration and future deployment of Unmanned Aerial Systems (UASs) in the National Airspace System (NAS). (D09, W03, & W10)

Application

A1. Regulation, Policy, and Ethics

A Technology Survey and Regulatory Gap Analysis of Command, Control, and Communication (C3)

The details of this research are described under *E2. Communications and Security*. (D23 & D25)

A Technology Survey and Regulatory Gap Analysis of Emergency Recovery and Flight Termination (ERFT) Systems for UAS

The details of this research are described under *E4. Autonomy and Control*. (D23 & D25)

An Unmanned Aircraft Classification Scheme to Aid the Development of Regulations for Operations in NAS

An investigation of current UAS classification techniques and UAS concept-of-operations (CONOPs) was performed to determine how different aircraft and different missions are differentiated from one another. Then, using House of Quality analysis, rules were written to determine aircraft requirements given mission, and alternatively mission envelop given aircraft. (D23)

Detect and Avoid (DAA)

ERAU is participating with the RTCA SC228 workgroup to develop Minimum Operational Performance Standards (MOPS) for DAA. (D03)

Implementing Low Cost Two-Person Supervisory Control for Small Unmanned Aerial Systems

The details of this research are described under *E4. Autonomy and Control*. (W03 & W09)

Integrating Unmanned Aircraft Systems into Airport Operations and Master Plans

The details of this research are described under *E6. Operational Environment*. (W03, W09, W11 & W12)

Privacy and Unmanned Aerial Systems Integration into the National Airspace System

This study identified themes among the dissent for UAS-related technologies as well as for UAS integration. Further, commonalities and occurrences in previous privacy related confrontations were characterized in order to serve as a guide for efforts to resolve the UAS privacy quandary. (D09, W03 & W10)

Public Perception of Unmanned Aerial Systems (UAS): A Survey of Public Knowledge Regarding Roles, Capabilities, and Safety While Operating Within the National Airspace System (NAS)

The details of this research are described under *E6. Operational Environment*. (D09, W03, & W10)

State and Local Legislation: More Hurdles for Unmanned Aerial Systems (UAS) Integration

This research covers the regulatory and legislative hurdles that currently exist for UAS stakeholders. This research analyzes state and local legislation to identify themes and trends in the development and passage of laws limiting UAS operations. (W03, W09 & W10)

UAS Regulation, Policy, and Ethics

This research focuses on the non-military use of UAS technology and its ethical impact on privacy. (D02 & D05)

Wiki on UAS

Focusing on the US industry only, and organized around major stakeholders, this wiki identifies and explores some of the looming challenges of integrating Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS). Additionally, this wiki proposes a potential solution path that will ameliorate these challenges. The wiki concludes with a focus on the role of US aviation industry leadership in managing the collective motivations and abilities of the highlighted stakeholders as the national and global airspace system undergoes intense modernization through the 2025-2030 timeframe. (W14)

A2. The Business Enterprise

Figure 8: The usage capabilities are widespread. As seen here, this quadcopter type UAS can be mounted with a variety of sensors such as cameras, infrared detection systems, or other analysis tools.

Integrating Unmanned Aircraft Systems into Airport Operations and Master Plans

The details of this research are described under *E6. Operational Environment.* (W03, W09, W11, W12)

The Business Enterprise

In this project the development of a leasing market for UAS is researched. (D02)

Unmanned Systems Career Opportunities, Educational Alignment, and Critical KSAs

Primary factors associated with the growth, availability, and sustainment of career and job opportunities in the unmanned systems field were examined and analyzed. These factors included critical topics, knowledge, skills, and abilities (KSAs), and technologies; available educational programs; and anticipated economic development areas, as described by industry, government, and academic sources. (W09)

A3. Operational Employment

CFD Analysis of Aerodynamic Surface Finishes

The details of this research are described under *E1. Design, Development, and Validation.* (W05 & W13)

Design of Hunter-Killer UAV's using Morphing Aircraft Technology

The details of this research are described under *E1. Design, Development, and Validation.* (W07)

Emergency Response using UAS

The details of this research are described under *E6. Operational Environment.* (D09, W01, W03, W08, W09, W10 & W11)

Hypersonic Flight of UAV as a Cargo Vessel

The details of this research are described under *E1. Design, Development, and Validation.* (W02, W05, W13)

The use of Orthogonal Arrays in Optimum Conditions for Drogue Re-fueling of Unmanned Aerial Vehicles

The details of this research are described under *E1. Design, Development, and Validation.* (W05, W11 & W13)

UAS-Aircraft Rescue Fire Fighting Response Conceptual and Application Analysis

The details of this research are described under *E3. Modeling and Simulation.* (W01, W03, W08, W09, W10 & W11)

UAS Operational Employment

UAS designated instructor pilot in the Air Force's largest formal training unit responsible for teaching both new instructors and inexperienced aviators the complexities of Unmanned Aircraft Systems operation. Test engineer for the Next Generation Airspace System Research; customs and Border Protection, and General Atomics, to test the use of ADS-B on a Medium Altitude Long Endurance UAS. (D05)

Wiki on UAS

The details of this research are described under *A1. Regulation, Policy, and Ethics.* (W14)

A4. Remote Sensing with UAS

Aerobiological Sampling Using UAVs

The details of this research are described under *E1. Design, Development, and Validation.* (D29)

Android Autopilot System

The details of this research are described under *E4. Autonomy and Control.* (D28)

Application of Autonomous Soaring

The details of this research are described under *E4. Autonomy and Control.* (D20)

Detect and Avoid (DAA)

The details of this research are described under *A1. Regulation, Policy, and Ethics*. (D03)

Development of a Fully 3-D Printed Fixed-Wing UAV

The details of this research are described under *E1. Design, Development, and Validation.* (D19, D28, D29 & D30)

Development of Multispectral Passive Aircraft Detection and Classification

This project seeks to develop a small, lightweight, and low power sensor suite for detecting neighboring aircraft. The system is designed for small (under 55 lbs) UAS, and utilizes passive sensing from the RF, infrared and visible spectra. (D19 & D27)

Intelligence, Surveillance and Reconnaissance

This study is a review of the technology and practices for remote sensing using different platforms including UAS, satellites and cyber techniques. This project is in conjunction with the development of new curriculum as well as a chapter in a book. (P01)

Laser-based Remote and Short Range Sensors

This research focusses on new types of laser-based remote and short range sensors. (D26)

Unmanned Aerial Systems for Agricultural Monitoring

The project entails of the development of a low-cost UAS and payload capable of monitoring water levels of agricultural fields using visible and near-infrared spectrum photography. (D27)

A5. Education and Training

AE623 – "Atmospheric Guidance, Control and Navigation" (Lecture)

This class helps the students to design flight control laws and test them aboard a UAV test-bed platform. Instrumentation and hardware assembly are the principal characteristics of this class. (D16)

Crew Resource Management Training

This research involves the development of Crew Resource Management Training for UAS as part of the undergraduate degree and is in response to the FAA requirement for UAS crews to have CRM training. (D04, D05, W03, W10 & D06)

Evaluating the Effectiveness of Previous Manned Flight Training on UAS Flight

ERAU is engaged in a multi-faceted project evaluating the effectiveness of previous manned flight training on UAS flight. (D03 & D04)

Real World Design Challenge – STEM Education Outreach

The Real World Design Challenge (RWDC) is a national high school Science, Technology, Engineering, and Math (STEM) design competition focused on introducing students to concepts, topics, and methods associated with engineering disciplines and real world challenges. The five-year focus of the challenge was identified as unmanned aircraft systems and precision agriculture (starting in 2013). ERAU has been tasked with developing both the State and National challenges for RWDC, using a multi-disciplinary team of contributors from across the University. (W04 & W09).

Figure 7: UAS operators working within a common system control station.

UAS Education and Training

Subject Matter Expert for the US Air Force's UAS formal training unit developed and reviewed courseware, syllabi and classroom materials for all Air Force Unmanned Aircraft Systems training units. While partnered with URs Corporation to develop the X-GEN Medium Altitude Long Endurance UAS simulator and documentation that would meet both the academic requirements of the newly minted degree and industry demands. Research also involved initiating an extensive overhaul of the ERAU program's curriculum to better align with regulatory demands and industry needs. Study encompasses the development of a bold new course to integrate UAS simulation through the acquisition of the largest private UAS laboratory in the country. (D05)

UAS ERAU Workshop

The project involves a module on UAS Integration into the NAS. (D05, D07, & D08)

UAS Operational Employment

The details of this research are described under *A3. Operational Employment*. (D05)

Unmanned Systems Career Opportunities, Educational Alignment, and Critical KSAs

The details of this research are described under *A2. The Business Enterprise.* (W09)

Wiki on UAS

The details of this research are described under *A1. Regulation, Policy, and Ethics*. (W14)

A6. Human Performance and Machine Interaction

<u>Advancement and Application of Unmanned Aerial System Human-Machine-Interface (HMI) Technology</u>

The objective of this study is to identify common themes in the advancement and application of human-machine interface technologies in UAS control. This research includes review of available literature and associated technology designs to identify how the UAS community can best leverage this technology and interaction concepts to support safe and efficient operations of UAS. (D09, W03, W09, & W10)

<u>Crew Resource Management Training</u>

The details of this research are described under *A5. Education and Training.* (D04, D05, W03, W10 & D06)

<u>Detect and Avoid (DAA)</u>

The details of this research are described under *A1. Regulation, Policy, and Ethics*. (D03)

<u>Effects of Visual Interaction on Unmanned Aircraft Operator Situational Awareness in a Dynamic Simulated Environment</u>

The details of this research are described under *E3. Modeling and Simulation.* (W03, W09 & W10)

<u>Emergency Response using UAS</u>

The details of this research are described under *E6. Operational Environment.* (D09, W01, W03, W08, W09, W10 & W11)

<u>Evaluating the Effectiveness of Previous Manned Flight Training on UAS Flight</u>

The details of this research are described under *A5. Education and Training.* (D03 & D04)

<u>Human Computer Interfaces for Supervisory Control of Multi-mission, Multi-agent Autonomy (OSD12-HS1)</u>

The details of this research are described under *E3. Modeling and Simulation (M&S).* (D09)

Human Factors Issues in Autonomous Aerial Vehicles

This project analyzed the effects of multiple-UAV monitoring, automation level, tasks uncertainty, systems reliability, time pressure and pilot experiences on the performance of autonomous aerial vehicle mission performance. (D09)

Implicit Coordination and Awareness Displays in Unmanned Aircraft Systems (UAS)

Because UAS teams are distributed, there are communication issues due to loss of sensory cues and non-verbal cues from teammates, as well as limited bandwidth for diagnosis, problem solving, and collaboration among team members. In this project two methods for overcoming some of these coordination limitations have been suggested: 1) awareness displays and 2) implicit communication, both of which are the focus of this research. (D13)

Measuring Shared Mental Models in Unmanned Aircraft Systems

This ongoing research focuses on measuring the shared mental model of the distributed members of the team and examining the effect that the distributed nature of the team has had on communication and operational effectiveness. (D05 & D13)

Multi-Rotor Vector Control User Interface

The details of this research are described under *E4. Autonomy and Control.* (W09 & W10)

NextGen Technology Evaluation to Support UAS in the National Airspace System

This research effort assessed future technology and procedural requirements for uninhabited aircraft systems (UAS) flying in the national airspace system (NAS). Live UAS flight demonstrations and simulation studies were conducted by a multi-organization team that included ERAU human factors faculty and students. Results included recommendations for designing cockpit traffic displays and a backup communications system for UAS flight operations. (D10)

NextGen UAS Human-Machine Interface (HMI) Evaluation

This FAA project examined HMI certification requirements for uninhabited aircraft systems (UAS) and whether those requirements exist in current FAA regulations. To identify requirements, ERAU human factors researchers assessed the demands of UAS piloting and UAS HMI designs. (D10)

Pilot-in-the-Loop Mobil Research Test Bed

The details of this research are described under *E3. Modeling and Simulation.* (D16)

Reinforcement Learning of Imperfect sensor for autonomous aerial vehicles

The details of this research are described under *E3. Modeling and Simulation*. (D09)

The Effect of Control and Display Lag on Unmanned Air System Manual Landing Performance

Simulator-based landing performance was compared under conditions of ms, 250 ms, and 1000 ms of lag. (D10)

UAS Degree Program

A UAS degree program was developed at ERAU. Research on the effect of manned pilot experience on the ability to learn to fly UAS was performed. (D01)

Project by Area Table

	E1. Design, Development, and Validation	E2. Communications and Security	E3. Modeling and Simulation (M&S)	E4. Autonomy and Control	E5. Propulsion and Power	E6. Operational Environment	A1. Regulation, Policy, and Ethics	A2. The Business Enterprise	A3. Operational Employment	A4. Remote Sensing with UAS	A5. Education and Training	A6. Human Performance and Machine Interaction
A Technology Survey and Regulatory Gap Analysis of Command, Control, and Communication (C3)		■					■					
A Technology Survey and Regulatory Gap Analysis of Emergency Recovery and Flight Termination (ERFT) Systems for UAS				■			■					
Advanced Verification Techniques	■											
Advancement and Application of Unmanned Aerial System Human-Machine-Interface (HMI) Technology												■
AE623 - "Atmospheric Guidance, Control and Navigation" (Lecture)											■	
Aerobiological Sampling using UAVs	■		■	■						■		
Aerodynamic Design Considerations for UAS during Refueling Operations	■											
An Optionally Piloted Unmanned Aircraft System	■											
An Unmanned Aircraft Classification Scheme to Aid the Development of Regulations for Operations in the NAS							■					
Android Autopilot System				■						■		
Application of Autonomous Soaring				■						■		
Capability Analysis and Effectiveness Response for Unmanned Systems (CAERUS) Framework			■									

	E1. Design, Development, and Validation	E2. Communications and Security	E3. Modeling and Simulation (M&S)	E4. Autonomy and Control	E5. Propulsion and Power	E6. Operational Environment	A1. Regulation, Policy, and Ethics	A2. The Business Enterprise	A3. Operational Employment	A4. Remote Sensing with UAS	A5. Education and Training	A6. Human Performance and Machine Interaction
CFD Analysis of Aerodynamic Surface Finishes												
Crew Resource Management Training												
Design of Hunter-Killer UAV's using Morphing Aircraft Technology												
Detect and Avoid (DAA)												
Development of a Fully 3-D Printed Fixed-Wing UAV												
Development of a Multispectral Passive Aircraft Detection and Classification												
Effects of Visual Interaction on Unmanned Aircraft Operator Situational Awareness in a Dynamic Simulated Environment												
Emergency Response using UAS												
Evaluating the Effectiveness of Previous Manned Flight Training on UAS Flight												
Guidance, Navigation, and Control (GNC) for Autonomous UAVs in Urban Environments												
High-Fidelity Modeling of Gust-Airfoil Interactions for UAVs												
Human Computer Interfaces for Supervisory Control of Multi-misson, Multi-agent Autonomy (OSD12-HS1)												
Human Factors Issues in Autonomous Aerial Vehicles												
Hypersonic Flight of UAV as a Cargo Vessel												

	E1. Design, Development, and Validation	E2. Communications and Security	E3. Modeling and Simulation (M&S)	E4. Autonomy and Control	E5. Propulsion and Power	E6. Operational Environment	A1. Regulation, Policy, and Ethics	A2. The Business Enterprise	A3. Operational Employment	A4. Remote Sensing with UAS	A5. Education and Training	A6. Human Performance and Machine Interaction
Image Processing in Support of "Sense-and-Avoid" for UAS Operations												
Implementing Low Cost Two-person Supervisory Control for Small Unmanned Aerial Systems												
Implicit Coordination and Awareness Displays in Unmanned Aircraft Systems (UAS)												
Integrating Unmanned Aircraft Systems into Airport Operations and Master Plans												
Intelligence, Surveillance and Reconnaissance												
Laser-based Remote and Short Range Sensors												
Lyapunov-based Adaptive Regulation of Limit Cycle Oscillations in Aircraft Wings using Synthetic Jet Actuators												
Measuring Shared Mental Models in Unmanned Aircraft Systems												
Modeling and Simulation												
Multi-Rotor Vector Control User Interface												
NextGen Technology Evaluation to Support UAS in the National Airspace System												
NextGen UAS Human-Machine (HMI) Evaluation												

	E1. Design, Development, and Validation	E2. Communications and Security	E3. Modeling and Simulation (M&S)	E4. Autonomy and Control	E5. Propulsion and Power	E6. Operational Environment	A1. Regulation, Policy, and Ethics	A2. The Business Enterprise	A3. Operational Employment	A4. Remote Sensing with UAS	A5. Education and Training	A6. Human Performance and Machine Interaction
NOAA Gale: An Unmanned Aircraft for In-Situ Study of Tropical Cyclones												
Operational Environment												
Pelican Water-Deployable UAV												
Pilot-in-th-Loop Mobil Research Test Bed												
Privacy and Unmanned Aircraft Systems Integration into the National Airspace System												
Public Perception of Unmanned Aerial Systems (UAS): A Survey of Public Knowledge Regarding Roles, Capabilities, and Safety While Operating Within the National Airspace System (NAS)												
Qualification of Verification Tools												
Real World Design Challenge - STEM Education Outreach												
Reinforcement Learning of Imperfect Sensor for Autonomous Aerial Vehicles												
Robust Nonlinear Aircraft Tracking Control using Synthetic Jet Actuators												
Smart Materials for UAV Flight Control and Morphing												
Software Engineering Process												
State and Local Legislation: More Hurdles for Unmanned Aerial Systems (UAS) Integration												
TeamAIR												
The Business Enterprise												

	E1. Design, Development, and Validation	E2. Communications and Security	E3. Modeling and Simulation (M&S)	E4. Autonomy and Control	E5. Propulsion and Power	E6. Operational Environment	A1. Regulation, Policy, and Ethics	A2. The Business Enterprise	A3. Operational Employment	A4. Remote Sensing with UAS	A5. Education and Training	A6. Human Performance and Machine Interaction
The Effect of Control and Display Lag on Unmanned Air System Manual Landing Performance												
The use of Orthogonal Arrays in Optimum Conditions for Drogue Re-fueling of Unmanned Aerial Vehicles												
UAS -Aircraft Rescue Fire Fighting Response Conceptual and Application Analysis												
UAS Clusters as a Source of Competitive Advantage												
UAS Degree Program												
UAS Education and Training												
UAS ERAU Workshop												
UAS Operational Employment												
UAS Regulation, Policy, and Ethics												
UAS Sense and Avoid												
UAV Autopilot Design Project												
UAV Flight Control with Macro-fiber Composite Actuators												
Unmanned Aerial Systems for Agricultural Monitoring												
Unmanned Aircraft Systems (UAS) Applications, Operations, and Support: Key Topics of Industry (Professional Development Workshop)												
Unmanned Aviation Systems (UAS) and Integration with National Air Space (NAS)												

	E1. Design, Development, and Validation	E2. Communications and Security	E3. Modeling and Simulation (M&S)	E4. Autonomy and Control	E5. Propulsion and Power	E6. Operational Environment	A1. Regulation, Policy, and Ethics	A2. The Business Enterprise	A3. Operational Employment	A4. Remote Sensing with UAS	A5. Education and Training	A6. Human Performance and Machine Interaction
Unmanned System Attribute Performance Model Development												
Unmanned Systems Career Opportunities, Educational Alignment, and Critical KSAs												
Vision-Aided Navigation												
Wiki on UAS												

Unmanned Aircraft System (UAS) Capabilities Matrix

	PI	Expertise	Keywords
D01	Ted Beneigh Professor Aeronautical Sciences Daytona Beach COA beneight@erau.edu	Prime author of ERAU's BASS UAS Degree. Performing research on the effect of manned pilot experience on the ability to learn to fly UAS.	UAS Pilot experience
D02	Daniel Friedenzohn Associate Professor Aeronautical Sciences Daytona Beach COA FRIEDEND@erau.edu	Study how society is addressing privacy, regulatory, and business issues pertaining to UAS and how a leasing market will develop for UAS.	Legal, privacy, leasing, insurance, policy
D03	Tom Haritos Assistant Professor Aeronautical Sciences Daytona Beach COA HARITOAA@erau.edu	Participating with the RTCA SC228 workgroup to develop Minimum Operational Performance Standards (MOPS) for DAA	Remote Sensing Detect and Avoid Applications UAS Education and Training UAS Classification and Certification UAS Simulation applications Human-Computer Interaction (HCI)
D04	Dan Macchiarella Professor and Chair Aeronautical Sciences Daytona Beach COA macchian@erau.edu	Media specialist due to issues of nondisclosure and security	Nondisclosure and security
D05	Alex Mirot Assistant Professor Aeronautical Sciences Daytona Beach COA mirota@erau.edu	UAS Regulation, Policy, and Ethics, UAS Operations and Applications, Team work, Crew Resource Management and UAS Education, Training and Certification	Regulation, Policy, and Ethics Operations and Applications Team Work Crew Resource Management Education, Training and Certification
D06	Janet K. Marnane Assistant Professor Aeronautical Sciences Daytona Beach COA marnanej@erau.edu	Crew Resource Management, Decision Making; Commerical Operations; Aviation Regulation/legislation	Decision Making Commercial Operations CRM Avaition Regulation/Legislation

	PI	Expertise	Keywords
D07	Clyde Rinkinen Associate Professor Air Traffic Mgnt Daytona Beach COA rinki613@erau.edu	Involved in ATM for 33 years and is a SME for integrating UAS into the NAS	Integrating UAS into the NAS
D08	Sarah Ochs Professional Programs Daytona Beach COA ochs839@erau.edu	Manager of UAS Workshops/Short-Courses for Daytona Beach	Logistical Planner and Event Director
D09	Dahai Liu Professor Human Factors Daytona Beach COAS Liu89b@erau.edu	Human Machine Interface in UAS; Supervisory Control of UASs; Reinforcement Learning in Autonomous UAVs; Modeling and Simulation	Workload Situation Awareness Supervisory Control Reinforcement Learning; HMI; Decision Support
D10	Kelly Neville Human Factors Daytona Beach COAS nevillek@erau.edu	Research methods for studying human-machine interaction, teams, situation awareness and decision making in complex, operational environments; identifying human operator information and control requirements; training requirements analysis; training, team training, expertise, expertise acquisition, cognition and information processing; situation awareness; decision making; cognitive work; automation design; human-automation interaction; multi-tasking and attention; mental workload assessment, stress and fatigue effects on cognition and cognitive work	Human Machine interface evaluation & assessment Human-system integration Training requirements analysis & team training Expertise, expertise acquisition Cognition & information processing Situation awareness Decision making Cognitive work Automation design; human-automation interaction Multi-tasking and attention Mental workload assessment Stress & fatigue effects on cognition
D11	Sergey V. Drakunov Associate Dean for Research and Graduate Studies Daytona Beach COAS DRAKUNOV@erau.edu	Control algorithms design for autopilots for autonomous UAVs and multiple UAVs formations.	Autopilots for autonomous UAVs Control for multiple autonomous UAVs formations
D12	William MacKunis Assistant Professor Engineering Physics COAS MACKUNIW@erau.edu	Feedback Tracking Control of an Unmanned Aerial Vehicle	Autopilots for autonomous UAVs

	PI	Expertise	Keywords
D13	Rosemarie Reynolds Mgnt, Marketing & Operations Daytona Beach COB reyno9bd@erau.edu	Teamwork, shared mental models, coordination, virtual teams	Teamwork Shared mental models Coordination Virtual teams
D14	Pat (Richard) Anderson Professor Aerospace Engineering Daytona Beach COE andersop@erau.edu	Faculty Advisor for NASA UAS Challenge to create an optionally piloted UAS surrogate with sense-and-avoid capability. UAS Guidance navigation and control.	Optionally piloted vehicle guidance, navigation, and control (GNC) aircraft certification
D15	Vladimir Golubev Professor Aerospace Engineering Daytona Beach COE golubd1b@erau.edu	Unsteady Aerodynamics, Flow/Flight/Propulsion Control, Aeroacoustics, Aeroelasticity, Computational Fluid Dynamics	Synthetic Jet Actuators Gust-Airfoil Interactions Micro Air Vehicles Transitional Flows Flow-Acoustic Resonant Interactions
D16	Hever Moncayo Assistant Professor Aerospace Engineering Daytona Beach COE moncayoh@erau.edu	Guidance, Navigation and Control, Flight dynamics Modeling and simulation. Aerospace Fault Tolerance	Unmanned systems Aviation Safety Navigation and control Fault Tolerance
D17	Richard Prazenica Assistant Professor Aerospace Engineering Daytona Beach COE prazenir@erau.edu	Guidance, navigation, and control of autonomous UAVs in complex environments; vision-aided navigation; terrain mapping from vision and LIDAR data; path planning and obstacle avoidance; UAV sense and avoid; smart materials for UAV flight control	LIDAR, computer vision, sense-and-avoid autonomous GNC path planning
D18	Dae Won Kim Assistant Professor Aerospace Engineering Daytona Beach COE kimd3c@erau.edu	Smart materials and systems, structural health monitoring,	Smart Materials Smart Structures Adaptive Structures Morphing Wings Structural Health Monitoring
D19	Billy Barott Associate Professor Electrical Engineering Daytona Beach COE barottw@erau.edu	RF engineering including passive radar. Sensors and Datalinks for the MSUASE program	RF engineering communications sensing radar passive radar sense-and-avoid

	PI	Expertise	Keywords
D20	Brian Butka Associate Professor ECSSE Daytona Beach COE butkab@erau.edu	Interested in how to sense UAVs with radar and acoustics, electrical system design	UAS sensing sense-and-avoid acoustics propulsion
D21	Andrew Kornecki Professor Software Engineering Daytona Beach COE kornecka@erau.edu	Familiarity with UAS concepts and operations, recent development on MOPS guidance as per RTCA Select Committee SC228, 14 CFR Sec. 11 FAA special conditions and exceptions, aviation systems safety and security (as per works of RTCA SC205 and SC216)	Tool Qualification for Complex Electronic Hardware Assessment of Software Development Tools Knowledge Based Methodology to support ATC Systems Analysis of ATC Sector
D22	Jianhua Liu Associate Professor ECSSE Daytona Beach COE liu620@erau.edu	Faculty lead on radar and faculty advisor for image processing for "Sense-and-avoid" for NASA UAS AOC competition.	sense-and-avoid radar image processing communication
D23	Richard Stansbury Associate Professor ECSSE COE stansbur@erau.edu	Technology surveys/regulatory gap analysis of UAS sub-systems; UAS classification / categorization; UAS sense-and-avoid; ADS-B based surveillance for commercial space	UAS/NAS Integration UAS in NextGen ADS-B UAS sense-and-avoid
D24	Massood Towhidnejad Professor ECSSE Daytona Beach COE towhid@erau.edu	Gale UAS project	NextGen UAS NAS Integration
D25	Timothy Wilson Chair and Professor Software Engineering Daytona Beach COE wilsonti@erau.edu	UAS NAS Integration studies with FAA tech Center (technology surveys and regulatory gap analyses)	UAS NAS Integration
D26	Susan Allen Distinguished Professor Mechanical Eng Daytona Beach COE ALLENS17@erau.edu	Have two patents (related) on laser sensors.	Lasers, remote sensing stand-off sensors laser-based sensors

	PI	Expertise	Keywords
D27	Eric Coyle Assistant Professor Mechanical Eng Daytona Beach COE COYEE1@erau.edu	Signal Processing, Computer Vision, UAS Platform and Payload Design	Sense-and-Avoid Multi-Spectral Imaging
D28	Patrick Currier Assistant Professor Mechanical Eng Daytona Beach COE CURRIERP@erau.edu	System design and integration with respect to autonomous systems including novel applications of new technologies such as mobile processing devices and 3D printing. Research interests include integration of advanced ground-based autonomy algorithms into UAS, development of technologies to shorten design and integration cycles, and rapid development of small UAS systems using low-cost components.	UAS integration autonomy 3D printing mobile devices student teams
D29	Charles Reinholtz Professor Mechanical Eng Daytona Beach COE reinholc@erau.edu	Unmanned and Autonomous Vehicles; mechanism and robotics	Unmanned and Autonomous Vehicles mechanism and robotics
D30	Heidi Steinhauer Chair and Associate Professor Freshman Engineering Daytona Beach COE steinhah@erau.edu	Sent request for info on 11-5	Fixed-wing UAV
P01	Jon Haass Associate Professor Cyber Security and Intelligence Prescott COA HAASSJ@erau.edu	UAS Cyber Security & Intelligence	Cyber Security & Intelligence
P02	Vince Pujalte Assistant Professor Applied Aviation Sci Prescott COA pujalo63@erau.edu	Flight control system integration; teaches AS473 and AS220	Flight control system integration

	PI	Expertise	Keywords
P03	Sara Nilsson Assistant Professor Aeronautical Sci Prescott COA fishe5ca@erau.edu	UAS Law and Regulation	Law Regulation Policy
W01	David Thirtyacre Assistant Professor Worldwide COA thirtyad@erau.edu	UAS operations, formal flight test, Low Observable (LO) Design, LO Operations, Sensors, Human-Machine Interface, Air Combat, Aerodynamics, Pilot training, STEM education; Professional Development Course, UAS Competition, ERAU Mobile UAS unit	Flight test, unmanned aircraft operations, Training, System integration, UAS application UAS Workshops, UAS Challenge, Sensors
W02	Orin Godsey Associate Professor Worldwide COA godseyo@erau.edu	Refueling of Unmanned Aerial Vehicles	Refueling of UAV
W03	David Ison Assistant Professor Worldwide COA isond46@erau.edu	Integrating UAS into Airport Master Plans; Human Machine Interface; Disaster Response and Recovery; Privacy, Legislation and UAS; Low Cost Two-Person Supervisory Control for sUAS; Privacy issues of UAS legislation	Integrating UAS into Airport Master Plans Human Machine Interface Disaster Response & Recovery Privacy, Legislation and UAS Low Cost Two-Person Supervisory Control for sUAS Legislation; regulation; privacy
W04	Robert Deters Assistant Professor Worldwide COA DETERSR1@erau.edu	Precision Agriculture Application and STEM Education; Real World Design Challenge	Precision Agriculture Application STEM Education Design
W05	Ian McAndrew Department Chair, Graduate Studies Worldwide COA mcand4f1@erau.edu	Drogue refueling of unmanned aircraft; Weibull analysis of docking probability of unmanned aircraft refueling	UAV refueling Weibull Analysis
W06	Kat Moran Associate Professor Worldwide COA morank@erau.edu	Aerodynamic Design considerations for UAS during refueling operations	Refueling of UAS

	PI	Expertise	Keywords
W07	Brian Sanders Full time Faculty Worldwide COA sanderb7@erau.edu	Precision Agriculture Application and STEM Education; Real World Design Challenge	Precision Agriculture Application STEM Education Design
W08	Todd Smith Assistant Professor Worldwide COA SMITHT39@erau.edu	Application and use of UAS in firefighting, emergency management, emergency response and disaster preparedness operations.	Safety Emergency management Emergency response Disaster preparedness
W09	Brent Terwilliger Program Chair, MS in Unmanned Systems Worldwide COA terwillb@erau.edu	Design, development, integration, test, application, and evaluation of unmanned systems and human-machine-interfaces; UAS regulatory and operational environment; Modeling and simulation (M&S); Situational awareness; STEM education; Curricula development and execution; Documentation	Unmanned aircraft, system integration, unmanned system application, HMI, M&S, STEM, UAS curricula development, documentation, sUAS
W10	Dennis Vincenzi Department Chair Undergraduate Studies Worldwide COA vincenzd@erau.edu	Unmanned systems including unmanned aerial systems (UAS), unmanned ground vehicles (UGV)s, and robotic systems; Situational awareness; Modeling and simulation (M&S); System design, development, integration, and test; Application, operation, and support of unmanned systems; UAS regulatory environment; Human-machine-interface	Unmanned systems including UAS, UGVs, and robotic systems; Situational awareness; Modeling and simulation (M&S); System design, development, integration, and test; Application, operation, and support of unmanned systems; UAS regulatory environment; Human-machine-interface
W11	Ken Witcher Dean Worldwide COA witchea8@erau.edu	Integrating UAS into Airport Master Plans; Refueling of unmanned aerial vehicles	Integrating UAS into Airport Master Plans Refueling of UAV
W12	David Worrells Associate Professor Worldwide COA WORRELLD@erau.edu	Integrating UAS into Airport Master Plans; Integration of UAS in National Airspace System	Integrating UAS into Airport Master Plans Integration of UAS in National Airspace System
W13	Elena Navarro Instructor Worldwide COAS NAVARRJ1@erau.edu	Mathematical Calculations	Refueling of UAS

	PI	Expertise	Keywords
W14	Kelly George Assistant Professor Worldwide COAS georged8@erau.edu	Co-authored a Wiki on UAS for the DAS 735 course (ERAU Ph.D. in Aviation program)	Economics Developing industries Monetary & fiscal policy
W15	Robert Materna Professor Business Admin Worldwide COB materc73@erau.edu	Wrote 12 page section on "The Benefits of Aerospace Clusters" in Embry-Riddle's *Aerospace Industry Report* 3rd Ed.; delivered presentation on "Sustainability in Aerospace: The Role of Clusters in Aerospace Manufacturing" to the annual meeting of the Aviation Council of Pennsylvania; delivered presentation on "The Role of Clusters in UAV Manufacturing" to Embry-Riddle's AIR3 Con in 2015. Preparing refereed pape4 on "The Evolving Role of Clusters in UAV Manufacturing."	UAS Manufacturing Clusters Manufacturing Clusters and the UAS Industry Clusters as a Source of Competitive Advantage in the UAS Industry USA's Role in UAS Manufacturing Leaders in UAS Design and Manufacturing Cluster Mapping and the UAS Industry Sustainability in UAS Manufacturing Repeat all the above for use with the acronym, UAV