The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

ANNUAL REPORT

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FORWARD

It is with great enthusiasm that we present the fiscal year 2023 ASSURE annual report highlighting the noteworthy progress and exciting prospects for our organization. As we reflect on the accomplishments of the past year, we are proud to share the remarkable outcomes of our research conducted for the FAA which have positioned us as a leading authority in Unmanned Aircraft Systems (UAS).

At ASSURE, we remain committed to pushing the boundaries of knowledge and innovation in the field of UAS and autonomy applied research. With thirty-two active FAA projects currently underway, our team has been diligently working towards informing policy, regulation, and standards supporting advancements in autonomy and aviation. One notable achievement includes our successful live engine test, running at full power, ingest of a small UAS at takeoff speed, a critical phase of flight. While the study of all the data from this important test is on-going, the knowledge gained from this and our other projects will help to ensure the safe integration of this new emerging technology for the advancement of public safety, benefit, and commerce.

In the past year, we also have completed eight projects, each contributing valuable insights and advancements to the UAS industry. These achievements serve as a testament to our dedication and expertise in delivering tangible results. We take considerable pride in our ability to translate research into practical applications that have real-world impacts. Looking ahead, we are thrilled to announce that we have an additional 10 projects in the pipeline. These projects cover a wide range of topics including safety risk management for Detect And Avoid (DAA), ways to increase small UAS conspicuity, human factors associated with DAA, operator medical certification standards, and advanced air mobility crash worthiness standards, just to name a few.

Our work garners continued interest across the whole of government and industry. We have been asked to support and speak on such issues as advanced air mobility operations, counter-UAS, the role of autonomous systems in shaping the future of the United States economy, and the very weighty topic of the ethics of unmanned and autonomous warfare.

Our influence is not limited to the United States alone. We have actively engaged with international partners to foster collaboration and knowledge exchange. Notably, we have added the Australian National University as an ASSURE affiliate and we participated as part of Australia's Community of Practice. Nearby, we are in discussions with the New Zealand government on how an ASSURE affiliate can be established there. Furthermore, we were honored that researchers and regulators invited us to a workshop in Europe, where we contributed our expertise in UAS DAA and traffic management.

In conclusion, we are confident that our research will contribute significantly to the advancement of UAS technology and shaping the future of autonomous systems while addressing critical ethical, legal, and economic considerations. We extend our sincere gratitude to our dedicated team, esteemed partners, and valued stakeholders for their unwavering support. Together, we will continue to pioneer new frontiers in UAS research and reshape the future of unmanned and autonomous systems.

Sincerely,

Stephen P. Luxion (Colonel, USAF-Retired)
Executive Director, ASSURE

MISSISSIPPI STATE UNIVERSITY

FEDERAL AVIATION ADMINISTRATION

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ASSURE LEADERSHIP

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MISSION:

Provide high-quality research & support to autonomy stakeholders both within the US and beyond to safely & efficiently integrate autonomous systems into the national & international infrastructure, thereby increasing commerce and overall public safety and benefit.

VISION:

ASSURE is the go-to high-quality research organization and brand for working complex autonomy issues with focus on unmanned aircraft systems (UAS) in policy, regulations, standards, training, operations, & education.

ASSURE TAGLINE:

Informing UAS policy through research

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ACKNOWLEDGEMENTS

We would like to express our sincere gratitude and appreciation to the Federal Aviation Administration (FAA) for their continued support and sponsorship of the critical research supporting key policy, regulations, and standards in safely integrating UAS in the nation's airspace. We applaud their steadfast commitment to advancing aviation innovation while maintaining the most complex and safe air transportation system in the world.

First and foremost, congratulations are due to Mr. Nick Lento for his promotion from managing our program within the NexGen New Entrants Division to his new role as Acting Deputy Director, Portfolio Management and Technology Development Office at the FAA. We extend a heartfelt farewell and a profound gratitude for years of invaluable guidance and support. Under his visionary leadership, he and his team have shaped and overseen our research ensuring it safely integrates this emerging technology with other legacy aircraft and systems. We are deeply grateful for his unwavering commitment to our mission and the teams of researchers and managers supporting it. We would also like to extend a warm welcome to Mr. Andras Kovacs, who has stepped in to replace Nick. We look forward to working with you going forward.

Our sincere appreciation to the FAA's entire ANG Management Team including Karen Davis, Bill Oehlschlager, Hector Rea, and their team of program managers whose steadfast support and guidance, expertise, and dedication have been instrumental in shaping our projects and ensuring alignment with the FAA strategic goals.

We would also like to express our appreciation to all other contributors, partners, and stakeholders who have supported us along the way. Together, we are making significant strides in advancing aviation safety, innovation, and the integration of uncrewed aircraft and autonomous systems into our national airspace.

We look forward to continuing to collaborate with the FAA in the years to come.

Thank you!

FINANCIALS

ASSURE FUNDING SUMMARY

TOTAL FUNDING : $86,119,745.64

	Award Amount	Expenditures	Remaining	Cost Share Required	Cost Share	Cost Share %
Program Office	$8,409,502.78	$7,913,310.80	$496,191.98	$5,339,538.78	$6,687,447.78	100%
Core Schools	$77,710,242.86	$48,067,098.75	$29,643,144.11	$43,795,077.08	$34,737,165.60	79%
Drexel University	$2,883,116.69	$1,860,316.31	$1,022,800.38	$1,607,196.16	$886,524.82	55%
Embry-Riddle Aeronautical University	$5,314,369.13	$3,869,945.00	$1,444,424.13	$2,456,742.59	$2,417,545.75	98%
Kansas State University	$3,728,826.00	$3,378,874.47	$415,501.76	$2,062,099.25	$1,928,895.53	94%
Mississippi State University	$9,838,478.38	$5,151,218.74	$3,157,945.82	$6,049,216.60	$3,340,500.37	55%
Montana State University	$709,062.28	$709,062.28	$0.00	$599,958.32	$599,958.32	100%
New Mexico State University	$7,198,093.33	$3,017,034.73	$4,331,058.60	$1,750,775.12	$2,612,784.06	149%
North Carolina State University	$1,377,140.39	$1,052,108.69	$325,031.70	$1,228,972.64	$545,232.69	44%
Ohio State University	$5,622,999.21	$4,416,739.83	$1,206,259.38	$3,157,046.52	$2,757,046.52	87%
Oregon State University	$3,378,962.00	$2,276,097.66	$1,102,864.34	$1,176,323.00	$754,916.94	64%
Sinclair College	$906,000.00	$79,415.64	$826,584.36	$906,000.00	$140,646.00	16%
University of Alabama-Huntsville	$7,217,278.43	$5,238,091.82	$1,979,186.61	$4,260,651.03	$4,240,496.32	100%
University of Alaska-Fairbanks	$6,749,739.40	$2,110,807.38	$4,638,932.02	$2,399,668.42	$1,936,228.01	81%
University of California-Davis	$144,730.00	$144,730.00	$0.00	$111,920.97	$93,287.00	83%
University of Kansas	$3,281,155.86	$2,187,453.13	$1,093,702.73	$2,296,869.86	$1,418,459.83	62%
University of North Dakota	$10,954,462.76	$6,894,814.37	$4,059,648.39	$5,325,807.60	$5,329,461.38	100%
University of Vermont	$1,195,000.00	$404,585.42	$790,414.58	$1,195,000.00	$459,380.08	38%
Wichita State University	$7,210,829.00	$5,275,803.28	$1,935,025.72	$7,210,829.00	$5,275,801.98	73%
Totals	**$86,119,745.64**	**$55,980,409.55**	**$30,139,336.09**	**$49,134,615.86**	**$41,424,613.38**	**84%**

FUNDING BY PROJECT

TOTAL FUNDING $86,119,745.64

	Award Amount	Expenditures	Remaining	Cost Share	Cost Share %
Program Management	$8,727,024.97	$8,228,918.17	$498,106.80	$7,003,055.15	100%
Projects	$77,392,720.67	$47,751,492.40	$29,856,778.50	$34,421,558.23	79%
A1: Unmanned Aircraft Integration: Certification Test to Validate sUAS Industry Consensus Standards	$299,996.00	$299,996.00	$0.00	$300,280.00	100%
A2: Small UAS Detect and Avoid Requirements Necessary for Limited Beyond Visual Line of Sight (BVLOS) Operations	$799,658.63	$799,658.63	$0.00	$799,944.34	100%
A3: UAS Airborne Collision Severity Evaluation	$1,000,000.00	$1,000,000.00	$0.00	$1,023,424.27	102%
A4: UAS Ground Collision Severity	$382,387.89	$382,387.89	$0.00	$409,098.69	107%
A5: UAS Maintenance, Modification, Repair, Inspection, Training, and Certification	$799,980.23	$799,980.23	$0.00	$829,733.21	104%
A6: Surveillance Criticality for SAA	$779,040.15	$779,040.15	$0.00	$779,040.15	100%
A7: UAS Human Factors Considerations	$717,601.08	$717,601.08	$0.00	$724,046.38	101%
A8: UAS Noise Certification	$50,000.00	$50,000.00	$0.00	$50,000.00	100%
A9: Secure Command and Control Link with Interference Mitigation	$329,996.24	$329,996.24	$0.00	$646,943.35	196%
A10: Human Factors Consideration of UAS Procedures & Control Stations	$798,182.05	$798,182.05	$0.00	$884,648.96	111%
A11: Low Altitude Operations Safety: Part 107 Waiver Request Case Study	$151,274.50	$151,274.50	$0.00	$184,588.38	122%
A12: Performance Analysis of UAS Detection Technologies Operating in Airport Environment	$284,186.03	$284,186.03	$0.00	$284,186.42	100%
A13: UAS Airborne Collision Severity Peer Review	$7,026.00	$7,026.00	$0.00	$7,026.00	100%
A14: UAS Ground Collision Severity Studies	$2,039,161.32	$2,039,161.32	$0.00	$2,274,960.61	112%
A15: Stem II	$149,982.00	$149,982.00	$0.00	$158,642.77	106%
A16: Airborne Collision Severity Evaluation - Structural Impact	$2,203,377.79	$2,203,378.80	($1.01)	$2,357,156.77	126%
A17: Airborne Collision Severity Evaluation - Engine Ingestion	$1,532,252.00	$1,532,132.43	$119.57	$1,580,974.27	164%
A18: Small UAS Detect and Avoid Requirements Necessary for Limited BVLOS Operations: Separation Requirements and Training	$1,199,608.52	$1,199,608.51	$0.01	$773,195.38	100%
A19: UAS Test Data Collection and Analysis	$409,627.10	$409,627.10	$0.00	$413,558.24	101%
A20: UAS Parameters, Exceedances, Recording Rates for ASIAS	$291,681.65	$283,842.44	$7,839.21	$396,319.22	140%

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FUNDING BY PROJECT

	Award Amount	Expenditures	Remaining	Cost Share	Cost Share %
A21: Integrating Expanded and Non-Segregated UAS Operations into the NAS: Impact on Traffic	$1,456,060.03	$1,456,060.03	$0.00	$581,984.23	112%
A23: Validation of Low-Altitude Detect and Avoid Standards- Safety Research Center	$1,500,000.00	$1,281,261.29	$218,738.71	$472,732.10	95%
A24: UAS Safety Case Development, Process Improvement, and Data Collection	$1,436,630.83	$1,046,436.98	$390,193.85	$492,538.20	100%
A25: Develop Risk-Based Training and Standard for Operational Approval and Issuance	$316,262.97	$316,262.97	$0.00	$166,054.00	100%
A26: Establish UAS Pilot Proficiency Requirements	$500,000.00	$500,000.00	$0.00	$166,666.00	100%
A27: Establish risk-based thresholds for approvals needed to certify UAS for Safe Operation	$478,277.78	$478,277.78	$0.00	$166,679.00	100%
A28: Disaster Preparedness and Response	$1,742,968.51	$1,721,897.39	$21,071.12	$962,923.16	144%
A29: STEM Outreach- UAS as a STEM Outreach Learning Platform for K-12 Students and Educators (STEM III)	$484,465.47	$466,014.56	$18,450.91	$130,269.09	57%
A31: Safety Risk and Mitigations for UAS Operations On and Around Airports	$1,598,185.90	$1,445,410.93	$152,774.97	$699,550.77	142%
A33: Science and Research Panel (SARP) Support	$70,383.00	$43,160.74	$27,222.26	$31,839.61	74%
A35: Identify Wake Turbelance and Flututer Testing Requirements for UAS	$1,498,921.00	$1,479,132.51	$19,788.49	$976,301.92	95%
A36: Urban Air Mobility (UAM): Safety Standards, Aircraft Certification and Impact on Market Feasibility and Growth Potentials	$1,115,400.73	$1,099,117.73	$16,283.00	$692,344.32	99%
A37: UAS Standards Tracking, Mapping, and Analysis	$456,559.84	$456,559.84	$0.00	$166,633.33	100%
A38: CyberSecurity and Safety Literature Review	$494,103.92	$494,103.92	$150,000.00	$164,745.33	63%
A40: Validation of American Society for Testing Materials (ASTM) Remote ID Standards- Safety Research Center	$750,000.00	$451,209.48	$298,790.52	$250,000.00	100%
A41: Air Carrier Operations- Investigate and Identify the Key Differences Between Commercial Air Carrier Operations and Unmanned Transport Operations	$799,745.00	$674,218.66	$125,526.34	$266,080.35	40%
A42: UAS Cargo Operations- From Manned Cargo to UAS Cargo Operations: Future Trends, Performance, Reliability, and Safety Characteristics Towards Integration into the NAS	$799,983.00	$756,565.90	$43,417.10	$206,420.79	77%
A43: High-Bypass UAS Engine Ingestion Test	$506,774.02	$322,207.94	$184,566.08	$213,333.33	100%
A44: Mitigating GPS and Automatic Dependent Surveillance- Broadcast (ADS-B) Risks for UAS	$874,000.00	$691,253.82	$248,296.41	$243,333.00	88%
A45: Shielded UAS Operations- Detect and Avoid (DAA)	$935,627.23	$700,818.77	$234,808.46	$293,767.44	95%
A46: Validation of Visual Operation Standards for Small UAS (sUAS)	$500,185.47	$471,241.95	$28,943.52	$246,666.88	100%
A47: Small UAS (sUAS) Mid-Air Collision (MAC) Likelihood	$960,786.14	$960,786.14	$0.00	$715,801.48	100%
A49: UAS Flight Data Research in Support of Aviation Safety Information and Sharing (ASIAS)	$469,262.00	$348,715.57	$120,546.43	$156,421.00	100%

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FUNDING BY PROJECT

	Award Amount	Expenditures	Remaining	Cost Share	Cost Share %
A50: Small Unmanned Aerial Systems (sUAS) Traffic Analysis	$2,436,407.73	$1,520,611.15	$915,796.58	$846,328.20	93%
A51: Best Engineering Practices for Automated Systems	$3,621,915.74	$1,865,938.05	$1,755,977.69	$792,256.03	56%
A52: Disaster Preparedness and Emergency Response Phase II	$3,535,662.06	$1,783,252.46	$1,752,409.60	$613,308.39	56%
A53: UAS Advanced Materials Investigation	$318,958.00	$314,425.10	$4,532.90	$317,223.50	99%
A54: Propose UAS Right-of-Way Rules for UAS Operations and Safety Recommendations (ERAU, KU, UND)	$1,525,882.93	$1,066,823.28	$459,059.65	$572,590.22	26%
A55: Identify Flight Recorder Requirements for UAS Integration into the NAS	$1,089,090.00	$888,992.49	$200,097.51	$662,749.84	95%
A56: Evaluate Unmanned Aircraft Systems (UAS) Electromagnetic Compatibility (EMC)	$975,872.70	$907,411.68	$68,461.02	$235,481.91	72%
A57: Investigate Detect and Avoid (DAA) Track Classification and Filtering	$1,513,441.00	$916,196.15	$597,244.85	$234,930.83	24%
A58: Illustrate the Need for UAS Cybersecurity and Risk Management	$1,869,991.00	$1,052,014.10	$817,976.90	$239,637.09	38%
A60: Evaluation of Unmanned Aircraft Systems (UAS) Integration Safety and Security Technologies in the National Airspace System (NAS) Program	$13,972,343.80	$2,991,062.22	$10,981,281.58	$3,079,639.68	66%
A61: STEM Outreach	$231,153.42	$138,090.00	$93,063.42	$116,340.15	50%
A62: Disaster Preparedness and Emergency Response Phase III	$2,768,070.00	$728,407.15	$2,039,662.85	$816,381.79	29%
A64: Identify Models for Advanced Air Mobility (AAM)/Urban Air Mobility (UAM) Safe Automation	$1,602,165.00	$354,038.03	$1,248,126.97	$709,219.43	44%
A65: Detect and Avoid Risk Ratio Validation	$2,052,702.27	$563,765.74	$1,488,936.53	$648,287.01	32%
A67: Determine the Collision Severity of Small Unmanned Aircraft Systems (sUAS) in Flight Critical Zones of Piloted Helicopter	$1,795,948.00	$580,486.50	$1,215,461.50	$580,486.50	32%
A66: Develop Methodolgies to Inform the Integration of Advanced Air Mobility (AAM) into the National Air Space System (NAS)	$2,000,000.00	$118,473.24	$1,881,526.76	$112,000.00	6%
A68: Validate sUAS Well Clear Definition	$2,113,515.00	$83,728.76	$2,029,786.24	$503,844.92	24%
Totals	$86,119,745.64	$55,980,410.57	$30,354,885.30	$41,424,613.38	84%

COST SHARE SUMMARY BY CONTRIBUTORS

Adaptive Aerospace Group, Inc.	$5,897.34
Advanced Thermoplastic Composites	$400.00
AIM Institute	$5,090.00
Airbus	$1,039,714.50
AgentFly Software	$50,000.00
ARC	$41,355.58
Aria Group, Inc.	$400.00
Arlin's Aircraft	$3,000.00
AUVSI	$15,873.00
A&P Technology	$410.00
Boeing	$46,235.64
CNA Corporation	$448,313.20
Composites One	$500.00
Composites World	$600.00
Consortium on Electromagnetics and Radio Frequencies	$2,675.00
C.R. Onsrud	$40,000.00
DJI	$63,285.84
DJI Research, LLC	$48,522.80
Drexel University	$647,514.82
Embry-Riddle Aeronautical University	$1,587,703.09
General Electric	$145,930.48
GFK Flight	$63,333.33
GoPro	$29,925.60
GreenSight Agronomics, Inc.	$37,777.00
Honeywell	$30,275.78
Huntsville Airport	$233,529.20
Impossible Objects	$500.00
Indemnis	$251,685.84
Intel	$113,101.60
IRIS Auomation	$71,000.00
Jaunt Air Mobility	$500.00
K.I.M. Inc.	$51,200.00
Kansas Department of Commerce	$282,180.00
Kansas State University	$2,311,252.55
Keysight Technologies	$566,690.00
Keystone Aerial Surveys	$1,750.00
Kongsberg Geospatial	$40,000.00
Mike Toscano	$147,500.00
Misc. External Match - Industry Funds	$310,605.12
Mississippi State University	$2,791,876.40
Montana Aircraft	$6,000.00
Montana State University	$521,387.68
911 Security	$88,781.54
Navmar Applied Sciences Corporation	$1,113,361.37
New Mexico State University	$2,612,784.06
North Carolina State University	$1,229,726.79
North Dakota Department of Commerce	$3,064,901.10
Novotech	$500.00
NUAIR	$20,923.02
Ohio State University	$1,686,390.54
Ohio/Indiana UAS Center (ODOT)	$298,188.75
Oregon State University	$679,916.94
OpenSky Network	$120,000.00
R Cubed Engineering	$6,970.09
RFAL	$21,343.30
Rochester Institute of Technology	$54,854.34
Rockwell Collins	$4,015.80
Sagetech Avionics	$52,350.00
Sandia	$2,257.00
SenseFly	$471,131.36
Sierra Nevada Corporation	$6,559.00
Simlat Software	$147,260.00
Sinclair College	$1,070,465.40
State of Kansas	$91,604.83
Skyfire Consulting	$350,480.00
Solvay	$254.00
Technion Inc	$3,939,422.84
Teijin Carbon America, Inc	$500.00
The Cirlot Agency	$116,824.90
University of Alabama in Huntsville	$2,316,415.78
University of Alaska Fairbanks	$1,936,228.01

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COST SHARE SUMMARY BY CONTRIBUTORS

University of California Davis	$93,287.00
University of Kansas Center for Research, Inc.	$764,451.21
University of North Dakota	$1,589,323.14
University of Vermont	$146,214.11
Unmanned Systems Group	$34,565.64
USRA, Inc	$500,467.00
Virginia Polytechnic Institute and State Unviversity	$450,580.65
Wichita State University	$4,285,822.48
Total	$41,424,613.38

SUMMARY BY YEAR

FY16 Cost Share	$4,197,084.44
FY17 Cost Share	$4,274,690.28
FY18 Cost Share	$1,789,332.05
FY19 Cost Share	$7,863,252.88
FY20 Cost Share	$5,601,392.05
FY21 Cost Share	($319,059.87)
FY22 Cost Share	$7,990,466.31
FY23 Cost Share	$10,027,455.24
Cumulative Cost Share	$41,424,613.38

SUMMARY BY SOURCE

Universities	$26,776,194.99
State Contributions	$3,736,874.68
3rd Party Contributions	$10,911,543.71
Total	**$41,424,613.38**

RESEARCH PROJECTS

VALIDATION OF LOW-ALTITUDE DETECT AND AVOID STANDARDS

LEAD UNIVERSITY : MISSISSIPPI STATE UNIVERSITY

A11L.UAS.55_A23

BACKGROUND:

The FAA provides academic institutions with the necessary resources to conduct scientific evaluations of newly developing technology within the UAS sector. Over two dozen institutions under ASSURE are studying the critical research topics for safe and efficient integration of UAS into the National Airspace System (NAS). Within the ASSURE consortium are multiple FAA designated UAS test sites, thousands of square miles of environmentally diverse flight test airspace, and various affiliates that contribute to ASSURE's portfolio. MSU has been designated as the UAS Safety Research Facility (UASSRF) by the FAA and is tasked with evaluating prior research that may need updated or expanded focus. The following report covers the research conducted under the A23 Validation of Low-Altitude Detect-and-Avoid standards effort started in October

2020 and continued until August 2023 by the UASSRF.

The tasking for this work expanded on prior research on the performance of human pilots to detect other air traffic, assess the potential for conflict, and analyze potential maneuver options for avoidance against an intruder aircraft when a potential conflict exists. The results of data and analyses conducted during this effort will be used by the FAA to support a determination of whether the Risk Ratio (RR) safety performance thresholds defined in the American Society for Testing and Materials (ASTM) Detect-and-Avoid (DAA) standard are adequate. The testing for this project took place at two locations. The first, Starkville, Mississippi, served as trial runs for the testing and data collection methods. Several procedures were improved over a handful of initial flight tests with MSU pilots. The remainder of the effort took place in Cleveland, Mississippi, with the Delta State University (DSU) Department of Commercial Aviation. DSU provided the Cessna aircraft used and the Subject Pilot participants under observation during flight testing for this research effort. DSU is an FAA-approved Part 141 flight training school with students from all levels of piloting experience. The Mississippi Department of Public Safety (DPS) provided an intruder rotorcraft, the Airbus H125, for generating encounters between subjects in fixed wing aircraft and a dedicated intruder rotorcraft. This pool of pilots helped provide data to better support a determination of the appropriateness of the ASTM DAA standards.

APPROACH:

Task 1: Program Management

Following the Kickoff Meeting, technical interchange meetings were held monthly. A research task plan was developed and provided to the sponsor.

Task 2: Literature Review

A literature review was produced using academic and industry sources, publicly available information, and regulatory documents. Past research efforts were acknowledged and discussed. The literature review provided an opportunity for the research team to gain extensive knowledge on the subject matter.

Task 3: Flight Test Plan

Due to the ongoing learn and implement nature of the research, the flight test plan was updated regularly throughout the duration of the project. Updates were provided the sponsor as needed.

The flight test plan accurately captures all test paths, procedures, equipment, data collection, and safety protocols required for the tests.

Task 4: Flight Testing and Analysis

Flight tests were executed monthly for a week at a time with DSU. The data collected during the tests was used by the research team to develop an avoidance model, determine CPAs, and finally develop a simulation to determine risk ratios. Following the flight testing, a flight test summary report was created detailing all flight test efforts. A data analysis report was also developed that was later improved and implemented to the final report.

Task 5: Final Report and Briefing

The research team completed the final report and provided it to the sponsor. There were two peer review sessions prior to the closeout of the project with the research team, project sponsor, and other vested parties.

KEY FINDINGS:

The goal of the A23 project was to understand research that was produced in the past such as the J.W. Andrews study from the 1980's and improve on the research using modern methods to propose a risk ratio set that could help the FAA develop UAS DAA regulations. The A23 effort led 298 crewed fixed-wing vs crewed fixed-wing encounters throughout timeline of the project. Additionally, the team obtained 48 crewed fixed-wing vs rotorcraft encounters during this time. These encounters were key to allowing the team to make quantitative conclusions on a pilot's ability to see other aircraft in the NAS. Of the fixed wing encounters in A23, pilots were only able to visually acquire the intruder aircraft 48% of the time.

Researchers were able to produce the study using modern methods that greatly improved on the accuracy of the data. They used ADS-B units equipped with WAAS GPS that would transmit and receive aircraft location in order to log the flight paths for further analyses. Additionally, researchers used audio recorders to hear exactly when a subject pilot would visually acquire the intruder aircraft and three action cameras to see the conditions of the flight and provide a visual on where the pilot was looking at the time of visual acquisition. A human factors researcher accompanied subject pilots on each flight to record the time

of visual acquisition on a specialized Android application.

The researchers took all the real-world encounter testing data and fed that into a visual acquisition simulation that would calculate the risk ratio based on the scenarios created in flight testing. This model also improved on previous research to include the actual field of view of the high-wing aircraft used in testing to provide a more accurate representation of how much pilots were able to see when sitting in the left seat of the cockpit. The model was run through 4.8 million simulations with various parameters to include pilot delay, turn rate, and avoidance mode. These simulations allowed researchers to produce the following table of risk ratio values, featured in the A23 Final Report, including the parameters. The highlighted values are for 6 and 9 seconds of pilot delay which seems to be an adequate estimation based on the flight-testing experience. During the analysis, it was found that the ASTM risk ratios initially seemed to be adequate when compared to the risk ratios calculated in this effort.

SIMULATION PARAMETER COMBINATIONS AND RISK RATIOS.

Turn Rate (x Standard)	Delay (s)	Risk Ratio, NMAC (Own Only)	Risk Ratio, Well-clear (Own Only)	Risk Ratio, NMAC (Both)	Risk Ratio, Well-clear (Both)
1	0	0.527	0.721	0.508	0.704
1	3	0.603	0.753	0.572	0.735
1	6	0.657	0.784	0.624	0.764
1	9	0.699	0.805	0.663	0.785
1	12	0.727	0.822	0.691	0.800
1	15	0.752	0.837	0.717	0.818
1.5	0	0.459	0.667	0.434	0.650
1.5	3	0.555	0.716	0.533	0.700
1.5	6	0.620	0.750	0.584	0.733
1.5	9	0.664	0.776	0.637	0.764
1.5	12	0.703	0.799	0.676	0.786
1.5	15	0.733	0.816	0.695	0.802
2	0	0.405	0.630	0.388	0.614
2	3	0.510	0.683	0.488	0.667
2	6	0.590	0.728	0.567	0.711
2	9	0.648	0.762	0.617	0.742
2	12	0.688	0.785	0.654	0.767
2	15	0.718	0.806	0.685	0.789
3	0	0.321	0.563	0.308	0.551
3	3	0.458	0.637	0.439	0.626
3	6	0.555	0.693	0.524	0.676
3	9	0.615	0.732	0.591	0.718
3	12	0.667	0.768	0.633	0.749
3	15	0.698	0.791	0.668	0.773

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UAS SAFETY CASE DEVELOPMENT, PROCESS IMPROVEMENT, AND DATA COLLECTION

UND UNIVERSITY OF NORTH DAKOTA · VIRGINIA TECH · NM STATE UNIVERSITY · UAF UNIVERSITY OF ALASKA FAIRBANKS · KANSAS STATE UNIVERSITY · MISSISSIPPI STATE UNIVERSITY · THE OHIO STATE UNIVERSITY

LEAD UNIVERSITY : THE UNIVERSITY OF NORTH DAKOTA

A11L.UAS.50_A24

BACKGROUND:

In the 2016 FAA Extension, Section 2211 mandates the FAA to establish a UAS research and development roadmap, including estimates, schedules, and benchmarks for UAS integration. This roadmap, the UAS Integration Research Plan, is updated on an annual basis to determine the most up-to-date research needs, research projects underway, and research planned to reach FAA UAS integration milestones. In support of this need and to enable more rapid production of safety cases, the team developed an enhanced data collection framework and safety analysis tools. This will inform the UAS Integration Research Plan by enabling users to cross-check needs for UAS data/research with test data stored in the system as well as enabling analysis to determine if the data meets needs and whether additional data/testing would be required.

This research relates to the development of the technical data requirements, test methods, risk assessments, safety risk management processes, data collection, and administrative processes/reporting used to inform safety cases in support of the UAS integration regulatory framework. Analyses of associated data will inform development of regulatory products (i.e., rules, standards, policy, etc.) needed to reach UAS integration milestones. Finally, it will facilitate querying and reporting of data in a consistent format.

APPROACH:

Task 1: Initial Build of the Test Data Collection and Analysis System (TDCAS)

- Front End Data Collection System
- Development of Initial TDCAS Analysis System

Task 2: Exercise System Using Advanced Operations

Test the system using data from previously-developed safety cases and tests.

Task 3: Develop Linkage to Industry Consensus Standards, Operations Over People (OOP) Notice of Proposed Rulemaking (NPRM), Other Rulemaking, and FAA Safety Management System (SMS) Risk Management Guidance

Determine how the system can be utilized to support develop of industry standards, rulemaking, and FAA SMS risk management guidance.

Task 4: Validation of TDCAS

Use an actual safety case to validate the TDCAS.

KEY FINDINGS:

The need for the TDCAS is significant. An FAA analysis of safety case deficiencies illustrated that many applicants do not understand what comprises an effective safety case. The TDCAS helps alleviate this issue by providing a framework that outlines the elements of an effective safety case. In addition, standardization of safety case structure will accelerate integration of UAS into the NAS by providing structure for both the applicant and the evaluator.

Numerous challenges exist regarding data collection. One involves provision of quantifiable data. Depending upon the format/structure used to provide data, analysis of those data can be challenging. Thus, the TDCAS has been designed to enable provision of quantifiable data that can be utilized in multiple types of analysis. In addition, a tension exists between the applicant and the evaluator in that the evaluator desires as much information as possible while the applicant desires the input process to be as easy as possible. Thus, design of the TDCAS has focused on test data elements that are needed for evaluation and the team has avoided overly burdening the applicant.

Another challenge is data ambiguity in which different users may provide the same information multiple ways (e.g., using two different names for the same aircraft). Such ambiguities present challenges at the analysis stage. When possible, the team has developed lists for data elements to ensure consistency. This is not a panacea, however, as the relatively low technology readiness level for some types of systems preclude use of lists for some data elements.
The developed system can accelerate integration of UAS into the NAS by streamlining the safety case process for both the applicant and the reviewer. In addition, this system enables cross-cutting analyses that utilize data from multiple applicants/projects. Such cross-cutting analyses, which at times can create a tension relative to the safety case objective, enable evaluations of research progress, needs, and system performance that cannot otherwise be easily completed.

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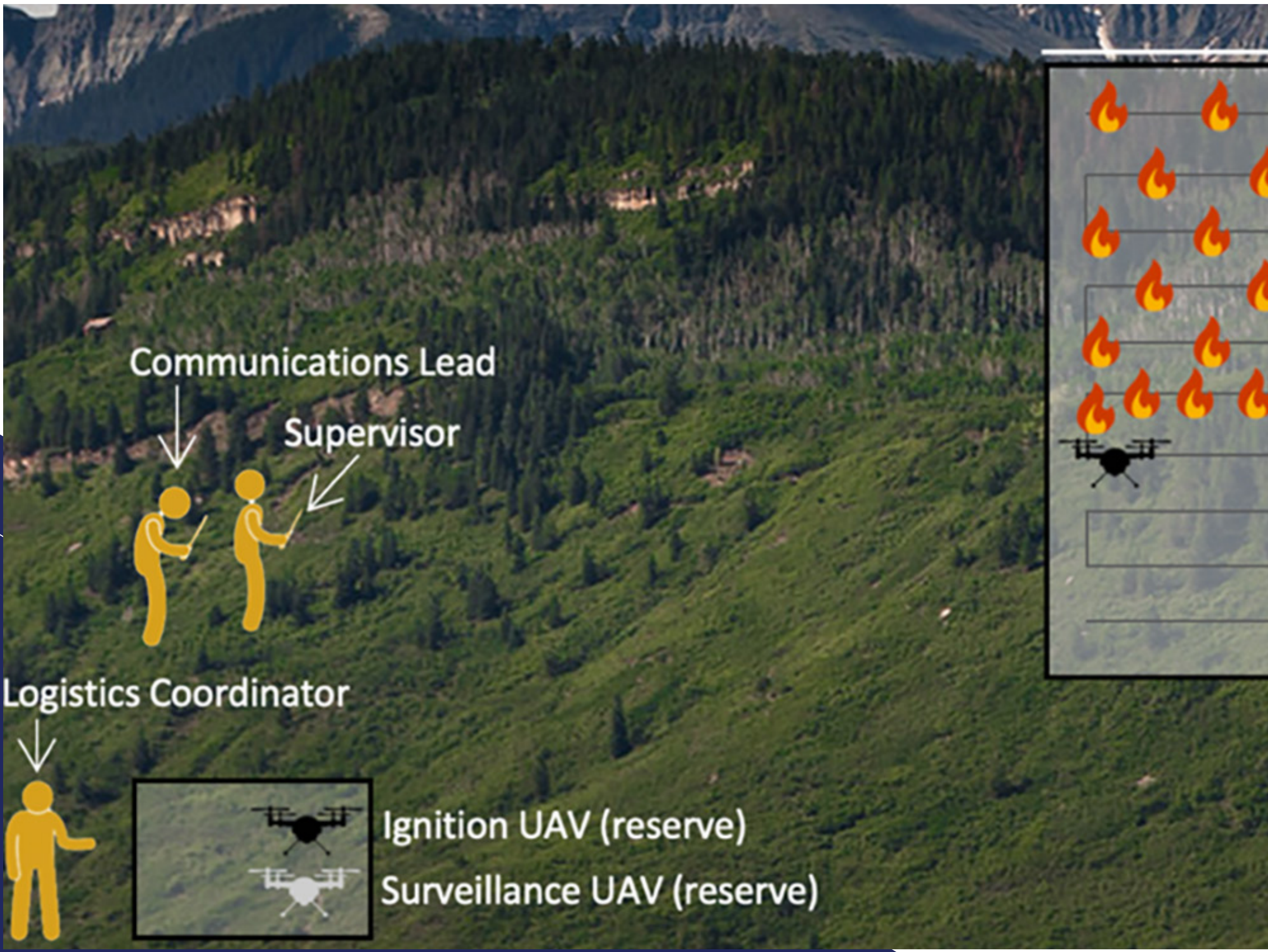
ESTABLISH PILOT PROFICIENCY REQUIREMENTS - MULTI-UAS COMPONENTS

LEAD UNIVERSITY : OREGON STATE UNIVERSITY

A11L.UAS.74_A26

BACKGROUND:

Several organizations have identified human factors issues unique to UAS, including the US Air Force Accident Investigation Board, the National Transportation Safety Board, the US Department of Transportation, National Aeronautics and Space Administration, RTCA Special Committee (SC)-228, and others. This research addresses gaps in knowledge that are currently a barrier to the safe, efficient, and timely integration of systems composed of multiple UAS into the national airspace, namely operation of multiple aircraft by a single pilot.



This research helps inform FAA regulations and industry standards addressing single pilot and multiple UAS operations. This research intends to:

- Identify human factors differences, limitations and use cases for operating multiple UAS.
- Identify available control systems, capabilities, limitations, and maturity levels.
- Determine and model predicted human factors limitations.

APPROACH:

The project includes a peer review of the research task plan and a review of the final report at the conclusion of the project.

Tasks 1 and 2: Literature Review and Gap Analysis

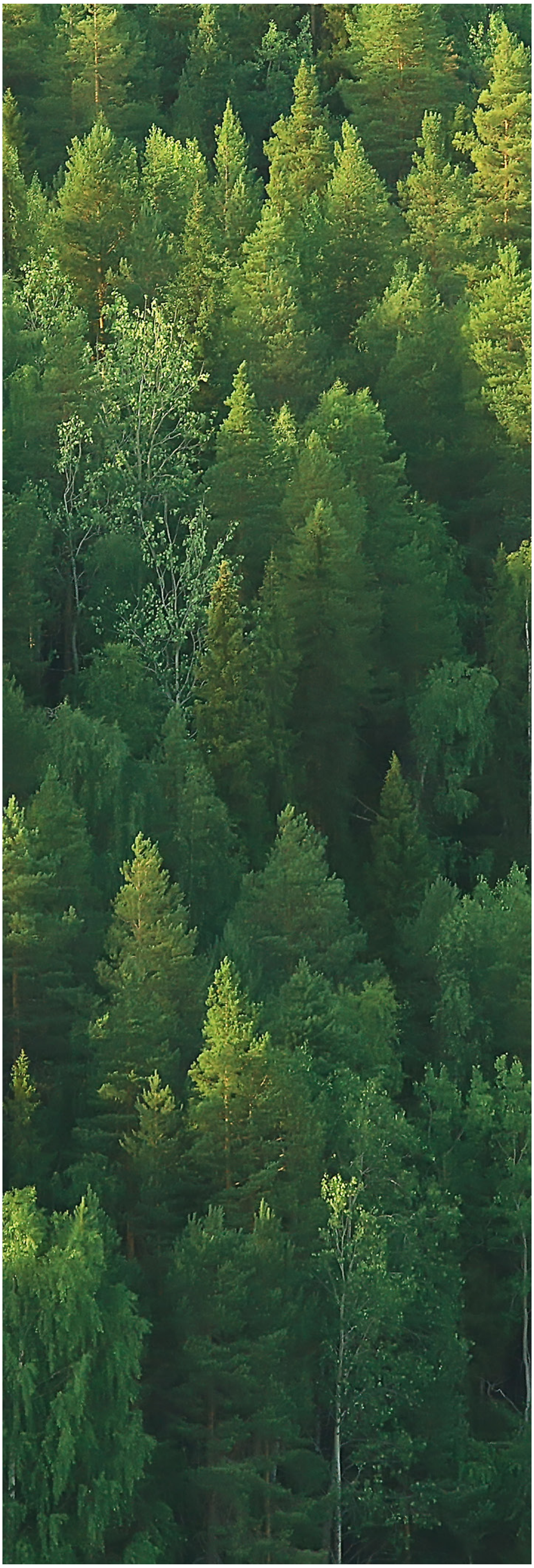
The team's literature review report:

- Identified the relevant literature, that encompassed 205 manuscripts,
- Developed a taxonomy to use to categorize the literature,
- Categorized the literature findings, and
- Identified research gaps.

Task 3: Assess Human Factors Limitations

This task identified the human factors limitations to monitoring multiple UAS, including potential hazards, mitigations, and controls for the mitigations, generates potential operational scenarios (use cases), a task analysis, and metrics. This task also generated a taxonomy of open problems. This task's report captures the human factors limitations when monitoring multiple UAS. The researchers:

- Identified potential human factors limitations, including potential hazards, mitigations, and controls.
- Developed relevant operation scenarios and a task analysis that consider prior aircraft procedures. The operational loosely coupled domain (e.g., delivery) scenario included the nominal use case, thirty-four unexpected events, and ten distraction events. The tightly coupled domain (e.g., wildland fire ridgeline aerial ignition) scenarios included a nominal use case, and identified sixteen unexpected events as well as seven distraction events.
- Reviewed the existing aptitude measurements and developed a taxonomy that informs gaps for single pilot multiple UAS deployments.



Task 4: Assess Required Aptitude

This task focused on developing computational user models that provide a predictive analysis of the human factors considerations for human Supervisors responsible for monitoring and controlling multiple UAS systems. The results from Tasks 1 and 3 were used, specifically, the task analysis and use cases directly informed the development of the computational user models. The computational models focused on the predominant human factors and training results developed during Tasks 1 and 3, but varied environmental conditions, mission duration, and number of vehicles. The researchers:

- Identified IMPRINT Pro (Archer et. al, 2005) as the modeling tool being used for developing the computation models.
- Developed a model of workload to be incorporated into the IMRPINT Pro models.
- Developed the computational models, including their ability to provide a predictive analysis of human factors limitations.
- Loosely Coupled: Nominal use case, three distraction (i.e., command and control link loss, emergency in the airspace, and mid-air collision) use cases and two distraction (i.e., fatigue and mindwandering) use cases.
- Tightly Coupled: Nominal use case and the fatigue distraction.

KEY FINDINGS:

The team identified sixty-three key findings/gaps across the primary tasks. A list of all key findings and gaps can be found in this effort's final report.

The team's literature review's primary key findings/gaps are:

- **Flight Phases:** It is well known in the aviation industry that takeoff and landing are the two most dangerous phases of flight. This literature review highlighted that very little research has focused on these flight phases, and the research has focused primarily on cruise flight. These critical phases, along with preflight, climb, descent, approach, recovery, and post-flight will need to be addressed.

- **Crew Roles:** When developing crew roles, one must consider the M:N UAS ecosystem as a whole, potentially including an entire organization. Factors to consider include (1) there may be one supervisor in charge (e.g., a traditional pilot in control), or an entire crew organization, (2) how many humans are considered a part of a specific crew, and (3) what new roles need to be defined or introduced.
- **Training:** More focus is needed to define required training. Since the systems are becoming more automated, there is less need for months or weeks of training. Previous work looked at training considerations for CFR Part 107.205 remote pilots verses UAS degree programs. The future of UAS autonomy forces the ASSURE team to look closer at everyday citizens any of the M crew roles and what that training needs to encompass.
- **Systems Requirements:** There is little research considering the type of system, which is broken down into two distinct groups, a single UAS or a multiple UAS structure. Factors that must be further investigated within the context of both definitions include, the maneuverability, weather, and system composition. The system composition can be further decomposed into how the system responds to communication link loss, transitions through airspace, and overall mission location (e.g., restricted airspace, or no fly zones).
- **Autonomy:** Although this gap falls under the system requirements gap, it drives the level of impact for most of the other gaps. The levels of autonomy will determine how many humans are needed, what training those humans will require, and what other system composition requirements will be necessary for safe flight.

The team's analysis of the human factors limitations identified eleven key findings/gaps. The primary finds/gaps are:

- **Use Cases:** The input from the subject matter experts may be very unique compared to what may be collected from those using other multiple UAV logistics models. As such, for the Loosely Coupled task, the developed use case is a notional use case that does not represent any specific company's UAV logistics model. Similarly, for the Tightly Coupled scenario, the developed use case is an abstracted exemplar with respect to ridgeline aerial ignition and the use of surveillance and ignition UAVs. A gap is the lack of validated use cases for a wider range of Loosely and Tightly Coupled tasks across domains for multiple UAV systems.
- **Unexpected Event Frequency:** There are no data about how frequently the unscheduled events may occur in practice. There is a gap in understanding the necessary levels of training and expertise required for addressing the unscheduled tasks when supervising multiple UAVs.
- **Multitasking Metrics:** Validated measures of multitasking for multiple UAV operations are not available. Thus, a gap is that there is no single aptitude or single validated measure that can capture all the human performance limitations related to

multitasking with respect to supervising multiple UAVs.

- **Team Roles:** Teamwork may be an important skill for supervisors and other roles. There is limited research on what type of coordination abilities may be important. Thus, a gap is determining the exact role for the human supervisor for delegation.

The team's modeling of the loosely coupled (i.e., delivery done) and tightly coupled (i.e., ridgeline ignition) tasks resulted in forty-six key findings/gaps, many of which are specific to the use case. The primary findings/gaps are:

- **Scalability:** Assuming highly autonomous UAS, that are capable of responding appropriately to unexpected events, does permit a single human supervisor to manage a larger number at lower overall workload levels.
- **Lack of Representative Models:** The common human factors modeling tools do not incorporate human performance models that account for the supervisor's performance when monitoring more than one or a few UAS. The Task 1 literature review also found that no reasonable models existed. The team conducted an additional investigation into the human-robot interaction research, human visual perception literature, and the human visual scanning literature, but was unable to identify any applicable models for human performance, specifically workload that are based on real systems (i.e., not simulated systems) and objective human factors results. A primary gap is the existence of representative models for the focus domains.
- **Model Fidelity:** The developed models are quite complex, but are unable to model the true complexity of the representative systems. Achieving a 100% match to the deployed systems is impractical; however, increasing the model complexity can provide additional insights. Further, the models can guide the design of human-in-the-loop evaluations by removing independent variables that had no impact on supervisor performance.

Limitations related to the UAS, autonomy, and the use case are:

- UAS characteristics, including heterogeneity of the fleet used in a mission, are rarely addressed.
- Levels of autonomy will determine staffing, training and related needs.
- Deployment domains will have different requirements that impact the supervisor's capabilities, tasks, and training.
- Most research addresses the cruise flight phase. Phases of flight, such as ramp up and ramp down, and parameters such as wave size are not addressed in the literature.

Limitations related to the analysis of multiple UAS supervision include:

- Modeling tools do not address all aspects of the supervisor's performance when monitoring multiple UAVs, including task switching.

- An analysis of supervisor workload needs to focus on all components of workload: cognitive, visual, speech, auditory, fine grained, and tactile.
- Validated objective data for workload associated with tasks are not readily available.

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ESTABLISH RISK-BASED THRESHOLDS FOR APPROVALS NEEDED TO CERTIFY UAS FOR SAFE OPERATION

LEAD UNIVERSITY : KANSAS STATE UNIVERSITY

A11L.UAS.71_A27

BACKGROUND:

ASSURE A27 examined the role of remote pilot training as a risk mitigation for UAS flights BVLOS and operations over people. The project also exercised the FAA's Durability and Reliability (D&R) Type Certification (TC) process. This enabled an examination of a new TC process, and it offered an opportunity to translate findings into an industry consensus standard.

The initial review explored existing literature regarding current regulations for UAS; 14 Code of Federal Regulations (CFR) Part 107, pilot certification standards from 14 CFR Part

61, airworthiness standards, and applicable industry consensus standards. This allowed the research team to identify differences between approaches to pilot training for conventionally piloted aircraft and UAS. It also shed light on concepts regarding the management of operational risk, offering an exploration of concepts surrounding airworthiness and pilot training as risk mitigation factors. The literature review enabled the research team to develop a conceptual approach to identifying recommended UAS remote pilot training for BVLOS flight and operations over people. It also provided insight into existing pathways for UAS airworthiness and type certification.

Following the literature review, the research team pursued a deeper exploration of remote pilot training, referencing existing industry standards, recommendations from international industry groups, and guidance from the FAA's Airman Certification Standards (ACS). This enabled the research team to develop a series of recommendations aimed at addressing additional risks and operational requirements associated with BVLOS and operations over people. The resulting eleven recommendations reflect a potential area for remote pilot training requirements to grow to suit UAS operations beyond those normally conducted under 14 CFR Part 107.

Additionally, this research exercised the FAA's D&R TC process. The research team followed multiple applicants through the process for 23 months. During this time, the research team documented applicants' successes and challenges, and tracked procedural elements of D&R for the sake of providing guidance. The research team arrived at eleven recommendations for process improvement for D&R.

APPROACH:

The research team explored various risk assessment methodologies to include a comparison of FAA safety management system concepts and the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) Specific Operation Risk Assessment. The exploration of risk in these assessment methodologies provided an opportunity to perform a comparison while assessing their usefulness regarding pilot training and sUAS flight operations. This approach contributed to remote pilot training recommendations for Task 3 – Operational

Training, while providing points of comparison for regulatory requirements within 14 CFR Part 107. Key findings of this element of the literature review were differences in scope between risk assessment methodologies when applied to sUAS flight operations of given operational complexities. As operational complexity increases, the scope of a given approach to risk assessment must increase as well.

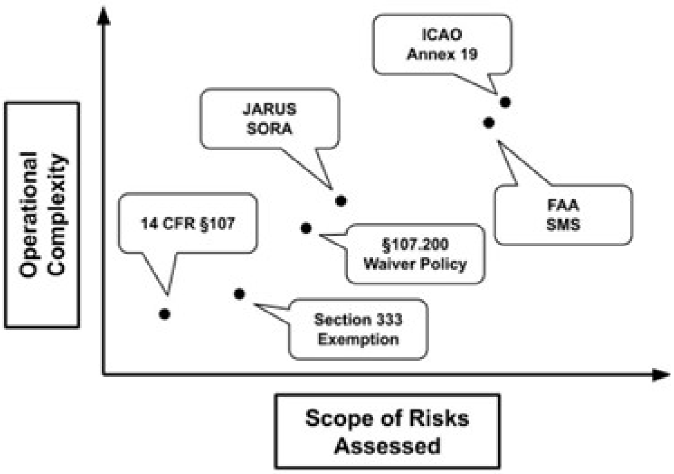

Figure 1. Operational Risk and Scope of Risks Assessed.

An additional component of this research was an overview of the concepts and approaches to aircraft airworthiness and type certification. While the approach depicted in 14 CFR §21.17(a) has proven sufficient for conventional piloted aircraft, there are disconnects when applying this methodology to sUAS, as they cannot rely on the same robust regulatory framework to address all elements of risk inherent to their design. A different approach for sUAS airworthiness and type certification using 14 CFR §21.17(b) offers an avenue for flexibility (See Figure 2). As a component of 21.17 (B), the research team highlighted an observational approach to analyze the FAA's D&R TC process for low-risk UAS.

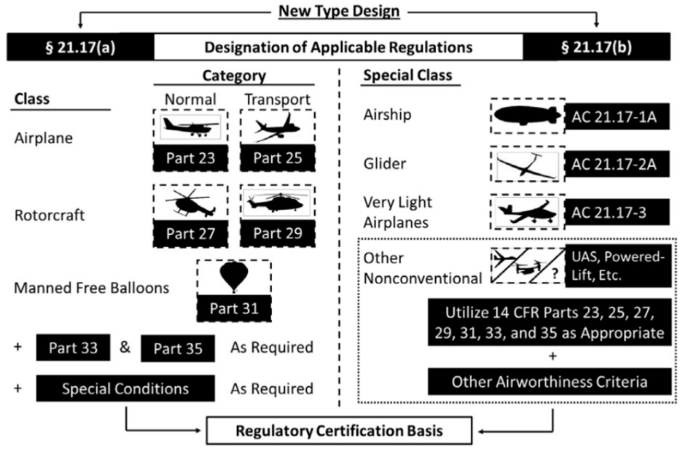

Figure 2. Model of the Type Certification Process.

The D&R TC process is not open to all UAS. OEMs meeting specified criteria may use the D&R process as a Means of Compliance (MoC). The D&R airworthiness and TC process is a novel means of demonstrating airworthiness for UAS deemed to be "low risk" according to the FAA. This process relies on demonstrations of overall system reliability, capacity to respond to likely failures, and meeting certain baseline design criteria rather than emphasizing costly and time-consuming testing that is normally associated with larger type certification programs. Per the D&R MoC, a UAS must meet a series of criteria for D&R to apply. The criteria specified in the MoC narrow the scope of D&R to apply to UAS that have characteristics that lend themselves to presenting a low risk to the airspace and ground environment.

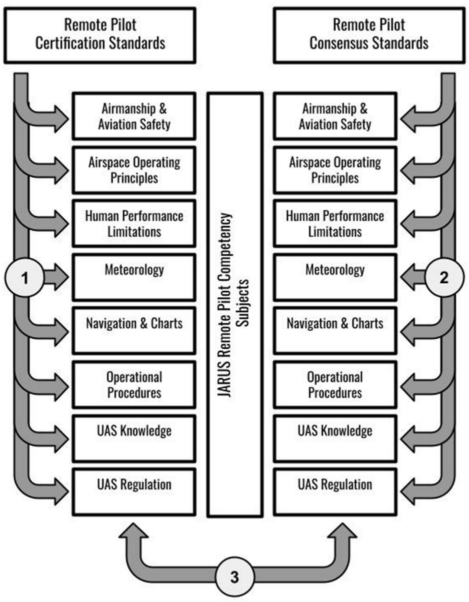

Figure 3. Remote Pilot Training Methodology Flow Chart.

Additionally, the research team reviewed the FAA Remote Pilot Airman Certification Standards (ACS) for remote pilot knowledge, skill, and abilities. This provided a baseline for remote pilot knowledge as well as a point of comparison for any additional areas that may exceed the accepted baseline, such as BVLOS and/or operations over people. For comparison, the research team consulted the JARUS Recommendation for Remote Pilot Competency (RPC) for UAS Operations in Category A (Open) and Category B (Specific) and F3266-18 Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement. These documents offered different perspectives regarding remote pilot knowledge, skills, and abilities from independent sources that addressed both industry consensus and international perspectives. More importantly, these documents provided differing perspectives to the existing remote pilot ACS and offered points of comparison. Upon further review of the JARUS Recommendation for Remote Pilot Competency, the research team found it provided a means to organize individual elements. It prescribed requirements for knowledge, skills, or practical ability, and facilitated easy comparisons. Using this concept, the research team devised a process to sort and compare individual elements within remote pilot training documents using a matrix. Figure 3 outlines the research team's approach.

KEY FINDINGS:

ASSURE A27 explored requirements for pilot training for expanded operations, the development of standards for UAS type certification under the FAA's D&R process, and the application of the D&R type certification process itself. As a result of this work, the research team:

Identified additional training areas for remote pilots for BVLOS and operations over people:
The following recommendations for operations over people stemmed from the analysis of the FAA Part 107 Remote Pilot ACS, ASTM F3266-18, and findings from the literature review. Recent rulemaking from the FAA regarding operations over people favors aircraft certification standards and operational limitations without additional requirements for remote pilots. Furthermore, the FAA's formal position on requirements for additional training for such operations is, "… a practical test for the issuance of a Part 107 remote pilot certificate, and testing requirements similar to those for Part 61 commercial pilot certificates, are not necessary" (Operation of Small Unmanned Aircraft Systems Over People (Final Rule), 2021, p. 4360). However, the following recommendations consider the fact that existing regulations are still subject to waiver. These recommendations still offer a potential means for risk mitigation for operations over human beings and are a star-

ting point for offering elements of an alternate means of compliance with existing regulations.

a. The applicant demonstrates an understanding of: authorizations issued under the Low Altitude Authorization and Notification Capability (LAANC), and the manual process to apply for an authorization with the Airspace Authorization Request Form.
b. The applicant demonstrates the ability to: identify controlled airspace at or below 400 feet and request access using the LAANC when available.
c. The applicant demonstrates the ability to: apply safety practices such as mission, crew, and safety briefings.
d. The applicant demonstrates the ability to identify, assess and mitigate risks, to encompass operational risk assessments, site surveys, and mission planning.
e. The applicant demonstrates the ability to: plan and execute basic maneuvers (e.g., flight, ground reference, and loss of control recovery) to demonstrate mastery of the unmanned aircraft.

Offered recommendations for process improvement for the FAA regarding D&R:

Recommendation 1: *Develop a D&R Advisory Circular (AC).* An AC would provide an excellent starting point for applicants to become informed on the D&R TC process prior to contacting the FAA. While Order 8110.4C offers an excellent overview of the TC process, there are significant differences between D&R and processes for conventionally piloted aircraft. Additional guidance could be of great assistance to applicants. This is especially true of applicants who may not have a great deal of experience in aviation.

Recommendation 2: *Promote early engagement with TC applicants. From the research team's observations, there is no FAA engagement with an applicant* prior to the FAA's acceptance of the applicant's formal TC application. At this stage, early engagement with applicants may help to mitigate challenges further in the TC process. This is especially true since applicants may not have as much of a background in aviation or aviation concepts as typical applicants for a more conventional TC process.

Recommendation 3: *Make the D&R MoC publicly available.* Similar to publishing an AC, making the D&R MoC publicly available would be helpful to applicants and the FAA. This would allow applicants to study the process prior to engaging with the FAA, understand how to lay out demonstration plans, and come into the process better prepared. This, in turn, could assist the FAA with allocating resources more effectively, as it would mean that applicants could exercise increased autonomy due to having a better knowledge of the process from the start. Similarly, applicants with an increased knowledge of the process and familiarity with expectations could be more adept at navigating the TC process and require less direct FAA oversight.

Recommendation 4: *Provide a straightforward means of entry into the D&R TC process – e.g., an entry portal.* Providing a simplified means of entry into the D&R TC process would benefit applicants and the FAA. A means of entry, such as a web portal, could serve as a single point of access to promote early engagement between applicants and the FAA while simultaneously providing a place to present vital information and process documentation.

Recommendation 5: *Continue to Adapt/Adopt industry standards, and/or revise existing industry guidance to address policy and knowledge gap.* Throughout this study, the research team noted that applicants faced challenges when generating documentation such as maintenance manuals, Instructions for Continued Airworthiness, and other documents. This was due to specific requirements for such documents being unclear. Guidance regarding content, style, and baseline information would aid applicants here. The FAA provided example documents as guidance, but those documents were often representative of conventional crewed aircraft, and they did not represent the ideal level of detail and rigor sufficient for D&R.

Recommendation 6: *Address incompatibilities with ICAO Annex 8.* During the process, FAA stakeholders noted inconsistencies between the D&R TC requirements and ICAO Annex 8 – Airworthiness of Aircraft. These inconsistencies may disincentivize potential applicants to pursue a TC for a low-risk UAS if they have the intent to export. Addressing any inconsistencies, particularly regarding AE, may eliminate this gap.

Recommendation 7: *Revise estimated timelines for the D&R TC process.* Initial estimates to complete the D&R TC process were approximately 90 days. This timeline was inaccurate according to the research team's observations. The team followed one applicant for a total of 20 months before the applicant eventually withdrew from the process without a TC. Another applicant pursued a TC for 25 months and had still not begun D&R demonstration flights at the time Task 2 had been completed. It is imperative that applicants have a complete understanding of the expectations, requirements, timelines, and deliverables so they may budget time, personnel, and other resources for TC activities before beginning the process. Applicants must be fully aware of the commitment up front.

Recommendation 8: *Develop a status tracking system for key deliverables in the D&R TC process.* One of the more noteworthy challenges throughout the D&R TC process was tracking deliverables and determining their status after applicant submission. This was problematic for the applicant and the FAA alike, creating slowdowns when reviewing UFMs, technical drawings, and other deliverables. A means to outline exactly where a document will go – e.g., directorates and personnel, as part of the review process will assist in ensuring transparency during document review.

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SAFETY RISKS AND MITIGATIONS FOR UAS OPERATIONS ON AN & AROUND AIRPORTS

LEAD UNIVERSITY : UNIVERSITY OF ALASKA FAIRBANKS

A11L.UAS.72_A31

BACKGROUND:

There are no policies, procedures, or criteria for operating UAS on and around the airport surface while aircraft operations are in progress. Integrating UAS into the airport environment will result in National Airspace System (NAS) changes. The ATO SMS Manual indicates safety analyses are performed in response to NAS changes or existing safety issues.

A recent change incorporated within FAA Order JO 7110.65 states that Air Traffic Control (ATC) services are not provided to any UAS operating

in the NAS at or below 500 ft Above Ground Level (AGL). However, ATC is not prohibited from providing services to civil and public UAS by this change.

As UAS integrate into the NAS, safety analyses should be performed to assess the risks associated with UAS operations on and around the airport surface, ensuring proper risk mitigation strategies are put in place. These safety analyses should address factors such as the integration or segregation of operational areas at airfields, signage and runway markings, communications infrastructure; approved frequencies, facilities for UAS ground control stations, external pilots near runway surfaces, and the variety and varying capabilities of UAS from small UAS through large UAS platforms and how these varied capabilities could impact airport design, function, and emergency response.
The research is intended to address gaps in knowledge that are currently a barrier to the safe, efficient, and timely integration of UAS into the NAS.

This safety and risk analysis focuses on evaluation of UAS operations on and around the airport surface. The research will identify the potential risks with regards to UAS operations near manned aircraft, communication with these UAS operators (if necessary), and Air Traffic services (if not provided). The research may inform potential changes to FAA regulations and industrial standards.

APPROACH:

Task 1:

Identify relevant research and documentation in the areas of UAS performance in and around airports including Urban Air Mobility (UAM) and UAS Traffic Management (UTM) implications.

Task 2:

Propose other potential areas of research beyond what is outlined in the task. Coordinate and prioritize the research to be conducted. Develop a Research Task Plan with potential increased/decreased scoping based on findings. Hold a scoping peer review with the FAA and other parties determined by the FAA to discuss the Research Task Plan and determine the appropriate scope level.

Task 3:

Determine research shortfalls identified from the literature review and develop case studies to address shortfall areas. Case study methods may include, but are not limited to modeling and simulation, and flight tests to address research shortfalls.

Define the overall concept and specific use cases for conducting operations on the airport surface. This includes but is not limited to: UAS airport inspections, perimeter security, Foreign Object Debris (FOD) inspections, runway inspections, emergency response, wake turbulence separation, and large UAS takeoff and recovery. Airspace class (B, C, D, E, G, towered/non-towered) for each use-case must be considered.

The research team and the program sponsor examined the research being conducted by the FAA's William J. Hughes Technical Center and identified three use cases that were non-duplicative with the current FAA-conducted research. The three use cases and leads for each use case are:

1. Large drone operations - UAF and NMSU
2. Landside building inspections - UND
3. Emergency response - KSU

The use cases all include flight operations at local airports. Additionally, the UND team purchased ADS-B data for each airport and is simulating the effects of different hazards on the risk to other aircraft and operations on airport. The team also simulated emergencies to inform the team about the hazards and potential mitigations that needed to be implemented during flights.

Task 4:

Using the FAA's ATO Safety Management System (SMS) process, identify the hazards and mitigations of the use cases. The research team developed a list of hazards and potential mitigations for the various use cases based on available literature and the teams' experiences. Each team developed a safety risk analysis that was used as the basis for the safety case included in each team's submission to DroneZone for flight permissions.

Task 5:

Evaluate at least three use cases by conducting a research team SMS panel using FAA SMS policies.

After discussion with the sponsors, the research team decided to meet the SMS panel review using all of the safety analyses done in support of a pre-existing Certificate of Authorization (COA) received by UAF 2022-

WSA-10342. This documentation includes all of the forms submitted into the FAA's COA Application Processing System (CAPS), previous hazard matrices calculations for the UAF SeaHunter large drone, letters of agreement, memoranda of agreement, the actual COA, and other associated documents. The research team conducted an internal analysis of the documentation provided to the FAA during COA submission and identified two places where the language in the paperwork needed to be clarified. The hazards and potential mitigations identified in the internal walkthrough were consistent with those identified by all team members during their hazards analyses. The COA included operations at Fairbanks International Airport.

Task 6:
Flight Testing – Propose flight testing and analysis with exit criteria for three use cases to validate the proposed mitigations. According to the Request for Proposals, this task can be completed in parallel with other tasks; however, the intent is to test the use cases that have undergone the SMS review in Task 5.

During FY23, the team conducted flight testing at the airports appropriate to each unique, pre-approved use case: UND flew its building inspection missions at Grand Forks International Airport starting in October, 2022; KSU flew its emergency response operation at Salina Regional Airport in December, 2022; and UAF flew its large drone operations at Fairbanks International Airport and Nenana Municipal Airport in August and September, 2023. The UAF team also collected information during a Merlin and FAA University of Alaska UAS Test Site project that pioneered autonomous Cessna Grand Caravan operations between six airports in Interior Alaska in June, 2023.

The UND team coordinated with Grand Forks International Airport and ATC to conduct several building inspection missions starting in October, 2022. The missions occurred safely and the team reviewed and revised their Safety Risk Analysis between flight campaigns to identify any unintended consequences with operation before conducting additional flights.

The KSU team, after months of back and forth with the FAA about what language/ authorizations could be implemented that not only allowed for KSU to conduct an emergency response demonstration with a NOTAM posted but also serve as a template for future airports hoping to conduct real-world operations by Airport Rescue and Firefighting (ARFF) during a call and for training purposes, received approval to fly their emergency response demonstration on November 10th, 2022. The successful demonstration occurred December 7th, 2022.

UAF with NMSU support conducted large UAS operations between Fairbanks International Airport (FAI) and Nenana Municipal Airport (ENN) with the SeaHunter UAS. This mission, with a chase plane, simulated conducting a large drone (299 lbs) cargo flight from a large hub to a smaller airport. This allowed the research team to look at airport operations under two types of airport conditions: one large towered, Class D hub (FAI) and a non-towered, Class G (ENN) airport. After a months-long delay due to runway construction at ENN and personnel unavailability, the flights were able to commence at the beginning of

August (Figure 1). SeaHunter conducted its first successful flight between FAI and ENN on August 2, 2023. The hand-off between Ground Control Stations at FAI and ENN in the middle of the flight went well and the aircraft landed successfully in ENN. The team then was delayed by questions about where the GCS was located at ENN and what permitting was required beyond the approval of the airport manager to be at that location. The questions were resolved through discussion with all levels of FAA. The team successfully completed the FAI-ENN flight on September 7, 2023 and the FAI-ENN-FAI flight September 8, 2023.

Merlin and UAF conducted on-airport operations from Fairbanks International Airport to airports in five other communities (Deadhorse, Ft. Yukon, Galena, Huslia and Tanana - Figure 2) in Alaska in June 2023. Merlin flew a converted, autonomous Cessna Grand Caravan with a safety pilot on board and two software engineers, for 25 flights between Fairbanks and the communities. The autonomous plane landed on both paved and gravel runways at a variety of towered and non-towered airports. This opportunity also provided valuable community engagement.

As intended, the flight testing addressed the similarities and differences between use case hazards and mitigations based on airspace class and towered/nontowered airport operations and the uniqueness of each airport, the communications between UAS operators, ATC, and other airport users/managers during UAS operations on and around the airport surfaces, the ability of the SMS process to identify and mitigate hazards prior to conducting the flight operations, and the effectiveness of the policies and procedures developed by the research team for operating on and around airport surfaces. The lessons learned from the operations will inform the development of policies and procedures for these types of operations.]

KEY FINDINGS:

During the FY23 period the key findings are:

Overall:

The Safety Risk Analyses developed for all three use cases were very similar in the hazards identified and potential mitigation strategies proposed for on-airport operations.

The Safety Risk Analyses procedures utilized by the research team were sufficient to obtain the required flight permissions from the FAA for all of the use cases.

The research team's pre-Safety Risk Management Panel analysis of the materials submitted for the large drone COA identified some areas for language improvement, but otherwise concluded that the materials submitted were sufficient to evaluate the risk of the operation.

Emergency Response Use Case:

Good communications are essential for effective deployment of the UAS during emergency operations. Pre-determined, sequenced language will assist in successful communications during emergency response operations.

Streaming video to other participants in an activity is very helpful in establishing situational awareness.

The main concern from the FAA airspace authorization processer was that for a UAS operation to occur over a movement area, it had to be closed with a NOTAM. Deploying from ARFF to a scene would therefore require a NOTAM. Alert 3's or 4's would close the airport until the determination could be made of what could be opened. AJT reviews all on-airport requests, so hopefully, they would consider an Alert 3/4 in lieu of the NOTAM closure, allowing the UAS to deploy from ARFF.

For an emergency response demonstration/training, what could be beneficial is an authorization that has a special provision with wording such as "Operations allowed only during an Alert 3/4 call, unless a NOTAM is filed at least 24 hours in advance…". This would not only allow us to conduct the demonstration for the project with a NOTAM posted, but also serve as a template for future airports hoping to conduct real-world operations in the future during an emergency call and for emergency training purposes.

Large UAS Cases:

The conditions at the airport will dictate what equipment is required on a UAS operating at the airport during specified weather conditions. Designing aircraft and operations to deal with these challenges will be essential for safe operations on airport surfaces in snowy regions.

- Small tires may not provide enough traction for high-speed taxiing.
- Differential braking is needed to control sliding.

Converted traditional cargo aircraft will have some of these issues handled (tire size, for example), but how the remote pilot or autonomy handles braking (brakes full on vs. differential braking) could create a challenge.

The process for getting all of the approvals required to operate a large drone at an airport is not clear.

An airport's not clearing of the trees in the Runway Safety Area (RSA) or Runway Object Free Area (ROFA) can inhibit drone operations at an airport.

An airport manager giving permission for a ground control station trailer to be located adjacent to a runway is not sufficient to meet FAA recommendations/regulations for that placement.

Ground NOTAMs must be issued in addition to airspace NOTAMs for placing a ground control station at different locations at an airport.

The ground control station is considered construction equipment and requires associated paperwork to be adjacent to a taxiway.

People could not believe the Cessna was the 'drone' that they heard was coming.

The autonomous aircraft learned during the flights and improved over the course of the flight test.

Rocks on a gravel runways present a challenge to autonomous (and traditional) aircraft landing on that runway.

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IDENTIFY WAKE TURBULENCE AND FLUTTER TESTING REQUIREMENTS FOR UAS

LEAD UNIVERSITY : UNIVERSITY OF KANSAS

A11L.UAS.75_A35

BACKGROUND:

The research team worked together to support the FAA effort to establish rules for mitigation of risks due to sUAS upset caused by wake vortex encounters and flutter flight testing of sUAS to establish risks due to sUAS upset due to flutter.

Although the FAA has started the wake turbulence re-categorization, the current regulation put all the aircraft with the maximum takeoff weight (MTOW) less than 15,500 lbs as Category F. New detailed separation rules and guidance to UAS/airport operators are needed to guide safe UAS operations in controlled or uncontrolled airspace including at or around airports, ranging from big passenger UASs (e.g., Kitty Hawk Cora UAS, ~4,000 lbs) to small package delivery UASs (less than 50 lbs).

APPROACH:

The research effort included:

- Literature review in the area of UAS response to wake turbulence.
- Determination of research shortfalls and development of case studies to address shortfall areas.
- Analysis and assessment of representative UAS responses to encountering wake vortices with varying strengths using:
  - Physics-based simulation of wake encounters.
  - sUAS flights through simulated wake velocity fields to validate simulations.
- Likelihood-based assessment of unfavorable UAS responses and a safety analysis considerations for FAA policy, guidance, and procedures for wake turbulence mitigation for UAS.
- Quantitative flight test support for assessing the gust response and flutter margins of existing and future UAS winged vehicles.
  - High-fidelity gust load measurement in wake vortex encounter.
  - Flexible damping to demonstrate new flutter prediction algorithms.
- Simulation of wake encounters and flutter onset for a range of conditions to allow extrapolation of methods to a wider range of UAS, including UAM vehicles.

KEY FINDINGS:

Literature Review/Gaps Analysis

- **Wake Vortex Modelling**

The team identified the existing wake vortex velocity field theories and mathematical models. For the evolution of wakes, NASA's Aircraft Vortex Spacing System (AVOSS) Fast-Time Wake Prediction Models software "suitcase" has been determined to include the most sophisticated theories for wake strength decay as well as wake position over time, considering atmospheric influences such as cross-wind and the natural sinking of a wake. The suitcase consists of stand-alone models that include AVOSS Prediction Algorithm (APA) versions 3.2, and 3.4, which utilize the Sarpkaya Out-of Ground Effect (OGE) decay model. The suitcase also includes the TASS Derived Algorithms for Wake Prediction (TDAWP) version 1.0 and 2.1 that use the APA framework, but OGE decay is derived from theoretical studies with the Terminal Area Simulation System (TASS). This software suite has been provided by NASA and was installed at KU.

For estimating the air velocities within a wake, the Burnham-Hallock model has been adopted. The combination of AVOSS and the Burnham-Hallock model have been trusted by NASA and the FAA to predict the effect of wake encounters for large aircraft to, with adequate safety factors, set separation distances for large aircraft arriving at and departing from airports.

- **UAS Dynamic Characteristics During Wake Encounter and Upset Conditions**

The team found a small number of flight test accounts of the effect of the wake vortex produced by a leading aircraft on a closely-following aircraft or rotorcraft. However, there is only one known prior research effort to predict UAS upset due to a wake encounter. That study, conducted by one of the members of the research team, addressed the effect of a leading sUAS vortex on a closely-following sUAS. However, there was no study found to cover the effect of an evolved wake vortex from a large aircraft on sUAS.

- **UAS upset due to flutter**

The team found that there is a rich history of analysis and test for large aircraft wings. However, there was no prior art found for sUAS, which have dramatically different structural configurations.

Assessment of the Severity of UAS Response to Encountering Wake Vortices.

Multiple mathematical models of UAS flight dynamics have been used to simulate the response of multiple UAS types flying through a simulated wake vortex pair. The air velocity profile for these simulations is derived from the Burnham-Hallock model for a range of circulations (vortex strength) characteristic of the vortices generated by commercial aircraft.

The flight dynamics models used for fixed wing UAS include the vortex lattice method and a number of variations of the "aerodynamic coefficient build-up modelling method." Flights have been simulated through wake vortex pairs at a number of approach paths ranging from along the axis of a vortex to at a right angle to the vortex axis. The simulated air velocity fields are all based on the Burnham-Hallock model. Some simulations are with only an "inner loop" controller (attitude control) while others are with control algorithms with a range of robustness. Flight dynamic simulations for multirotor UAS encountering a wake vortex have also been conducted using a rotor lift-based dynamics model.

Wind machines have been used to simulate air velocity fields which represent a small number of wake vortex encounter geometries. One facility uses a bank of laterally-spaced wind machines providing a steady or linearly-varying cross-wind. Another facility uses a pair of wind machines producing encounter velocities oriented 45 degrees to the horizon, providing a wind field with a vertical component.

Both fixed-wing and multirotor UAS have been flown through the physically-simulated wake vortex encounters created by the wind machines. The flight responses, including some loss of control or near-loss of control events, have been compared with what has been predicted by the simulations of UAS response. For fixed-wing UAS, a study of the effects of controller robustness has been conducted.

A number of candidate metrics to assess UAS loss of control have been studied. For both fixed wing and multirotor, some simple metrics have focused on departures of attitudes and rates of change in attitude. Others consider limits on control authority, much like the leading metric for large aircraft, the oft-cited "roll control ratio". Some effort has also been spent on novel metrics such as noting

departure from expected behavior, as assessed by noting changes in "normal" and "abnormal" correlations between aircraft states, for instance, pitch rate and elevator deflection.

Safety Analysis Considerations for FAA Policy, Guidance, and Procedures for Wake Turbulence Mitigation for UAS.

Wake vortex core strength, dissipation, settling (sinking) and drifting (laterally) has been modelled based on techniques used in the NASA AVOSS software suite. The severity of the environmental risk to UAS wake vortex encounter has been proposed to be based on the definition of envelopes of airspace within which the circulation exceeds a range of prescribed levels based on the vortex modelling. The overall severity of risk of upset is based on defining the circulation strength for which a UAS has been predicted to avoid loss of control. In this way, the volume of airspace through which that UAS can safely fly can be predicted. The prediction of the circulation strength leading to upset may be based on a number of competing simulations with a range of control authority and controller robustness—from a simple attitude hold controller to a trained AI-based controller. Perhaps equally important for the robustness assessments is propulsion capability and, specifically, the extent of available power to recover from upset.

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URBAN AIR MOBILITY: SAFETY STANDARDS, AIRCRAFT CERTIFICATION AND IMPACT ON MARKET FEASIBILITY AND GROWTH POTENTIALS

LEAD UNIVERSITY : WICHITA STATE UNIVERSITY'S NATIONAL INSTITUTE OF AVIATION RESEARCH (NIAR)

A11L.UAS.76_A36

BACKGROUND:

In the FAA Modernization and Reform Act of 2012, Congress tasked the FAA with integrating UAS into the National Airspace System (NAS). To comply with the Congressional mandate, the FAA established a sUAS rule, published within the Code of Federal Regulations as 14 CFR Part 107, allowing sUAS to operate in the NAS. At its core, the present research is "basic and an early-stage applied research" to understand Urban Air Mobility (UAM) operations in the NAS. Designed as a short-term research project, the primary results will likely yield effective and "quantitative metrics" in evaluating UAM (Mulvaney & Kratsios, 2017) as a further

step toward UAS integration into the NAS. Identifying and determining the volume and magnitude of UAM is essential for understanding the safety implications and prioritization of Agency resources together with the timing of allocating these scarce resources. Accordingly, this research is designed to capture the following characteristics of the market potential together with the implications on resources:

- Potential size and growth of the market at the local and/or national level;
- Economic feasibility, including price points at which individual market becomes viable;
- The anticipated cost to enter the market, considering factors such as vehicle acquisition and life cycle, operation liability, maintenance and replacement, and upgrade schedules;
- Customer segments (e.g., regular business commuters, ad hoc travelers, etc.) for UAM viability;
- Characteristics of population density, traffic patterns including congestion, affordability, and preferred locations;
- Competition for UAM transportation or services (e.g., driverless cars and multi-modal transportation options, on-demand ride-hailing services, virtual presence, etc.), providing cost comparisons where applicable;
- Ground infrastructure requirements, legal and management strategies consistent with the envisioned UAM network, and connectivity to other transportation modalities as needed for efficient, "door-to-door" travel and unplanned landing sites.

Furthermore, as part of the 14 CFR Part 107 rulemaking effort, the FAA selected the American Society for Testing and Materials

(ASTM) to establish a set of standards for airworthiness, maintenance, and operation in support of Part 107. Understanding safety requirements for UAM, drawing upon the lessons learned from 14 CFR Part 107, will require identifying barriers for additional demands on the NAS. While some of the existing constraints have been documented (Thipphavong et al., 2018), detailed analyses are presently unavailable, and the implications for UAM emergence and its penetration are unclear. This research addresses some of the fundamental questions about how UAM:

- May impose a demand on additional Air Traffic Control (ATC) infrastructure, including airspace and workload on controllers;
- May require a new paradigm to integrate with UAS Traffic Management (UTM) and/or Advance Traffic Management (ATM);
- May impose a demand on regulatory requirements, including standards for airworthiness, certifications for design, maintenance, and operations for vehicle-level and system-level safety and security;
- Will economically scale to high-demand operations with minimal fixed costs;
- Will support user flexibility and decision-making, including demands emanating from emerging UTM.

This research will identify weaknesses and develop a framework to make the standards more robust and increase the safety of potential UAM operations in the NAS.

APPROACH:

WP 1: Evaluation of UAM Market Potential - Economic Feasibly, Potential Size and Growth, Characteristics of Population, and Ground Infrastructure

UAM is rapidly evolving, providing accelerated mobility for people, goods, and services. Worldwide market projections for various UAM use cases estimate hundreds of billions of dollars in business sales and associated economic activity. Business leaders, policymakers, and public stakeholders all stand to benefit from understanding the economic feasibility of a fully integrated UAM ecosystem.

This research will evaluate the potential market size and growth associated with discrete scenarios of technology and infrastructure

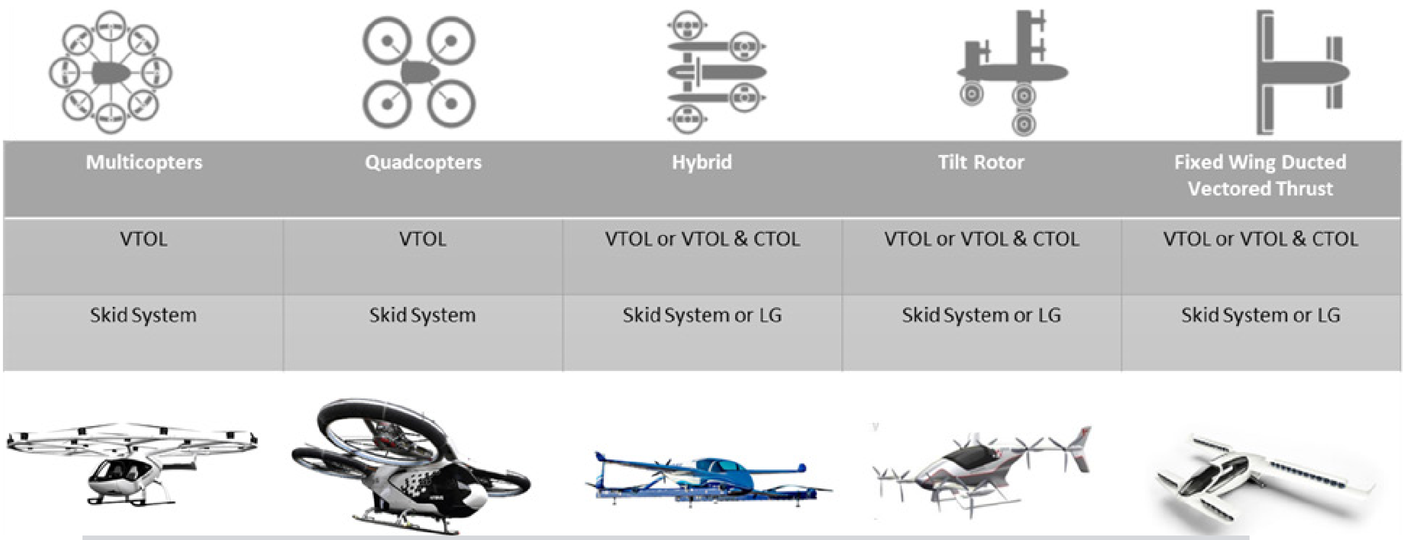

Figure 1. Advanced Air Mobility Architectures

investment. The market analyses will evaluate primary and support businesses in key market segments, including an analysis of existing revenue, projected growth, and changes in demand based on various technology and infrastructure investments. The research team has access to ESRI's Business Analyst dataset, featuring more than 12 million businesses classified by North American Industry Classification System (NAICS) code and geographically referenced to a point location. This dataset will be leveraged to conduct the market analysis and visualize the economic findings.

WP 2: Airworthiness Regulations and their Applicability to UAM Aircraft Certification

Safety is a fundamental condition for UAM activities to be accepted by regulators, users, and the general public. The use of UAM vehicles to transport passengers will strain the certification process since they pose new technical challenges that are not covered with current 14 CFR Part 23 or 27 Type Certification requirements for fixed-wing or rotorcraft. These aircraft have non-conventional architectures, single or distributed electric propulsion, complex battery systems, autonomous flight, noise, etc.

To understand the potential certification differences between conventional and UAM aircraft, a detailed UAM classification was first conducted (See Figure 1). This classification provided information about the different UAM architectures considered, and the specific design characteristics of each aircraft. This data was analyzed to understand trends and document the main differences between UAM architectures. Subsequently, the current established and proposed airworthiness standards and requirements were studied and evaluated. Due to the broad scope of work and the different disciplines involved in the certification of an aircraft. The FAA identified three specific areas with higher priority: Crashworthiness, Battery Crashworthiness, and Noise.

Additionally, due to the novelty of UAM aircraft, poteintial rigor, oversight, and costs to streamline the certification process are a main gap in knowledge. A General Aviation industry organization's past and current cost analysis for certification of similar aircraft attributes was leveraged and implemented in UAM aircraft design and production processes as an attempt to conduct a cost analysis for the certification of a UAM aircraft.

WP 3: Evaluation of UAM integration on the National Aerospace System – Air Traffic Control and Operations

UAM and AAM are two newly introduced concepts to be a new form of transportation within urban and other areas. To enable their integration within the transportation networks of our urban environments, the UAM ecosystem must achieve compatibility with the NAS and other novel ATM environments, such as UTM.

This research seeks to identify the impact of UAM on the NAS with respect to ATC, infrastructure, and operations via the introduction of common terms and definitions, research gaps that exist for successful integration, as well as certain assumptions and limitations that are imposed on this research study.

A Daytona Beach International Airport (KDAB) airspace UAM integration concept was developed to model the airspace environment, including UAM corridors, vertiport locations, vertiport ingress/egress, operational limits (altitudes, velocities, etc.), and Communication, Navigation, and Surveillance (CNS) requirements. The key thought behind this UAM concept was to combine already existing airspace elements with the novel concepts of UAM operations and environment. Simulation scenarios used for the purpose of this study attempted to closely replicate the teams' vision of the airspace environment formed based on the literature review, FAA guidance, and subject matter expertise.

KEY FINDINGS:

The research team has identified the following key findings:

- The top 100 Metropolitan Statistical Areas (MSAs) were ranked and scored, and their output was used in conjunction with a Bass diffusion market penetration modeling framework to estimate how demand within these MSAs evolves from 2022 to 2045.
- During the study period, it is anticipated that approximately 30 metropolitan statistical areas will become domestic UAM or RAM markets with VTOL missions. In the year 2045, it is estimated that 85.4 million advanced passenger mobility trips will be made (a cumulative total of 525.3 million trips from 2022-2045). This equates to $72.5 billion in cumulative revenue over that time period.
- The UAM market has come with several regulatory challenges since (at the time of the release of this research).
  - The main recommendations for the amendment of crashworthiness regulations are for the FAA to provide a concrete definition of emergency landing conditions for UAM operations and the inclusion of mechanical abuse tests for batteries in the regulatory framework for UAM vehicles.
  - Several limitations were identified in the current set of noise regulations, i.e., 14 CFR Part 36, in their applicability to UAM vehicles. Some high-level recommendations to amend Part 36 were provided, with the major ones being accommodation of different UAM architectures, lowering of flightpath altitude, and expanding the definition of "worst-case" conditions for UAM vehicles.
- The UAM and UAS markets come with several infrastructure challenges.
  - A substantial amount of infrastructure must be built and installed to enable UAM operations, in addition to the required aircraft, procedures, and airspace planning.
  - Vertiport: Multi-modal interfaces are critical infrastructure for UAM.
- Operational and procedural requirements must leverage previous work to enable UTM integration into the NAS UAM system.
- With increased air traffic, Providers of Service for UAM (PSUs) must coordinate traffic within the PSU network and plan flight operations while considering urban airspace congestion, the location of nearby airspaces, weather restrictions, ATC coordination, and enabling greater use of automation.

- Studies pointed out that combining UAM aircraft with conventional aircraft in the same airspace is more effective than separating them. A long-term solution is anticipated to combine all operations into a single conjoint system.

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VALIDATION OF ASTM REMOTE IDENTIFICATION STANDARDS

MISSISSIPPI STATE UNIVERSITY

LEAD UNIVERSITY : MISSISSIPPI STATE UNIVERSITY

A11L.UAS.55_A40

BACKGROUND:

The use of UAS has increased considerably over recent years, leading to an influx of recreational and commercial drones in low-altitude airspace. The safety and security of the National Airspace System (NAS) is paramount to the FAA and is at the forefront of considerations for integrating UAS into the NAS. The FAA's effort to increase the safety of the NAS while working to integrate uncrewed aircraft systems has included the implementation of a Remote Identification (RID) rule for UAS users and manufacturers. This technology works by enabling UAS to self-disclose pertinent information regarding its operation for the awareness of other users in the surrounding area. The American Society for Testing and Materials (ASTM) International has developed a standard for RID performance clarifying the means of compliance for UAS

in relation to the FAA's RID rule. This project focused on analyzing the performance of various RID systems in different test settings to develop a baseline of RID behavior in relation to UAS operations. The performance data acquired throughout the A40 project can be used in conjunction with the ASTM RID performance standards to gain an idea of the capabilities of existing commercial off-the-shelf RID products. Understanding the capabilities of RID systems ultimately helps to inform their role in maintaining and improving the safety and security of the NAS as UAS integration continues to progress.

APPROACH:

Remote ID broadcast equipment was evaluated for range, reliability, accuracy, and other performance metrics. These tests were performed at

the ASTM minimum for Wi-Fi NAN, Wi-Fi Beacon, BT4, and BT5.

Task 1: Program Management

The research team coordinated with the FAA throughout the project. Technical Interchange Meetings were held monthly during the period of performance, along with providing quarterly and annual reports.

Task 2: Literature Review

The team conducted a literature review of the FAA Notice of Proposed Rulemaking for UAS Remote Identification/RID Rule, the ASTM Remote Identification standard, academic/industry sources, publicly available information online, and other available sources. The literature review identified and documented RID stakeholders and their associated needs from RID broadcasts and also identified potential expanded uses of RID-Broadcast technologies and their stakeholders not listed in the NPRM/RID Rule.

Task 3: Simulation, Demonstration, and Analysis Plan

The Simulation, Demonstration, and Analysis Plan was developed to provide an overview of the different types of tests in the research, as well as how they were planned to be executed and what data the team hoped to gather. Flight test plans were also developed in this task that had more in-depth information on the tests described in the deliverable.

Task 4: Simulation, Demonstration, and Analysis Plan Execution

The research team executed the plan created in Task 3.

Task 5: Final Report Package and Briefing

The performers summarized and aggregated the plans, results and reports executed during this task into a final report for the overall effort. Conclusions and findings were mapped to project objectives and clear identification and explanations provided when research objectives were not satisfied by the activities undertaken.

KEY FINDINGS:

The team completed a multitude of tests within the past year using three different remote ID systems. Range tests were conducted with the Parrot ANAFI (WiFi Beacon), Dronetag Mini Production Model (Bluetooth), and Aerobits idME (Bluetooth). The Dronetag Bluetooth module underwent a series of range tests to explore the difference in performance when an external antenna is added to the module. Additionally, the Dronetag Bluetooth module was tested at lower horizontal ranges. These tests were performed at the minimum rate and power level provided in the ASTM RID standard. Analysis of these results show range limitations of the WiFi systems when compared to the performance of the Bluetooth systems. There were also noticeable trends in the decrease of the number of messages received as ranges near 1000m. Researchers have repeatably seen a decrease around 700m when using the external Bluetooth module.

A directionality test was performed on the Dronetag module to determine the impact, if any, orientation may have on the reception rate. The Dronetag module was placed on an sUAS and oriented at true North, South, East, and West, and changed in increments of nine degrees between each cardinal direction.

A range test in an altered Radio Frequency (RF) environment was recently conducted to determine the impact the RF noise floor may have on a Bluetooth RID system. For this test, data was collected at three different distances over a period of time in which it was predicted that the RF environment would degrade.

The final test accomplished under this effort was a series of encounters between a manned aircraft and a sUAS equipped RID. This test was broken down into two separate tests. The first was a series of "ground encounters" where a manned aircraft with an RID receiver was stationary on the ground while the drone flew a series of paths above the aircraft. The second test was a series of "air encounters" in which the drone hovered at 400 feet above ground level while an aircraft flew a series of paths above it at an altitude of 1000 feet. This test was conducted with both the Bluetooth and WiFi Beacon systems. Performance was severely degraded for all devices in both of these tests. However, the Bluetooth systems were able to receive a small number of messages in the first test on the ground. The Wi-Fi system did not receive anything during the tests.

Overall, the data gathered shows that, at the minimum, RID systems will work within 1 km reliably for ground users. Beyond this, future research will need to examine performance at higher levels if RID is to be used in future technologies.

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INVESTIGATE AND IDENTIFY THE KEY DIFFERENCES BETWEEN COMMERCIAL AIR CARRIER OPERATIONS AND UNMANNED TRANSPORT OPERATIONS

LEAD UNIVERSITY : KANSAS STATE UNIVERSITY

A11L.UAS.83_A41

BACKGROUND:

It is anticipated that Urban Air Mobility (UAM) or autonomous UAS will be larger than 55 pounds. Recent analysis by NASA indicates that UAS carrying up to six passengers may require a payload of 1200 pounds. According to FAA rules, UAS weighing 55 pounds or greater must be registered using the existing aircraft registration process. Larger UAS are presently flown within the NAS by federal agencies, including the Departments of Defense (DoD), Homeland Security (DHS), Interior (DOI), Energy (DOE), Agriculture, NASA, some state and local

governments, and academia. While some of these departments require certificates of authorization (COAs) lasting two years, others have their own self-certification for authorizations, e.g., DoD and Customs and Border Patrol (CBP). While defense and civilian agencies are already using large UAS in the NAS, it is anticipated that these UAS may also be used for commercial purposes in the near future. One of these commercial uses could potentially be transportation of cargo and passengers. Continued safe integration of UAS is essential, and the FAA is taking a proactive approach in understanding trends, identifying potential markets, and forecasting the integrations of large UAS in the NAS. These forecasts are used throughout the Agency for safety and investment analysis along with workload planning.

Recent experiments of UAM, combined with the fact that large UAS are indeed flown in the NAS today, lead to the anticipation that large UAS will be used to facilitate air transportation in the future. New and additional procedures, airspace rules, and equipment standards, including their performances and reliability, will need to be developed and/or modified to accommodate safe integration of UAS in the NAS.

For the FAA to be prepared for this eventual transformation and integration needs, it will be essential to:

- Understand key differences with existing commercial air carrier and charter operators and likely trends in large UAS, particularly with a focus to understand its role in transporting passengers, both scheduled and unscheduled routine operations in short haul (UAM) and longer haul (autonomous UAS);
- Forecast larger UAS requiring analysis of market viability, adoption rates, technology, rules and procedures and the anticipated trajectories into non-segregated airspaces together with anticipated timelines;

- Consider effects of pandemics, such as COVID-19, in impacting market viability and adoption trends;
- Understand performance characteristics, reliability, and standards of larger UAS within the ATC-serviced classes of airspace in the future;
- Understand performance requirements of ATC to allow larger UAS to be flying in the airspaces e.g., under what circumstances, can these large UAS fly within the Mode-C veils;
- Understand separation requirements and/or rules for integration (i.e., communication, navigation, and surveillance rules, in particular) into these airspaces;
- Understand strategic and tactical airspace clearance requests arising from UAM operations;
- Understand requirements for type design, airworthiness, and production approvals (e.g., type certificates, airworthiness certificates and production certificates) and how changes in these may facilitate regulatory initiatives. Also, understand safety risk management requirements emanating from these integrations;
- Provide projection of additional workforce required at towers and/or TRACON because of these anticipated changes and implications on airspace requirements including procedures and regulations;
- Provide physical infrastructure requirements, e.g., airport redesign, vertiport, etc., to accommodate this new mode of air transportation.
- To address these issues, an approach to predicting the

larger (>55lb) commercial aircraft growth into the higher non-segregated altitudes (e.g., above 400ft AGL) is needed, with special emphasis on the use of these UAS in transportation of passengers. The approach (i.e., modeling and simulation of airspaces) along with near-term forecast is necessary to understand and prioritize NAS resources as these newer aircraft evolve in serving greater civilian and commercial needs such as air transportation. Finally, the Task Order will inform future regulatory updates to UAS right-of-way rules, DAA performance standards, and collision avoidance standards.

APPROACH:

Task 1: Literature Review and Market Analysis

The research team conducted a literature review and market analysis focused on technical requirements of AAM on the NAS and the potential infrastructure requirements, whereas the market analysis identified market trends, potential for industry growth, and the ramifications of establishing AAM infrastructure in rural and moderately populated areas. Completion of the literature review, market analysis, and related recommendations for this study should were based upon lessons learned from prior research, including NASA-sponsored studies. Additionally, the market analysis explored questions of market demand, observe/predict trends, and determine impacts relating to the integration of UAM into both existing and potentially novel infrastructure.

Due to similarities in subject matter and scoping, the literature reviews for A41 and A42 were linked and combined into a single document. This was done to ensure that there was no duplication of effort and to identify distinct similarities and differences between unmanned air transport and unmanned air cargo. As such, a single combined literature review document was submitted for both projects.

Task 2: Use Case Development

Use case development for Task 2 built upon the literature review and market analysis for Task 1. For this task, the research team used data from the literature and initial market analysis to generate considerations for use cases. The research team would then refine considerations for use cases and scoped future tasks based upon the use cases chosen for further investigation. A key consideration at this stage of the project was to determine a use case, or use cases, such that they were representative of likely industry trends.

Based on the market analysis, the research team considered several potential AAM use cases including corporate campus, airport shuttle, regional air mobility, emergency services, and air taxi. Regional air mobility and air taxi cumulatively made up nearly two thirds of the projected market shares with air taxi garnering 37.8% and RAM following with 27%. The research team chose these use cases because they made up the most significant of the market share (Figure 1). While the team initially considered investigating additional use cases, the emphasis on air taxi and RAM was commensurate with their anticipated market shares. As such, the research team did not consider other use cases, such as airport shuttle, corporate campus travel, and emergency services for future tasks.

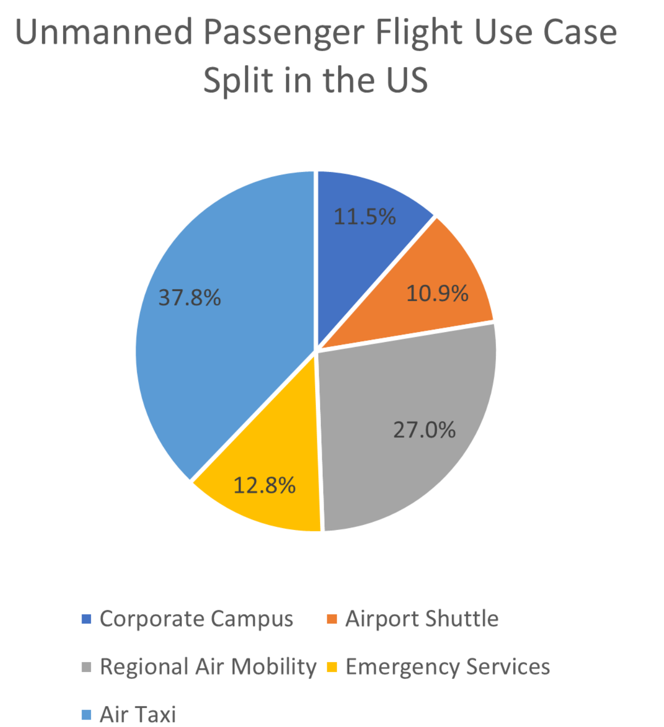


Figure 1. Unmanned Passenger Flights by Market Share (UAM Geomatics, 2021).

Task 3: Methodology

Given the variables and use cases identified in Task 2, the research team devised a research methodology that employed a two-pronged approach to answer research questions. This approach (Figure 2), offered insight into the use cases from two perspectives, seeking insight from AAM OEMs and those who would use the systems – i.e., the "flying public." The experiment, consisting of a two-pronged approach using interviews and a survey instrument, enabled the exploration of variables identified in previous tasks while simultaneously addressing guiding research questions. More importantly, the researchers designed the experiments such that they would shed light on areas of potential growth in AAM and highlight areas of future research.

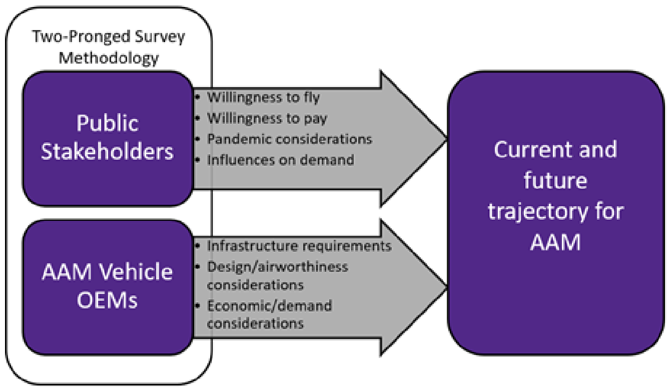


Figure 2. Two-pronged approach to exploring key variables for AAM.

More specifically, the research methodology consisted of:

1. A targeted interview for OEMs to identify important design and operational considerations for their systems, and
2. A survey aimed at addressing perceptions the public may hold regarding AAM, to include economic considerations.

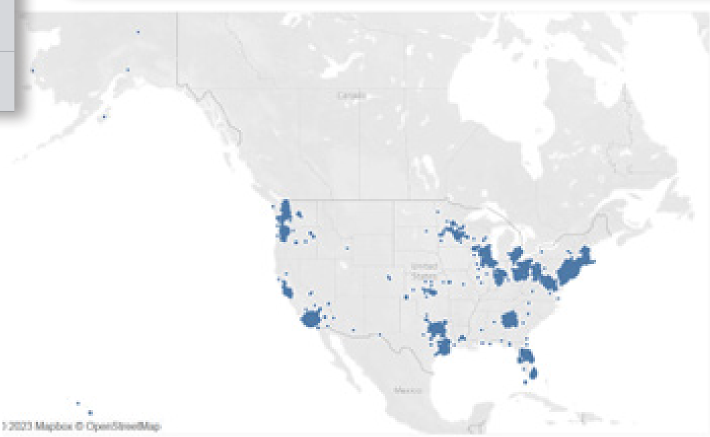
Task 4: Conduct Designed Experiments

The research team distributed a survey to gather data regarding views, opinions, and willingness to fly/pay for AAM. The team distributed the survey using a distribution service known as LUCiD. LUCiD provided a reliable method for distributing the survey across the United States, ensuring broad coverage and census grade representative sampling. The survey also targeted the top 30 potential AAM site locations (Table 1) described in the ASSURE A36 Site Suitability Analysis. The ASSURE A36 research team found the locations listed in Table 2 to be particularly suitable for the growth and development of AAM over time.

AAM SITE SUITABILITY – TOP 30 LOCATIONS FOR AAM GROWTH.

RANK	METROPOLITAN STATISTICAL AREA
1	NEW YORK-NEWARK-JERSEY CITY, NY-NJ-PA METRO AREA
2	LOS ANGELES-LONG BEACH-ANAHEIM, CA METRO AREA
3	DALLAS-FORT WORTH-ARLINGTON, TX METRO AREA
4	BOSTON-CAMBRIDGE-NEWTON, MA-NH METRO AREA
5	SAN JOSE-SUNNYVALE-SANTA CLARA, CA METRO AREA
6	ORLANDO-KISSIMMEE-SANFORD, FL METRO AREA
7	DETROIT-WARREN-DEARBORN, MI METRO AREA
8	MIAMI-FORT LAUDERDALE-POMPANO BEACH, FL METRO AREA
9	SAN FRANCISCO-OAKLAND-BERKELEY, CA METRO AREA
10	COLUMBUS, OH METRO AREA
11	MINNEAPOLIS-ST. PAUL-BLOOMINGTON, MN-WI METRO AREA
12	CHICAGO-NAPERVILLE-ELGIN, IL-I N-WI METRO AREA
13	BRIDGEPORT-STAMFORD-NORWALK, CT METRO AREA
14	WASHINGTON-ARLINGTON-ALEXANDRIA, DC-VA-MD-WV METRO AREA
15	HOUSTON-THE WOODLANDS-SUGAR LAND, TX METRO AREA
18	INDIANAPOLIS-CARMEL-ANDERSON, IN METRO AREA
19	SEATTLE-TACOMA-BELLEVUE, WA METRO AREA
20	ALLENTOWN-BETHLEHEM-EASTON, PA-NJ METRO AREA
21	ATLANTA-SANDY SPRINGS-ALPHARETTA, GA METRO AREA
22	MADISON, WI METRO AREA
23	PROVIDENCE-WARWICK, RI-MA METRO AREA
24	POUGHKEEPSIE-NEWBURGH-MIDDLETOWN, NY METRO AREA
25	HARTFORD-EAST HARTFORD-MIDDLETOWN, CT METRO AREA
26	PITTSBURGH, PA METRO AREA
27	WICHITA, KS METRO AREA
28	PORTLAND-VANCOUVER-HILLSBORO, OR-WA METRO AREA
29	CLEVELAND-ELYRIA, OH METRO AREA
30	MILWAUKEE-WAUKESHA, WI METRO AREA

Figure 3 offers a snapshot of the survey distribution. The distribution of the survey correlated with the top 30 AAM sites in addition to surrounding areas, covering both coasts, southern regions of the country, and the midwest.



Task 5: Economic Assessment & Methodology

The team conducted an economic impact assessment to evaluate how AAM passenger mobility will affect the US economy. This required defining the period of analysis (the duration of time for measuring impacts), isolating the determinants of economic impact (the key drivers that cause changes to the economy), developing the process to model economic impacts (building the economic model), and reporting the analysis findings. For this study, the period of analysis was determined to be from the present day through 2045. Figure 4 depicts the economic impact assessment framework.

KEY FINDINGS:

- Primary considerations for unmanned air transport fall into the following categories:
  - Airspace considerations
  - Regulatory considerations
  - Automation
  - Airman certification and training
  - Design and airworthiness
  - Unmanned Aircraft System Traffic Management (UTM)
  - Economic considerations
- **Airspace** – Changes will be required regarding traffic management.
- **Regulatory Considerations** – The current regulatory framework will likely require updates to accommodate new technologies, practices, and airworthiness/certification considerations to accommodate unmanned air transport aircraft.
- **Automation** – The shift to automation will begin by phasing out the pilot, starting with Simplified Vehicle Operation (SVO), moving to remote operation, and ending with full automation.
- **Airman Certification and Training** – Airman certification and training must accommodate shifts in trends towards increasing automation.

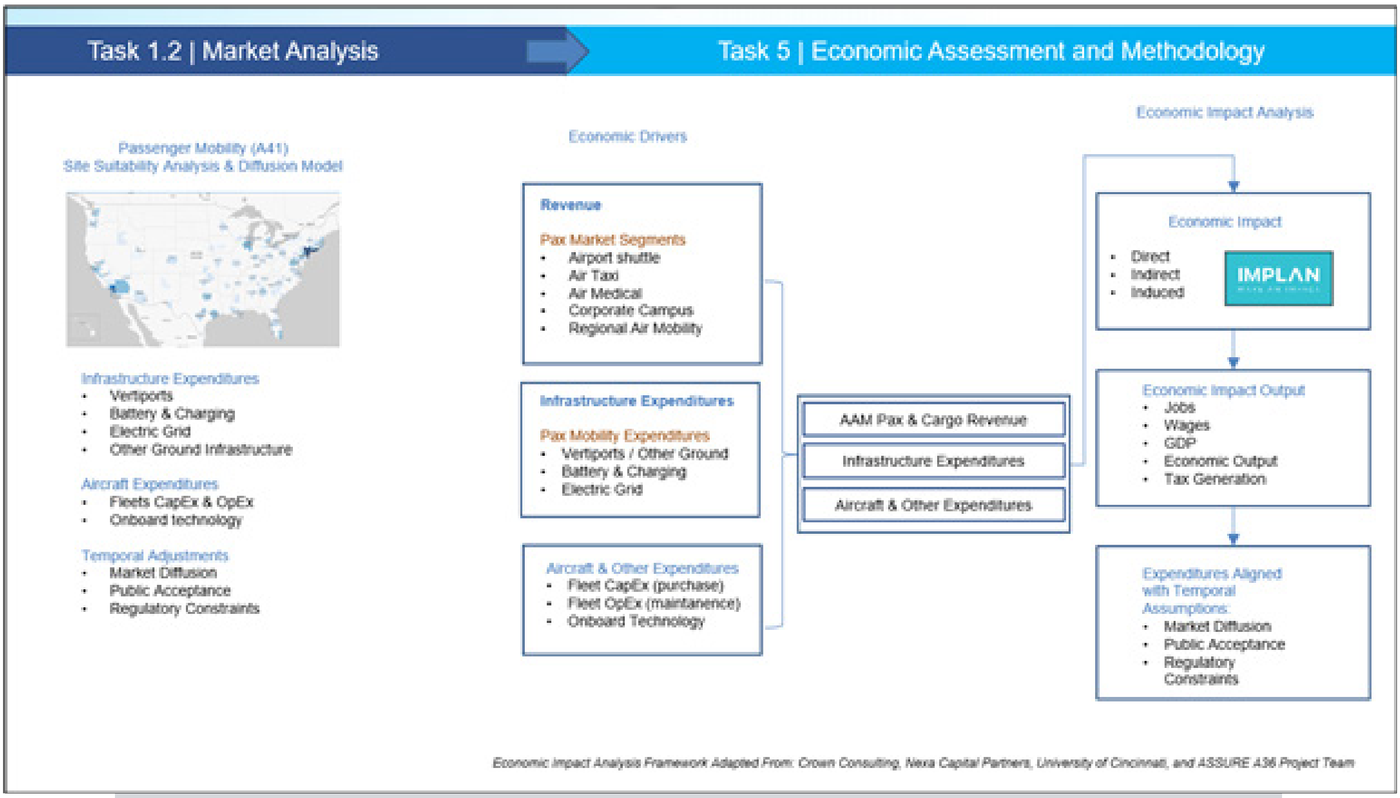


Figure 4. Economic Impact Assessment Methodological Framework.

- **Design and Airworthiness** – With the large number of designs, standardization is needed, as are mechanisms to validate new technologies and approaches to aircraft design. Regulatory changes may be required, and industry standards may serve as both a means of compliance and a mechanism for defining design and airworthiness requirements.
- **Unmanned Aircraft System Traffic Management (UTM)** – UTM will be essential for handling traffic volumes and will likely follow a phased-in approach, beginning with low-risk (non-passenger) traffic.
- **Economic Considerations:**
  - Demand is highly coupled with public acceptance.
  - Public acceptance is dictated by (1) safety, and (2) privacy/security.
  - Infrastructure will need significant expansion to achieve large scale usage.
  - The ability for air transport to alleviate congestion may give air transportation an edge over ground transportation. Integration with existing public transport is critical, but there is also potential for adverse effects – e.g., wait times, impact of weather, etc.
  - Due to expectations, UAM can likely be more expensive than alternative transportation modes, but must also provide overall time savings (access and process times included).
  - Congestion may give UAM an edge over ground transportation, especially in certain markets. It will likely be critical (to achieve widespread adoption of UAM) to integrate UAM access with existing public transportation networks. Note that UAM has the potential to adversely affect existing public transportation networks.
  - To achieve large scale usage, UAM infrastructure will need a significant expansion: more access points (vertiports) and electric grid upgrades to handle charging the vehicles. Access point operational efficiency will be important to maintaining low costs and significant time savings for the users.
  - Regulations will also play a key role as well (e.g., affecting infrastructure or minimum clearances affecting climb rates and hence vehicle recharge (and client wait) times.
  - The relative influence (or even existence) of these factors may vary significantly across various locations and demographics, making careful planning essential to successfully targeting and serving a market.
  - With such an untested technology, many of these conclusions are tentative, and in places there is still disagreement in the literature.

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FROM MANNED CARGO TO UAS CARGO OPERATIONS: FUTURE TRENDS, PERFORMANCE, RELIABILITY, AND SAFETY CHARACTERISTICS TOWARDS INTEGRATION INTO THE NAS

LEAD UNIVERSITY : UNIVERSITY OF ALASKA FAIRBANKS

A11L.UAS.84_A42

BACKGROUND:

According to FAA rules, UAS weighing 55 pounds or greater must be registered using the existing aircraft registration process. Many of these aircraft are presently flown within the NAS by federal agencies, including the Departments of Defense (DoD), Homeland Security (DHS),

Interior (DOI), Energy (DOE), Agriculture, NASA, and some state and local governments, and academia. In 2018, these Agencies had flown 3,784 flights (by 42 Reapers or 90 ops per aircraft per year); 494 flights (by 23 Shadows or 21 ops per aircraft per year); 362 flights (by 13 Predator A or 28 ops per aircraft per year); and 290 flights (by 3 Global Hawks and Tritons or 97 ops per aircraft per year). While some of these organizations require Certification of Authorizations (COAs) lasting two years, others have their own self-certification for authorizations, e.g., DoD, Customs and Border Patrol (CBP). While defense and civilian agencies are already using large UAS in the NAS, it is anticipated that these UAS may also be used for commercial purposes (e.g., agricultural spraying, commercial real estate, pipeline inspections, communication relay, etc.) in the near future. One of the uses could potentially be transportation of air cargo.

Continued safe integration of UAS is essential, and the FAA is taking a proactive approach in understanding trends, identifying new markets, and forecasting large UAS in the NAS. These forecasts are used throughout the Agency for safety and investment analysis along with workload planning.

The FAA has observed an increasing trend in operational requests, via waiver of Part 107 regulations, for expanded UAS operations in Night Operations, Ops Over People, and Beyond Visual Line Of Sight categories in both segregated and non-segregated areas (i.e. airspace where the likelihood of encountering a manned aircraft is greater and/or demand on airspace is likely). The expanded operations typically occur within the 'segregated' domains where traffic and population density are relatively low. Consistent with the FAA's strategic approach to integration, there is increased interest (via waiver requests), and industry coordination (e.g., existing Integration Pilot Program or IPP) to migrate such operations into non-segregated areas as well.

These three future trends, i.e., large UAS (i.e., both public and anticipated commercial), sUAS transitioning into non-segregated airspaces, and gradual proliferation of sUAS in package delivery indicate that there may be more innovations in the near future. The team anticipates that large UAS will be used to facilitate cargo delivery in the near future. New and additional procedures, airspace rules, and equipment standards including their performances and reliability will need to be developed and/or modified to accommodate safe integration of UAS in the NAS.

Given these anticipated trends, it will be essential to:

- Understand trends in large UAS, particularly with a focus to understand its role in cargo delivery, both scheduled and unscheduled routine operations;
- Establish likely relationships between likely manned cargo transitioning into large UAS;
- Establish any significant change following the onset of COVID-19 and likely adoption of larger UAS in cargo carrying capabilities;
- Forecast large UAS, both civil and commercial, and transitioning sUAS requiring analysis of market including competition, technology, and the anticipated trajectories into nonsegregated airspaces together with anticipated timelines;
- Understand performance characteristics, reliability and standards of large UAS and those sUAS anticipated to transition within the ATC-serviced airspaces (G, D, E, A, B, and C in probable order of importance) over the next few years;
- Understand performance requirements of ATC to allow large UAS to be flying in the airspaces e.g., under what circumstances, can these large UAS fly within the Mode-C veils?
- Understand separation requirements and/or rules for integration (i.e., communication, navigation, surveillance, informational (CNSi) rules, in particular) into these airspaces;
- Understand requirements for type design, airworthiness and production approvals (e.g., type certificates, airworthiness certificates and production certificates); understand also how changes in these may facilitate regulatory initiatives such as MOSAIC;
- Understand safety risk management requirements for these integrations; and
- Provide projection of workforce associated with these anticipated changes and implications on airspace requirements including procedures and regulations; and
- Provide an understanding of physical infrastructure required to facilitate large UAS delivering cargo incrementally in the NAS, e.g., redesigning of airport including ramps, delivery points, etc.

To address these issues, an approach to predicting the larger (>55lb) commercial aircraft growth into the higher non-segregated altitudes (e.g., above 400ft AGL) and the migration of the sUAS into the higher non-segregated altitudes is needed, with special emphasis on the use of these UAS in transportation of air cargo. The approach (i.e., modeling and simulation of airspaces) along with near-term forecast is necessary in order to understand and prioritize NAS resources as these newer aircraft evolve in serving greater civilian and commercial needs such as air transportation of cargo.

APPROACH:

The approach to this project included the following tasks:

- **Task 1:** Literature and Market Analysis
- **Task 2:** Use Case Development
- **Task 3:** Experiment Plan
- **Task 4:** Conduct Designed Experiments
- **Task 5:** Economic Assessment and Methodology

Task 4 FY23 Activities:

The team prepared a survey, had it approved by school Institutional Review Boards, and sent it to 1700 live email addresses at the end of September, 2023.

The survey was broken up into 5 sections: Current State of Air Cargo Operations; Potential for Future Air Cargo/Changes to Enable Autonomous Air Cargo; Current Market-Related Questions; Future Market-Related Questions; and End User-Related Questions (Exploring the Effects of Large/Medium UAC).

The research team organized these sections to focus on the perceived interests/lines of effort of the following target audiences: Original Equipment Manufacturers (OEM)/Air Carriers with a focus on aircraft, maintenance, etc.; Airport/Airfield Operations with a focus on infrastructure; and end users with a focus on premium for timely delivery, critical items, etc.

Within each section, the questions were grouped into 3 sets corresponding to their perceived order of importance: (1) These begin with the most critical questions for the viability of the effort (Vital); (2) followed by questions considered to be of moderate importance (Significant); (3) finally by questions of interest that would be helpful in formulating a set of well-thought strategies and recommendations (Helpful).

Additionally, the survey respondents were asked to identify their experience with the following air cargo classes:

- HLM+HRM: Heavy, Long-Range & Medium-Range (500 to >3,000 nm) aircraft with payload capacities (10T to >40T)
- Regional: Regional-Range (75 – 1,000 nm) aircraft with payload capacities (1 – 10T)
- Light: Short-Range (<250 nm) aircraft with payload capacities (50 – 1,000 lb)

The team selected a subset of the questions for use during interviews with representatives from current air carriers.

Merlin Flights

Merlin flew a converted Cessna Grand Caravan with a safety pilot and two software engineers onboard between the Everts Air Cargo Facility at Fairbanks International Airport (FAI) and the remote communities of Deadhorse, Ft. Yukon, Galena, Huslia, and Tanana. They completed 25 flights in total and landed on challenging gravel runways. Research team personnel observed the landing and operations at the remote communities with an eye to determining what support infrastructure and personnel support are required to receive the aircraft, unload it, reload it, prepare it for flight, and launch it and how these needs vary based on airport location and community size. The community residents were positive about the aircraft and its mission to deliver cargo to their communities. People had trouble believing the Cessna was the 'drone' that they were expecting.

Fairbanks International Airport to Nenana Municipal Airport

During the fall of 2023, UAF intended to fly a large UAS from FAI to Nenana Municipal Airport (ENN) with a chase plane to simulate conducting a large drone (300 lbs) cargo flight from a large hub to a smaller, non-towered airport with no cargo facilities. SeaHunter conducted its first successful flight between FAI and ENN on Aug 2, 2023. The hand-off between Ground Control Stations (GCS) at FAI and ENN in the middle of the flight went well and the aircraft landed successfully in ENN. The team then was delayed by questions about where the GCS was located at ENN and what permitting was required beyond the approval of the airport manager to be at that location. The questions were resolved through discussion with all levels of FAA and UAF resumed operations. The team collected information on what infrastructure and personnel support are required to receive the aircraft, unload it, reload it, prepare it for flight, and launch it at a Class G airport with minimal infrastructure. This case also demonstrated a potential use case with a remote pilot and visual observer being available in the community to safely land the aircraft at the airport and ensure the runway is clear of people and obstructions prior to landing.

Task 5 FY23 Activities:

The economic assessment and methodology team developed demand forecasts for three use cargo use cases: HLR/HMR, Regional/ Feeder, and Light/ Vertical Takeoff and Landing (VTOL). They also developed associated demand projections to be used as the basis for the economic impact analysis. They were looking at traditional markets with partial Advance Air Mobility market capture using combination of forecasts (BTS, LMI Consulting et al., IATA, FAF) as well as new markets using a site suitability analysis and LMI Consulting forecasts.

The site suitability analysis is designed to identify the most suitable airports in the US and in each state, and rank the states in terms of suitability for the implementation of large UAS cargo.

In the site suitability analysis, the team determined that some of the most important factors for site suitability include:

- Runway lengths at VTOL gateway meet regional aircraft standards:
  - 1,970'-3,000'
  - 3,001-3,600'
  - 3,601'+
- VTOL gateway is not congested with commercial operations (<1,460 commercial operations per year)
- Gateway has JetA fuel.
- Population within gateway service area
  - SA 1 = 17 miles
  - SA 2 = 75 miles
  - SA 3 = 150 miles

- Highway lane miles in service area
- Elevation changes in service area
- Class G airspace available & not congested
- Existing investment(s) being made
- Someone available to unload cargo
- Location with severe or hazardous events

For regional and light use cases, the research team focused on the following to achieve a site suitability score:

- Testing for confluence of geospatial variables
- Locations with the greatest confluence of variables receive the highest score
- Each variable can be weighted individually
- The findings are based on the literature, but the literature is not complete.
- Creating a workbook tool capable of weight adjustments

Figures 1A and 1B show examples of two different weighting schemes. The red areas in Figure 1A show locations that score well with existing enabling infrastructure (runway length, fuel, near electric utility substations). The red areas in Figure 1B show locations that score well by having remotely located populations (located away from freight networks, population clusters, limited Class B airspace to interfere with ops). The areas most suitable for implementation of large UAS cargo operations are very similar under the two weighting schemes for the contiguous United States. However, the weighting schemes provide very different results for Alaska with the remote areas with populations cluster weighting scheme showing higher favorability for large drone cargo implementation in Alaska than the infrastructure readiness weighting

These site suitability analyses and demand projections from the literature provide the basis for estimating economic impacts..

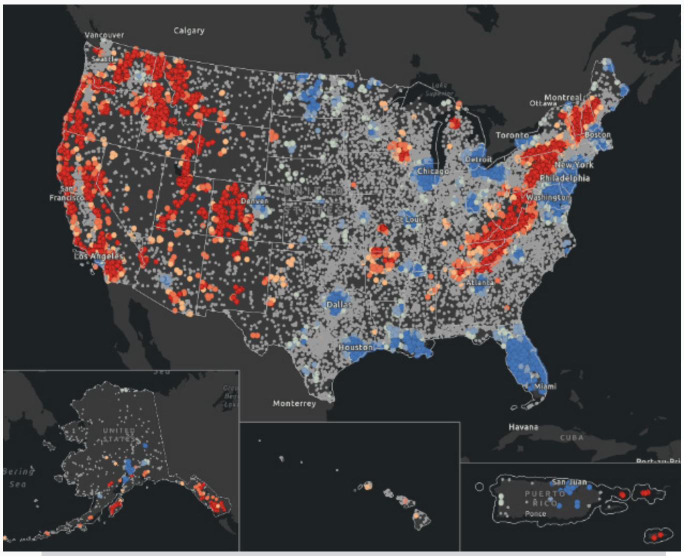

Figure 1A. "Infrastructure Readiness"

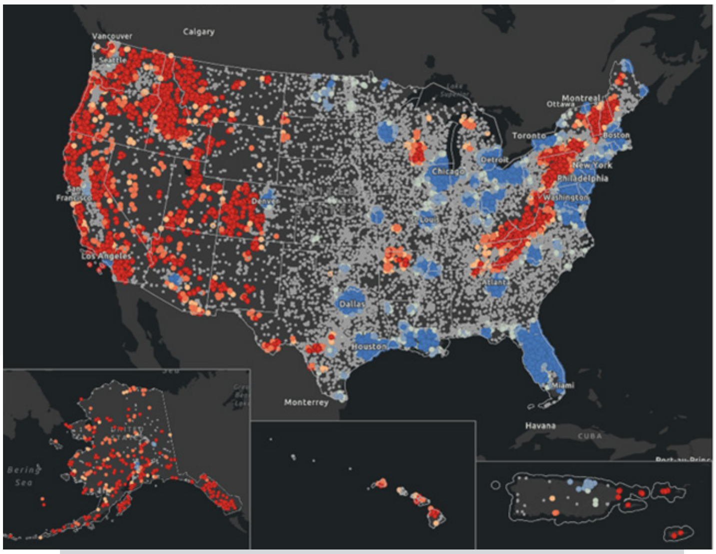

Figure 1B. "Remote Areas with Population Clusters"

KEY FINDINGS:

The implementation of economically-feasible, large UAS cargo in remote communities will be determined by need, location, existing infrastructure, and personnel.

The areas most suitable for implementation of large UAS cargo operations as determined by the site suitability analysis are very similar under the two weighting schemes for the contiguous United States. However, the weighting schemes provide very different results for Alaska with the remote areas with populations cluster weighting scheme showing higher favorability for large drone cargo implementation in Alaska than the infrastructure readiness weighting.

Solid communications with the remote communities are essential for smooth operations in those communities. For example, it was difficult to contact the fuel provider in Galena, which could lead to an aircraft reaching a community and the infrastructure and supplies to refueling it not being available.

Rocks on a gravel runways present a challenge to autonomous (and traditional) aircraft landing on some remote communities' runways.

The personnel available to pilot and/or observe the large UAS will help determine what model (remotely piloted from one point, remotely piloted with a hand-off during flight, or autonomous) of UAS command and control will provide the most robust operations for remote communities.

Flight crew, cargo handlers, and remote community population safety and aircraft/payload security must be incorporated in the planning for remote cargo delivery.

Weather will be one of the biggest challenges in implementing year-round cargo delivery. The remote pilot in command or the autonomous system piloting the aircraft must be able to handle poor weather reporting and unexpected or unreported conditions such as high winds. The Merlin aircraft encountered high winds on an approach at an airport where the winds were listed as low/calm.

Community engagement will be essential for the acceptance of UAS cargo deliveries in remote communities.

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HIGH-BYPASS TURBOFAN UAS ENGINE INGESTION TEST

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A11L.UAS.85_A43

BACKGROUND:

Inclusion of large numbers of small Unmanned Aircraft Systems (sUAS) into the National Airspace System (NAS) may pose unique hazards to other aircraft sharing the airspace. It is necessary to determine the potential severity of sUAS mid-air collisions with aircraft in order to define an equivalent level of safety to manned aviation.

H.R. 636 – FAA Extension, Safety, and Security Act of 2016, Section 2212, Unmanned Aircraft Systems – Manned Aircraft Collision Research,

mandated UAS research to determine the impact severity of ground and airborne collisions. Since there is no similarity of a UAS to any other foreign body currently being regulated, understanding the severity of the ingestion event is critical to be able to estimate the extent of damage encountered in a typical incident/accident.

To aid in the longevity of the information gathered during this research, high fidelity data gathering, instrumentation, and model validation is crucial for future FAA regulatory and policy development surrounding safe UAS integration into the NAS.

APPROACH:

The research will be carried out in close collaboration with the test partner and the FAA. The team will help inform and review the test plan created by the test partner. The team will be provided with a model of the fan stage used in the experiment by the test partner. A Finite Element (FE) model will be created using material models given by the test partner or will leverage the closest pre-existing material models in alignment with the recently completed computational engine ingestion research. All the reduced and processed data obtained by the test partner, including high speed and regular speed videos, onboard engine performance data during the test, ambient conditions, and onboard and non-contact measurement system data from systems run by the test partner will be shared with the team for their independent analysis. The team will run computational simulations at the conditions of the test using LS-DYNA (a finite element analysis software that specializes in highly nonlinear transient dynamic analysis) following the best practices set forth by the LS-DYNA Aerospace Working Group. This work will provide an analysis of the fan impact to inform the overall computational modeling approach conducted in the recently completed computational engine ingestion research. The test partner will also provide a final test report and their analysis of the test event, which will be reviewed by the research team based on their expertise and independent analysis. Finally, the research team will coordinate with the FAA on the overall messaging on the engine ingestion research.

Task 1: Testing Oversight

The objective of this research task is to provide testing oversight and analysis for the live engine ingestion test. Task 1 can be broken into the following sub-tasks:

Sub-Task 1.1: Test Plan Input and Review

The objective of this task is to ensure a test plan that will produce a valuable data set for answering current and future research questions related to UAS engine ingestions. This task includes coordinating with the ongoing computational research and the FAA to provide the test partner with input on the test plan. The test plan will include the planned conditions for the test (i.e., operating conditions of the engine, launch speed, location and orientation of UAS). The test partner in consultation with the FAA/ASSURE team will select an operational engine for the test. The test plan will also include planned measurement instrumentation and setup location. Scans of the blades pre- and post-test will also be provided to the research team for use in the computational studies. The research team will provide additional input on the measurement data that should be taken and recommendations for the setup to obtain needed data for the initial analysis and potential future work. The test partner will be responsible for the overall test plan and incorporating all the needed instrumentation, and implementing the test plan to complete the test and capture all the necessary data.

Sub-Task 1.2: Post-Testing Analysis

The objective of this task is to conduct an independent post-test analysis of the engine ingestion test. The test partner will be conducting their own analysis of the engine ingestion and will provide the reduced and processed measurement data from the experiment. This task is focused on reviewing the analysis of the test partner and conducting a computational simulation of the ingestion event for comparison purposes. Similar to the ingestion work in the recently completed computational research program, an ingestion analysis focused on the damage from the primary impact of the UAS with the fans will be performed to evaluate damage in the blades of the fan section. The damage from the computational simulation will be compared to the experiment. Elastic material properties will be used for the casing and nose cone to provide appropriate boundary conditions and to determine secondary impacts and loading pattern.

Sub-Task 1.3: Final Test Report and Modeling Validation

The objective of this task is to provide a final test report on the research program that includes both the research team and the test partner's results and conclusions from analyzing the engine ingestion test. Moreover, the work will also be used to validate the modeling approach used in the currently ongoing computational engine ingestion research. In particular, a comparison of the computational simulation of the ingestion with the full scale test will be conducted. Differences in the response and damage are expected due to the prior use of the actual fan and the unknown proprietary materials processing in the construction of the actual fan. Finally, the simulated proprietary fan ingestion case and the representative fan from the computational research will also be compared to give a better frame of reference for how the damage in the representative fan compares to an actual in-service engine.

Sub-Task 1.4: Engine Research Messaging

The objective of this task is to coordinate with the FAA, test partner, ASSURE, and other stakeholders in the appropriate messaging of the research in the public release of the research findings. This task will require discussions with key stakeholders in the proper framing of the research conducted and the results obtained in the overall context of safely integrating UAS into the national airspace.

KEY FINDINGS:

The team has supported the research efforts of the test partner in identifying an outer radial span impact location with fan operating at takeoff conditions being ideally suited to understand a critical impact case. The team has also supported the UAS launcher development, which has been completed by the test partner. The test partner has successfully completed the test per the agreed upon test plan and is working on their final report and data processing.

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MITIGATING GPS AND ADS-B RISKS FOR UAS

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A11L.UAS.86_A44

BACKGROUND

Unvalidated or unavailable GPS and Automatic Dependent Surveillance–Broadcast-In (ADS-B In) data poses security and safety risks to automated UAS navigation and to Detect and Avoid (DAA) operations. Erroneous, spoofed, jammed, or drop-outs of GPS data may result in unmanned aircraft position and navigation being incorrect. This may result in a fly away beyond radio control, flight into infrastructure, or flight into controlled airspace. Erroneous, spoofed, jammed, or drop-outs of "ADSB-In" data may result in automated unmanned aircraft being unable to detect and avoid other aircraft or result in detecting and avoiding illusionary aircraft. For automated DAA, a false ADS-B track can potentially be used to corral the unmanned aircraft to fly towards controlled airspace, structures, terrain, and so on. This

research is necessary to enable safe and secure automated sUAS navigation and safe and secure automated sUAS DAA operations. Goals for the project include reports and recommendations useful for FAA policy development and UAS standards development. It is expected that this information will be used to better understand the risks, potential mitigations, and help the FAA to reassess and refine FAA policy with respect to validation of ADS-B data. The research may lead to new navigation requirements related to GPS as well.

APPROACH:

The research approach included the following tasks:

- **Task 0:** Program Management
- **Task 1:** Literature Review and Risk Assessment

- **Task 2:** Identification of Potential Mitigations
- **Task 3:** Planning and Testing & Demonstration of Mitigations
- **Task 4:** Test, Analysis, and Demonstration Report(s)
- **Task 5**: Draft Final Report and Peer Review
- **Task 6:** Final Briefing and Final Report

KEY FINDINGS:

This project begun on May 1, 2021. Reports were delivered throughout the period of performance and the final report was delivered to the FAA in August 2023.

Task 1 – Literature Review and Risk Assessment

This task provided a literature review and meta-analysis that identified the potential safety and security risks of relying on GPS and ADS-B data used for UAS operations. It is divided into three areas of investigation: signal dropouts and erroneous data, jamming, and spoofing that may result in safety or security risks to UAS operations that rely on GPS and ADS-B data. Based on the information gathered, a safety and security risk assessments of potential UAS operations that rely on GPS and ADS-B data is presented.

A summary of the risk assessments is provided using the Safety Management System (SMS) Air Traffic Organization (ATO) SMS Manual and Safety Risk Management Guidance for System Acquisitions (SRMGSA). This manual provides guidelines to assess the severity and likelihood of identified risks. The risk assessment is broken into four classifications: Part 107 Operations, Beyond Visual Line Of Sight (BVLOS), Urban Areas, and Near Airports. For each category, the severity and likelihood probability, associated references, and mitigation schemes associated with the increasing risk profile are presented. Part 107 Operations specifies a near pristine risk level, or the best-case scenario and will serve as the base reference for the increasing risks in the other environments. BVLOS is the next category as it is a crucial for many UAS operations and is of great importance to the UAS community. Urban area operations represent a unique case due to signal interruptions and other artifacts along with the density of humans and infrastructure. Near airports operations represents another unique situation due to the air traffic density and potential impacts to commercial airline traffic.

Table 1 is a summary of the risk levels for the six classes and four classifications of operations to illustrate continuum of risk levels in the various combinations.

From this analysis it is evident that the only low risk situations occur with operations in the Part 107 conditions. This was expected due to the nature of Part 107 and the current operability allowed by the FAA. In the medium risk category, most of the operating environments are in the BVLOS operations. This is also expected since both cases can be allowed by using a FAA waiver process to allow operations in these areas. The waiver and potentially other situations may be mitigated using additional processes, procedures, and technology to reduce the risk to a lower acceptable level. The high risk category contains mainly urban and near airport operations. These areas result in high risk operations and significant mitigation schemes are needed to reduce the risk to an acceptable level.

RISK	PART 107	ROVAL BVLOS	URBAN BVLOS	NEAR AIRPORT BVLOS
ADS-B Dropout	LOW	MEDIUM	MEDIUM	HIGH
GPS Dropout	LOW	MEDIUM	HIGH	HIGH
ADS-B Signal Jamming	LOW	LOW	MEDIUM	HIGH
GPS Signal Jamming	LOW	LOW	MED/HIGH	HIGH
ADS-B Signal Spoofing	LOW	MEDIUM	MED/HIGH	HIGH
GPS Signal Spoofing	LOW	MED/HIGH	MED/HIGH	HIGH

Table 1. Summary of the risk levels for the six classes and four classifications of operations.

BVLOS operations are of special interest as these are in great demand from operators and industry. Mitigating BVLOS operations flying at low altitudes and conducting long linear infrastructure inspection, agriculture operations, package delivery, or aerial surveillance are focus areas. As mitigation strategies are found and evaluated, their impact and associated costs will be assessed. There is a desire to minimize cost and weight while still providing a high level of safety. These operations have significant potential for adverse outcomes, however several mitigation techniques show promise as tools to be used in conjunction with regulatory requirements.

Task 2: Identification of Potential Mitigations

Examination of recorded ABS-B data was conducted to expose potential risks and provide guidance on mitigation schemes. The examination reveals dropouts and anomalies that occur in flight operations. Based on the risk assessments in Task 1, the performer conducted a market survey of market solutions to mitigate loss of GPS and loss of ADS-B data as well as a market survey of market solutions to mitigate unvalidated GPS and unvalidated ADS-B In data. The market surveys include estimated costs, ease of implementation, and a preliminary assessment of the effectiveness of market solutions to mitigate the various risks identified in Task 1.

The mitigation strategies identified were evaluated using an assessment tool to provide a metric to the overall effectiveness. The proposed assessment metrics assessed the overall effectiveness of mitigation schemes. Five things were evaluated to quantify the overall score to rank the proposed methods: cost, technical readiness, ease of implementation/use, Size, Weight, and Power (SWaP), & impact.

Each factor was ranked with a numerical score from 1 to 5, with 1 being the "worst" and 5 being the "best" in each category. A detailed guide for each ranked factor is provided in the final report based on the effectiveness of the implementation of the mitigation scheme on a small UAS. Therefore, the factors are the added impact on the "standard' operating configuration.
The cumulative score of the ranked factors generates a value that is indicative to the overall effectiveness. Each factor in the total score has an equal weighting and the sum of all ranking produced the overall score. A scoring breakdown is color coded to outstanding, high, medium, or low value to indicate the overall effectiveness, as shown in Table 2.

The scoring system provides a numerical score to aid in overall effectiveness, however this score is to be used for a guide to aid in identifying mitigation strategies with high effectiveness in the current state of development. Some mitigation strategies may have great potential but are early in their development. These strategies, that perhaps do not score high at this time, may have the potential to have a great impact with further development.

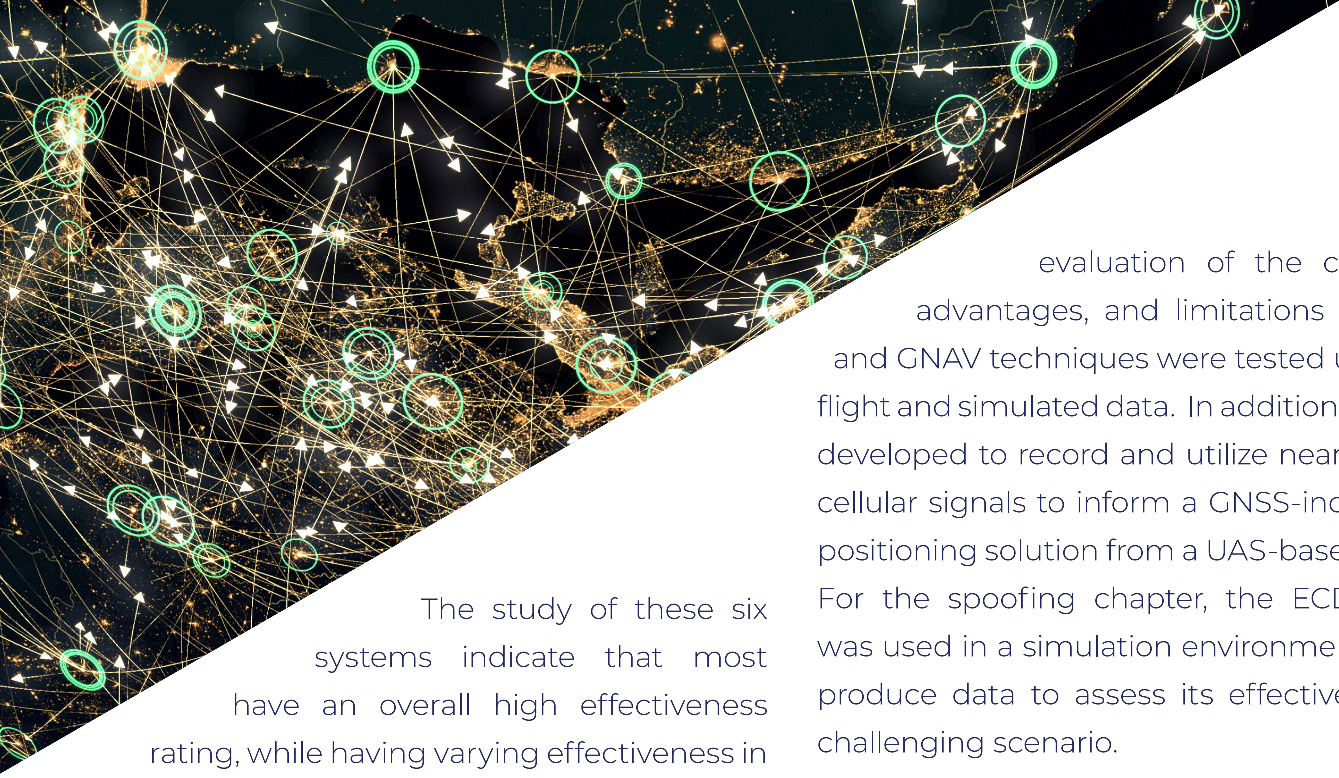
SCORE	EFFECTIVENESS
5-10	Low
10-15	Medium
15-20	High
20-25	Outstanding

Table 2. Potential mitigation effectiveness scoring system.

Several mitigation schemes were evaluated for their effectiveness in jamming and spoofing conditions. The mitigation schemes evaluated were optical flow, geomagnetic navigation, cellular signal navigation, WIFI navigation, and Eichelberger's Collective Detection (ECD) method. The findings are summarized in Table 3.

MITIGATIONS SCHEME	CONDITION	ASSESSMENT SCORE	EFFECTIVENESS
AI Path Prediction	Drop Outs	13	MEDIUM
Optical Flow	Jamming	16	HIGH
Geomagnetic Navigation	Jamming	14	MEDIUM
Cellular Signal Navigation	Jamming	15	HIGH
Wi-Fi Navigation	Jamming	12	MEDIUM
ECD	Spoofing	17	

Table 3. Summary of the GPS and ADS-B risk mitigation methods.



The study of these six systems indicate that most have an overall high effectiveness rating, while having varying effectiveness in each of the five factors scored. It is the team's opinion that flight and simulation testing should continue on all six of the mitigation methods and continued efforts be made in identifying dropouts and erroneous data in the current data sets along with new data sets obtained.

Task 3: Planning and Testing and Demonstration of Mitigations

This task prioritizes the mitigations in Task 2 for further analysis based on those that show the most promise for reducing risks while remaining cost effective and implementable. It places particular emphasis on prioritizing mitigations that support sUAS operations that will be tested in Task 4. The use of simulated flight data is included as a significant source of test data for evaluation.

The report contains a test plan for UAS navigation anomalies including dropouts and erroneous data, GPS and ADS-B signal jamming, and GPS and ADS-B signal spoofing. The UAS anomalies chapter focused on using ADS-B data sets to identify ADS-B anomalies that would result in ceasing operations and to identify the scenarios that are most common. With this data the use of hybrid machine learning models were explored. For the jamming chapter, the evaluation of the capabilities, advantages, and limitations of OPNAV and GNAV techniques were tested using both flight and simulated data. In addition, a test was developed to record and utilize nearby LTE/4G cellular signals to inform a GNSS-independent positioning solution from a UAS-based receiver. For the spoofing chapter, the ECD method was used in a simulation environment that will produce data to assess its effectiveness in a challenging scenario.

With the test plan outlined in this Task 3 report, significant flight and simulator data was acquired to best inform on the capabilities and weaknesses of GPS and ADS-B data.

Task 4: Test, Analysis, and Demonstration Report

The Task 4 report contained summaries of the testing and demonstration of mitigations of UAS navigation anomalies including dropouts and erroneous data, GPS and ADS-B signal jamming, and GPS and ADS-B signal spoofing. The UAS anomalies section focused on using ADS-B data sets to identify ADS-B anomalies that would result in ceasing operations and identify the scenarios that are most common. The data analyzed was collected by using flight test operations at UAF as well as from a unique case study of public use ADS-B data from the Dallas Fort Worth airport where ADS-B data was unavailable for an extended length of time over a large area. Additional metrics are recommended for ADS-B reception quality and the distance and altitudes of the ADS-B receiver and transmitting aircraft should be tracked. The DFW case illustrated that extended loss of ADS-B signals may occur, and mitigation strategies are critical for aerospace safety. The jamming section included flight tests that were developed to record and utilize nearby LTE/4G cellular signals to inform a GNSS-independent positioning solution from a UAS-based receiver. Based on the findings from the cellular navigation study, precise cellular signal positioning approaches show strong potential for mitigating risk in UAS operations and should be further considered as a supporting or backup navigation source in the case of GNSS signal dropout or jamming. For the spoofing chapter, the ECD method was studied in a simulation environment to produce preliminary data to assess its effectiveness. The research efforts have shown the viability and power of ECD to do three things that other countermeasure technologies cannot do: detect spoofed signals in four or more false satellite transmitters, mitigate the false and true signals, and recover the true signals. A functional GPS simulation model was created by ERAU which needs further modification to explicitly prove the ECD validity. The researchers feel they are on the verge of a huge success in terms of ECD as a countermeasure to reduce the potentially high-risk or catastrophic effects of spoofing and pre-jamming of GNSS/GPS/ADS-B navigation signals in air, land, and sea scenarios. Lastly, the evaluation of the capabilities, advantages, and limitations of optical flow and GNAV techniques were tested using both flight and simulated data. These algorithms demonstrated significant potential in improving the accuracy and robustness of navigation systems. Several challenges and limitations persist and serve as a valid rationale for further research in these areas.

The testing of UAS navigational anomalies including dropouts and erroneous data was accomplished by collecting ADS-B data from a custom receiver payload that was integrated and flown onboard a UAS. The payload flew multiple missions and collected data from a variety of local aircraft. The data was analyzed to determine the effect of aircraft altitude, size, range, and number of aircraft detected. Details of the payload, data processing, and analysis findings are presented in the subsequent sections. In addition, a study was done on a significant event where GPS interference around Dallas Fort Worth airport, that lasted for about 48 hours, and impacted 40 NM around the airport area. The event was analyzed and provided insights into this unique interference event.

The cellular navigation mitigation strategy utilized nearby LTE/4G cellular signals to assist the UAS navigation in GNSS challenging environments. Considering possible safety risks due to the erroneous, jammed or dropped GNSS data, published cellular navigation approaches, in combination with expanding cellular infrastructure, have strong potential to assist UAS navigation, and should be further investigated.

OrSU investigated this topic and collaborated with the UAF team to conduct flight testing and manage UAS and sensor equipment logistics. OrSU performed the data processing, interpretation, and discussion components using the acquired test data. Within Task 4, OrSU performed the following tasks: (1) assess accuracy of a signal-strength informed cellular positioning solution, (2) test hybrid integration with a GNSS-based solution acquired in tandem, and (3) contextualize results as they relate to applications in practical, law-abiding UAS operations.

Though hardware and logistical components limited the flight and processing potential for a true signal strength-based method in Task 4, productive characteristics and methods for leveraging cellular signals as a UAS-based navigation source can be identified from the case study. RSSI-informed cellular positioning approaches fundamentally yield an accuracy threshold in the range of hundreds of meters, in-line with results found in the flight data analysis. This level of uncertainty can be utilized in very specific dropout conditions but is too high for practical and reliable application in real-time UAS operations. However, more precise methods available in literature such as carrier phase positioning, with use of a software defined receiver, have shown potential for meter to sub-meter in early test cases.

Research in using ECD as a mitigation scheme is that that both GPS (part of the GNSS family) and ADS-B systems are vulnerable to spoofing attacks on both manned and unmanned aircraft. In general, GPS vulnerabilities translate down to the more specific ADS-B subset which has its own vulnerabilities. Dr. Michael Eichelberger describes a functional tool known as CD to detect, mitigate and counter spoofing attacks on all stages of GPS. The attacks on GPS then become part of the spoofing of the ADS-B systems that incorporate the GPS information within its data stream. However, since the spoofed GPS is part of the ADS-B data stream the same techniques can be used utilize to detect, mitigate, and counter spoofing attacks on the ADS-B system. GPS is ubiquitous and is incorporated into so many applications (aircraft, ship, car /truck navigation; train routing and control; cellular network, stock market, and power grid synchronization) that it makes a "rich" target for spoofing a receiver's perceived location or time. Wrong information in time or space can have severe consequences.

Research in development and implementation of optical flow and geomagnetic navigation studied the operation of UAS in GNSS degraded environments that face significant challenges due to various factors such as signal blockage, interference, intentional jamming, and spoofing attacks. These factors can degrade the accuracy and reliability of GNSS signals, especially in urban environments where the demand for UAS services is increasing. To ensure the safe and efficient operation of UAS in such environments, it is crucial to develop navigation methods and technologies that can compensate for the reduced quality of GNSS signals. Efforts focused on the description of the data acquisition and analysis process to support the development and implementation of Optical Flow (OF) and Geomagnetic Algorithm (GMA) approaches. These approaches enable UAVs to maintain accurate positioning and navigation capabilities even in situations where GNSS signals are partially compromised or degraded. Specifically, the data acquisition process and performance analysis showcase the capabilities of these two techniques.

Task 5: Draft Final Report and Peer Review

The draft final report was delivered and sent out for peer review. The comments were addressed, and appropriate actions were taken in modifications to the report.

Task 6: Final Briefing and Final Report

The final report provides in-depth studies of several navigational mitigation techniques and events that help better inform the FAA and standards bodies with detailed information to create appropriate regulations and operational guidelines. A significant takeaway from the work completed is that mitigations to reduce the potential risks with better safeguards and protections from GPS and ADS-B dropout/jamming/spoofing events are needed. All the mitigations investigated show the ability to increase the safety of sUAS operations, yet none are currently fully vetted or mandated by standards bodies. While several mitigation schemes were studied, there are additional tools and processes being developed utilizing new technologies and methodologies. These need further studies to fully evaluate their potential to mitigate the risk of GPS and ADS-B dropout/jamming/spoofing events. This is especially true for operations that were not investigated including small high drone densities managed by UAS traffic management via UTM, large UAS operations, UAS carrying hazardous cargo, UAS receiving ATC services, or future remotely piloted urban air mobility aircraft with passengers where the risks may be larger and new risks may emerge such as disruption to traffic management operations.

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SHIELDED UAS OPERATIONS : DETECT AND AVOID (DAA)

LEAD UNIVERSITY : UNIVERSITY OF NORTH DAKOTA

A11L.UAS.87_A45

BACKGROUND:

Certain sUAS Beyond Visual Line of Sight (BVLOS) operations, such as infrastructure inspection, may be in close proximity to structures that are collision hazards for crewed aircraft. These types of operations that are in close proximity to crewed aviation flight obstacles such that they provide significant protection from conflicts and collisions with crewed aircraft are termed "shielded" operations. This work effort is intended to identify risks and recommend solutions to the FAA that enable shielded UAS operations. This effort will identify risks, determine whether shielded operations can be made safe, to what degree UAS Detect and Avoid requirements can be reduced, and recommend UAS standoff distances from crewed aviation flight obstacles

APPROACH:

Task 1: Literaure Review and Risk Identification

The research team conducted a comprehensive literature review of shielding research, of risks associated with shielded operations, and related topics.

Task 2: Shielding Classes, Risk Assessments, and Listing of Mitigations

The team identified Shielding Classes/ Categories, with an emphasis on current use cases being explored (e.g., current BVLOS ARC efforts). The team identified hazards and mitigations and prioritized each.

Task 3: Analysis of DAA Requirements and Obstacle Avoidance Requirements

The team developed a simulation environment that enabled assessment of risks and potential solutions identified in Tasks 1 and 2. Numerical simulations were be performed to analyze the competing shielding requirements to manage risks associated with flight near obstacles and to manage risks involving crewed aircraft.

Task 4: Flight Test Plans

The team is developing flight test plans to evaluate findings from earlier tasks.

Test 5: Tests and Reports

The team is executing flight tests according to the developed test plans.

Task 6: Standards and Development

Research produced is valuable to standards development efforts. The team is supporting relevant standards development efforts and is enhancing them by providing relevant esearch results.

Task 7: Final Briefing and Final Report

The research team will summarize and aggregate all of the previous papers and reports into a final report package for the overall project. The final report will answer the previously mentioned knowledge gaps and provide clear recommendations to the FAA.

Task 8: Peer Review

The research team will support a peer review of the final report to ensure public availability of the research within 30 days of the final report delivery.

KEY FINDINGS:

The literature review illustrated that the amount of literature that directly addresses shielded UAS operations is scarce. However, significant research has been conducted in related areas, such as aircraft operations at low altitudes and the impact of structures/objects on supporting systems (e.g., GPS).

Key factors that impact shielded operations (i.e., create risk for such operations) include:

- Crewed aircraft behavior in these environments;
- Wind and turbulence effects;
- Bird densities/behaviors; and
- Impacts on supporting systems (GPS, command and control, etc.).

Shielding Classes/Categories have been identified. In addition, associated hazards and mitigations have been evaluated, with the latter being prioritized. One of the most significant challenges is determining likelihood of events, as they depend upon airspace density (which is not generally known and is highly variable). The team has developed a proposed foundation for evaluating likelihoods associated with interactions with crewed aircraft (loss of well clear, near mid-air collision, etc.) that is based upon probability theory. This approach has the benefits of a rich theoretical basis and the ability to translate to other metrics (e.g., risk ratio). In addition, the team is using multiple approaches (survey and data analysis) to estimate safety benefits associated with shielded operations (e.g., reduction in crewed traffic density).

The team has simulated multiple hazards associated with shielded operations. These include GPS degradation, electromagnetic fields associated with power lines, and wake turbulence impacts. These simulations provide guidance regarding hazard trade-offs (flying too close to objects resulting in increased risks versus losing shielding benefits that limit interactions with crewed aircraft).

The team has also executed one round of flight testing to evaluate the benefits of using a shielding object to enable well clear status by placing the object between the uncrewed and crewed aircraft. This approach, behind local obstacle well clear, has the potential to reduce the amount of time needed for maneuvering, which can decrease the detection range requirement for DAA systems.

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VALIDATION OF VISUAL OPERATION STANDARDS FOR SMALL UAS (sUAS)

LEAD UNIVERSITY : KANSAS STATE UNIVERSITY

A11L.UAS.88_A46

BACKGROUND

The emergence of copious sUAS operations in the last decade, for both hobby and commercial purposes, highlighted the need for further research and reforms to current regulations. The current regulations (14 Code of Federal Regulations (CFR) Part 107) require sUAS operations to be conducted within Visual Line of Sight (VLOS) of the Remote Pilot (RP). Due to these requirements, the RP must always maintain visual contact with the sUAS without any visual aids except for corrective lenses. Beyond Visual Line of Sight (BVLOS) operations are regularly

used in military applications and are desired for commercial UAS operations. A major challenge associated with the integration of UAS operations within the National Airspace System (NAS) is the ability to comply with 14 CFR § 91.111, 91.113, and 91.115, which require UAS operations to ensure collision avoidance with other traffic in the airspace. The current regulations (14 CFR § 107.31) allow for a Visual Observer (VO) to assist the RP in maintaining safety, providing an additional set of eyes to scan the airspace around the sUAS for air traffic that may pose a collision risk. The RP has the final authority in the operation of the aircraft, including commanding maneuvers, flight planning, and ensuring the overall safety of flight. Both the VO and RP serve critical roles in the operation of sUAS.

The following concerns were identified regarding VO capabilities as they relate to 14 CFR Part 107:

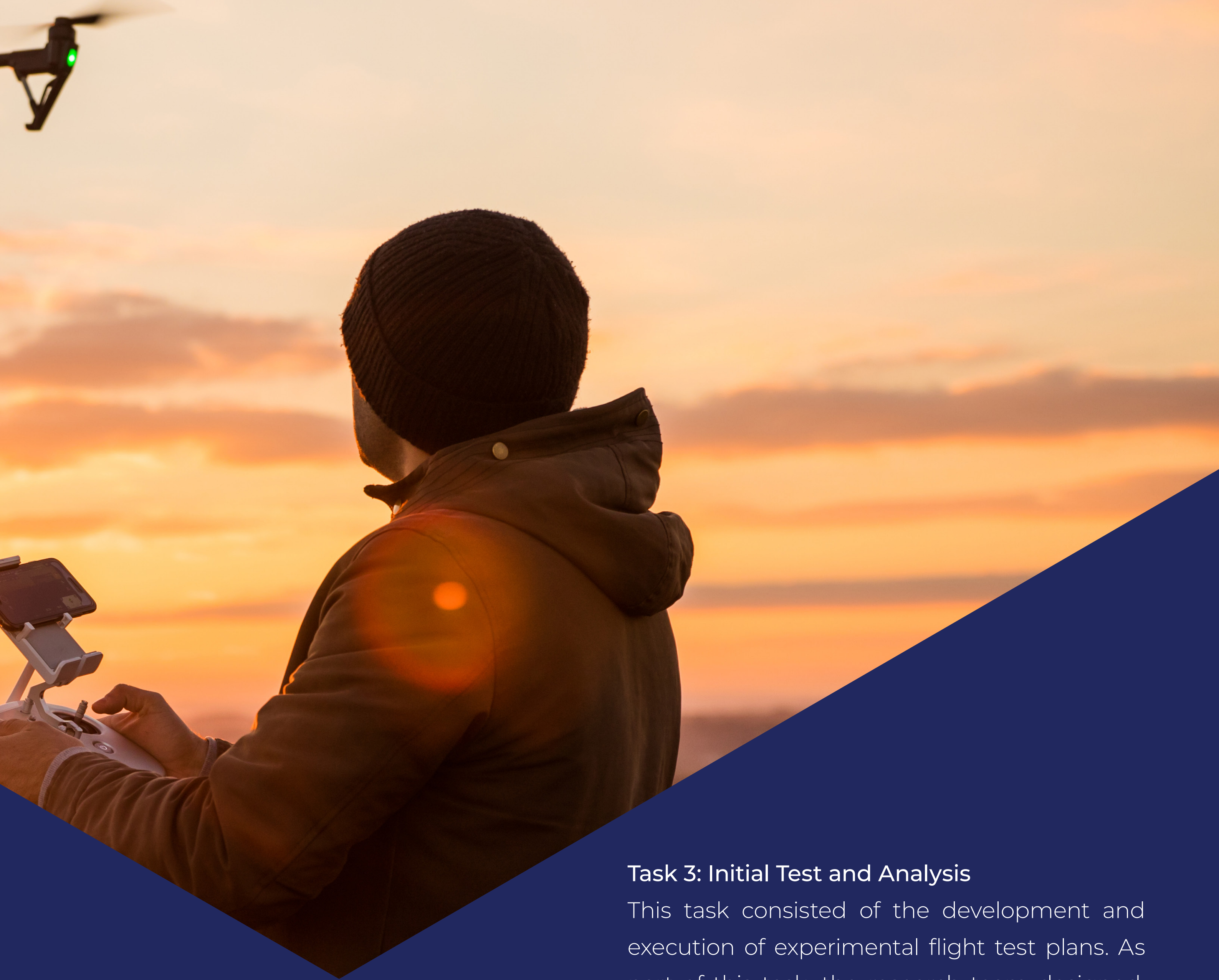
- Part 107.29, it is unknown how well VOs/RPs could avoid manned aircraft at night (e.g., a waiver to Part 107.29) or during periods of civil twilight when the sUAS is equipped with anti-collision lighting visible for at least 3 statute miles. It is unknown what factors VOs/RPs may encounter and how this may impact future training standards.
- Part 107.31, it is unknown how well VOs/RPs are able to ascertain the position of an unmanned aircraft in terms of location, attitude, altitude, and direction of flight using vision unaided by any device other than corrective lenses. It is also unknown how well RPs are able to use visual reference information to detect and avoid other air traffic and/or collision hazards.
- Part 107.33, it is unknown what challenges may arise from VO and RP communications when a VO relays information to an RP about a perceived intruder aircraft or other potential collision hazard.
- Part 107.37, it is unknown how well VOs/RPs are able to give way to conflicting aircraft and avoid the creation of a collision hazard.

Task 1: Literature Review

For this task, the A46 research team reviewed the literature associated with the human visual system, human factors, and human visual performance models to establish a foundation towards a methodology to investigate VO effectiveness in an extended VLOS environment. The team identified the most common type of visual illusions that VO/RPs could experience. There are only a limited number of experiments, publicly available, that have been executed

to assess the role of VO/RPs in visual detection of sUAS. The information captured in this literature review was used to plan for simulations, tests, demonstrations, and or analysis required to assess VO/RP performance. Key takeaways from the literature include:

- The human visual system is limited by the following factors: blind spot, acuity threshold, accommodation of the eye, empty field myopia, and focal traps. The human visual system during nighttime is limited by the following factors: mesopic vision, scotopic vision, night blind spot, and dark adaptation.
- Visibility of the UAS drops to fewer than ten arc-minutes when operated over 400 ft altitude.
- VOs are poor at estimating the distance and the altitude of the sUAS and are likely to overestimate both the distance and the altitude of the sUAS.
- Key factors that affect sUAS visual detection by manned aircraft pilots include sUAS motion, the contrast of sUAS against the background, employment of vigilant scanning techniques, and scanning using the peripheral field of view.
- Pilots can experience illusions but remain spatially aware, and disorientation is the single most common cause of human-related aircraft accidents.
- Auditory information can provide an initial location estimate that the VO can use to reduce the size of the visual scan area, speeding up visual detection.
- VOs are able to estimate the location of an aircraft quite accurately using only auditory information.
- There are no standardized training requirements for VO; however, many universities and institutions have their own training guidelines.
- While the number of categories covered and the depth of training by subject did vary, the Test Sites and university materials reviewed had central core topics such as airspace knowledge, COA requirements, waivers, FAA requirements, and communication procedures.
- VO training should identify and explain the various communication aids that may be used during an EVLOS operation when the RPIC and VOs may be in separate locations, as well as proper communication procedures.



- There is no one set of published standards for performing testing of Detect and Avoid (DAA) systems, and there is no current uniform way to characterize the roles of the VO/RP in the broader scope of DAA testing.

Task 2: Updated Research Task Plan

A key component of this work was to maintain an up-to-date Research Task Plan (RTP) to inform all stakeholders involved with this work. The research team updated the RTP as tasks were designed and completed. A final RTP was delivered as a component of this task.

Task 3: Initial Test and Analysis

This task consisted of the development and execution of experimental flight test plans. As part of this task, the research team designed, reviewed, and executed a flight test plan to investigate the effectiveness of VOs in a real-world flight environment.

Task 4: Flight Test Methodology

The research team utilized a sUAS flight test campaign in Kansas to collect data associated with this experimental design. The experimental design allowed the research team to collect general information regarding VO detection performance, such as ambient noise, light levels, and individual physiological differences related to visual acuity, color deficiency, and hearing capabilities. A series of preliminary test runs of the experiment design were conducted at NMSU in advance of the final data collection flights conducted in Kansas. This initial testing was used to assess personnel layout, data llection methods, flight path geometries, data gathering approaches, data analytics, and other testing elements to ensure successful testing with participants in Kansas.

Task 5: Case Study

To provide a substantial contribution through Task 5, the research delivered a Lessons Learned document detailing the processes, procedures, and limitations of the current methodology towards enhancing future research and flight tests in this domain. The document detailed the process and procedures followed by both KSU and NMSU towards flight testing. Limitations of the study were also documented, and recommendations for future research were provided.

KEY FINDINGS:

The A46 KSU flight tests spanned 8 days with 19 participants acting as VOs. On a given day, either two or three VO stations were active. The VO stations were located about 200 ft apart from each other. The KSU flight tests utilized two different crewed aircraft as intruders – the Cessna 172 Skyhawk or the Cirrus SR20. The research team processed and analyzed 157 and 183 valid runs for the C172 and SR20 intruder aircraft, respectively. The Great Shark 330 UAS was selected as the ownship in the flight tests. The UAS mission was simulated to operate about 1.25 miles north of the VO stations. The UAS mission was set to fly a box pattern flight path with a groundspeed of 45 kts and an altitude of 400 ft AGL.

The primary dependent variable in the A46 experiment design was the intruder detection distance. Table 1 provides the descriptive statistics for intruder detection distance calculated for the A46 encounters with C172 intruder aircraft, SR20 intruder aircraft, and the combined data-

INTRUDER DETECTION DISTANCE [MILES]

INTRUDER AIRCRAFT: C172 & SR20, SAMPLE SIZE = 340 RUNS				
MIN.	MAX.	MEAN	MEDIAN	STD. DEV.
0.05	4.24	1.67	1.54	0.70
INTRUDER AIRCRAFT: C172, SAMPLE SIZE = 157 RUNS				
MIN.	MAX.	MEAN	MEDIAN	STD. DEV.
0.05	4.24	1.90	1.69	0.81
INTRUDER AIRCRAFT: SR20, SAMPLE SIZE = 183 RUNS				
MIN.	MAX.	MEAN	MEDIAN	STD. DEV.
0.22	3.90	1.46	1.45	0.51

Table 1. Descriptive statistics for intruder detection distance calculated for the KSU flight test encounters.

set. The VOs detected the intruder aircraft (C172 & SR20) at an average distance of 1.67 miles. The VOs detected the C172 intruder aircraft at an average distance of 1.90 miles and the SR20 intruder aircraft at an average of 1.46 miles.

Figure 1 shows the percentile distribution for intruder detection distance calculated for the A46 encounters with C172 intruder aircraft, SR20 intruder aircraft, and the combined dataset. The VOs detected the intruder aircraft (C172 & SR20) at a distance of at least 1 mile in 89.5% of the runs, a distance of at least 2 miles in 22.6% of the runs, and a distance of at least 3 miles in 3.3% of the runs. The VOs detected the C172 intruder aircraft at a distance of at least 1 mile in

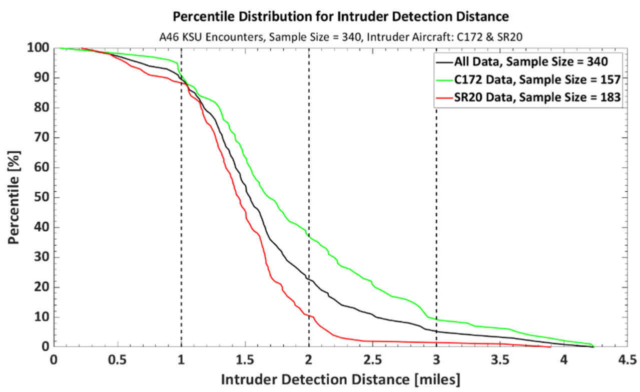


Figure 1. Percentile distribution for intruder detection distance calculated for the KSU flight testencounters.

90.8% of the runs, a distance of at least 2 miles in 37% of the runs, and a distance of at least 3 miles in 9.2% of the runs. The VOs detected the SR20 intruder aircraft at a distance of at least 1 mile in 88.3% of the runs, a distance of at least 2 miles in 10.5% of the runs, and a distance of at The research team also evaluated the statistical relationship between the intruder detection distance and the independent variables in the A46 experiment design. The first independent variable investigated was the ambient light level at the time of detection. Figure 2 shows the relationship between the intruder detection distance values and the ambient light level at the time of detection. A linear regression model was computed for this data. The coefficient of determination (R2) value for the regression model is very low (< 1), indicating a high spread for the data. The Spearman correlation (rs) value was computed to be -0.17 for this data indicating a weak negative correlation between the intruder detection distance and the ambient

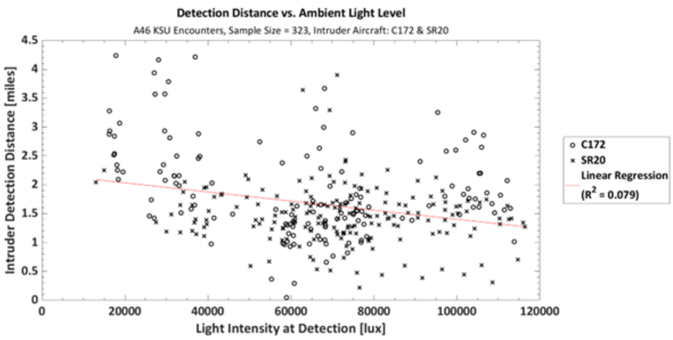


Figure 2. Scatter plot for intruder detection distance vs. light intensity at detection for the KSU flight test encounters.

light level. The Spearman probability (ps) value was computed to be 0.022 (< 0.05), indicating a statistically significant relationship between the intruder detection distance and the ambient light level.

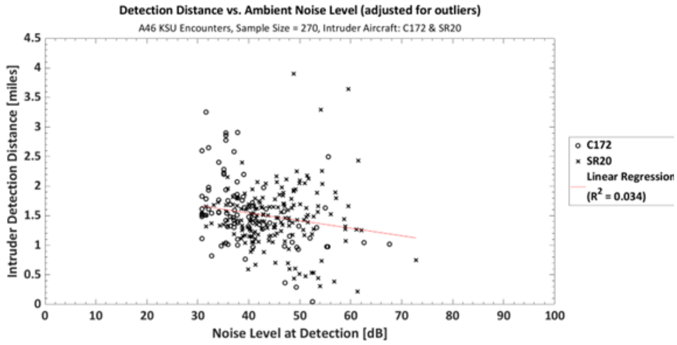


Figure 3. Scatter plot for intruder detection distance vs. noise level at detection (adjusted for outliers) for the KSU flight test encounters.

The second independent variable investigated was the ambient noise level at the time of detection. Figure 3 shows the relationship between the intruder detection distance values and the ambient noise level at the time of detection, adjusted for outliers. The majority of the noise level readings shown in the figure are in the range of 30 to 60 dB. The outlier data included noise level readings from the Day 2 tests in the 60 to 90 dB range.

The third independent variable investigated was the VO Aviation Experience level. The research team defined three categories for the VO Aviation Experience level – Low, Medium, and High. VOs with no prior aviation experience were categorized as Low. VOs that were remote pilots or student pilots were categorized as

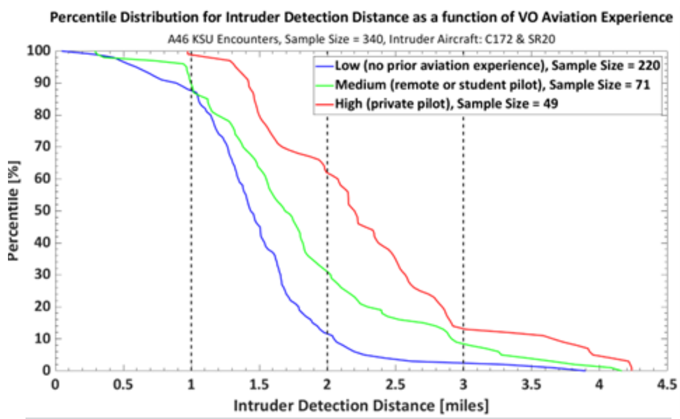


Figure 4. Percentile distribution of intruder detection distance as a function of the VO Aviation Experience categories for the KSU flight test encounters.

Medium. VOs that completed their private pilot certification were categorized as High. Figure 4 shows the percentile distribution for the intruder detection distance as a function of the VO Aviation Experience categories.

Figure 5 shows the percentile distribution for the intruder detection distance as a function of the VO Visual Acuity categories. The ANOVA test

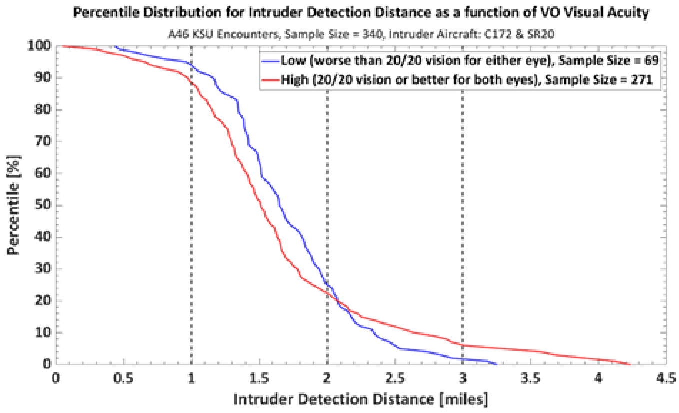


Figure 5. Percentile distribution of intruder detection distance as a function of the VO Visual Acuity categories for the KSU flight test encounters.

p-value was computed to be 0.6140 (> 0.05), indicating a statistically insignificant relationship between the intruder detection distance and the VO Visual Acuity. As seen in Figure 5, the VO detection performance was similar for the Low and High categories of VO Visual acuity. The total number of observations was 69 for the Low category and 271 for the High category.

The fifth independent variable investigated was the intruder aircraft speed at the time of detection. Figure 6 shows the relationship between the intruder detection distance values and the intruder aircraft speed at the time of detection. A linear regression model was computed for this data. The coefficient of determination (R2) value for the regression model is very low (< 1), indicating a high spread for the data. The Spearman correlation (rs)

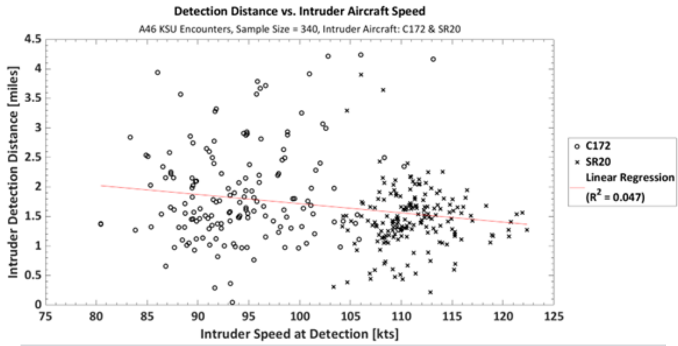


Figure 6. Scatter plot for intruder detection distance vs. intruder speed at detection for the KSU flight test encounters.

value was computed to be -0.18 for this data indicating a weak negative correlation between the intruder detection distance and the intruder aircraft speed. The Spearman probability (ps) value was computed to be 0.001 (< 0.05), indicating a statistically significant relationship between the intruder detection distance and the intruder aircraft speed.

INTRUDER SPEED AT DETECTION [KTS]

Intruder Aircraft: C172, Sample Size = 157 Runs				
Min.	Max.	Mean	Median	Std. Dev.
80.4	113.1	94.2	93.7	5.9
Intruder Aircraft: SR20, Sample Size = 183 Runs				
Min.	Max.	Mean	Median	Std. Dev.
103.3	122.4	111.1	110.6	3.6

Table 2. Descriptive statistics for intruder speed at detection for the KSU flight test encounters.

Table 2 provides the descriptive statistics for intruder speed at detection for the A46 encounters for both the C172 and SR20 intruder aircraft. The average speed for the SR20 intruder aircraft was 18% higher than the average speed for the C172 intruder aircraft. The statistical analysis suggests that a higher intruder aircraft speed degrades VO detection performance, as seen in Figure 1 for the SR20 intruder aircraft runs.

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SMALL UAS (sUAS) MID-AIR COLLISION (MAC) LIKELIHOOD

LEAD UNIVERSITY : WICHITA STATE UNIVERSITY'S NATIONAL INSTITUTE OF AVIATION RESEARCH

A11L.UAS.89_A47

BACKGROUND

This research focused on sUAS Beyond Visual Line of Sight (BVLOS) operations. Specifically, operations where a Detect and Avoid (DAA) system can be used to waive sections 14 Code of Federal Regulations (CFR) §107.31 and §107.51 or for BVLOS operations entirely outside of Part 107 (such as those under Part 91). This research provides analytical results of encounter set evaluations in terms of the probability of a Mid-Air Collision (MAC) given a Near Mid-Air Collision (NMAC), P(MAC|NMAC).

This research employed six sUAS models with up to 15 ft. wingspan. Similarly, four different

manned aircraft models were identified to perform the collision analysis. Airborne Collision Avoidance System (ACAS) sXu DO-396 was adopted as the DAA logic, along with two surveillance sources for the mitigated encounter evaluation: Automatic Dependent Surveillance-Broadcast (ADS-B) for cooperative intruders and a generic ground-based radar-like for non-cooperative intruders. The DO-396 draft informed the minimum operational performance requirements of each sensor.

A MAC severity assessment of unmitigated and mitigated MAC was completed. The assessment utilized past MAC severity research findings between manned aircraft and sUAS. This study adapted the past findings to fit the broader conditions of the recorded MAC cases. Each manned aircraft model's average unmitigated and mitigated severity was estimated on a 1 to 4 scale. However, the low number of unresolved MACs hindered the mitigated severity distribution. The wide confidence intervals evidenced this in the mitigated datasets. The lack of severity data was also evident throughout the MAC severity analysis. Previous research only addressed conservative worst-impact conditions in manned aircraft locations where head-on collisions were expected. The development of an impact severity classification was divided into these elements:

- **Estimating the MAC probability** between UAS and manned aircraft. This was analyzed as a function of the operating airspace, aircraft operating within the airspace, and the sUAS configurations operating within the shared airspace. The mitigation performance of a DAA system (ACAS sXu DO-396) was evaluated and compared to the results from the unmitigated MAC analysis.
- **Evaluation of damage potential for typical sUAS** (classes based on weight, architecture, and operational characteristics like altitude and velocity) mid-air collision scenarios per manned aircraft class in order to assess the damage severity to manned aircraft. The primary objective was to assess the severity of collisions involving standard quad and fixed-wing sUAS with manned aircraft, with the sUAS size specifications being guided by ASTM F3442 standards. Mitigated and unmitigated results were evaluated to understand the efficacy of the DAA system, not only in reducing the probability of MAC but also in diminishing the severity of such incidents when they occur.

APPROACH:

Task 1: Literature Review

The research team successfully identified pertinent research and documentation related to MAC between UAS and manned aircraft. This encompassed a thorough historical analysis of sUAS MAC incidents and an assessment of bird strike risks involving manned aircraft. The collected information was crucial in preparing simulations, tests, demonstrations, and subsequent analyses to assess MACs and validate associated standards.

Task 2: Unmitigated MAC Probability

The researchers investigated and developed detailed estimations of unmitigated MAC probabilities utilizing MIT Lincoln Laboratory (MITLL) encounter models. Each model generated statistically representative trajectories by following the data employed during its training. For example, the initial uncorrelated model was trained using radar data sourced from the 84th Radar Evaluation Squadron (RADES) network. To create an encounter, sUAS and manned aircraft trajectories had to be paired. In this study, sUAS trajectories generated from the Geospatial Encounter model were paired with manned aircraft trajectories from six Bayesian uncorrelated encounter models. These datasets included a variety of representative sUAS as well as general aviation and commercial aircraft, focusing on encounters that did not utilize a DAA system. Furthermore, the research performed an analysis of collision probabilities with individual components of a manned aircraft, such as wings, canopy, rudder, elevator, and others.

Task 3: Mitigated MAC probability

The research team investigated and developed detailed mitigated MAC probabilities, focusing on encounters wherein a DAA system was utilized to minimize MAC events. Specifically, the ACAS sXu DO-396 was identified as the DAA algorithm employed for the mitigated analysis. The researchers studied the impact of sUAS DAA system capabilities in reducing the probability of collisions between an sUAS and a manned aircraft. Additionally, the investigation identified required surveillance sources, both on-board and off-board the sUAS, for cooperative and non-cooperative encounters, which included ADS-B and ground-based radars. Each surveillance source's noise, error, or bias was derived from the Minimum Operational Performance Standards (MOPS) DO-396. In a manner similar to the unmitigated analysis, a MAC probability analysis was executed, wherein the collision location was identified, and corresponding impacted parts, such as wings, rudder, and cockpit, were also determined.

Task 4: sUAS Unmitigated and Mitigated MAC Risk Assessment for General Aviation, Rotorcraft, and Commercial Aircraft

The research team blended studies of MAC probabilities and past research on collision severity to make a complete risk assessment for manned aircraft. Using earlier research sponsored by the FAA, a scoring system was used to rank the severity of the MAC events. This system used earlier findings from ASSURE and the FAA, tying sUAS size, type, and speed to the damage seen on the aircraft. The methodology used was built on several mid-air collision damage assessments from past research. This used available data on the severity of collisions for different sUAS and manned aircraft models and created a link between severity level and impact energy to assess unknown cases by interpolating known data. This method allowed all MAC cases to be studied based on impact energy, considering all the vehicles' sizes, weights, and speeds involved.

A novel approach was employed using a machine learning algorithm, the Random Forest Regression, to better estimate collision events' severity based on factors like impact orientations and energy. This model, trained on a subset of MAC cases, predicted energy scale factors for diverse collision situations. This led to more accurate recalculations of impact energy and severity levels. The method enhanced both the precision of MAC severity evaluations and adaptability for real-world interactions between sUAS and manned aircraft in the NAS.

Task 5: Comparative Risk Assessments With Other Aviation Risks to Include Bird Strikes

The research team successfully conducted an extensive risk assessment analysis, comparing the risks posed by sUAS to those of bird strikes, leveraging and synthesizing data from existing FAA-sponsored studies. Focusing on incidents involving entities of similar weight, the severity and frequency of both sUAS and bird strike incidents were critically examined.

Task 6: Final Report

After completing the specified tasks, all findings and recommendations for future research were compiled into a Final Report. This document was submitted for review, subsequently approved, and is now publicly available on the ASSURE official website.

KEY FINDINGS:

The research team generated 3 million encounters using MITLL encounter models, evaluating them both with and without the ACAS sXu DAA system for mitigation. ADS-B and ground-based radar were utilized in the analysis. Sensor errors were modeled following the RTCA SC-127 Minimum Operational Performance Standards for Airborne Collision Avoidance System sXu (ACAS sXu) (DO-396). Some of the key findings include:

- ACAS sXu meets the NMAC and loss of well clear ratio safety targets specified in ASTM F3442-20.
- ACAS sXu mitigated all MACs in the cooperative encounter sets
- ACAS sXu mitigated approximately 95% to 98% MACs in the non-cooperative encounter sets
- ACAS sXu also provides a net benefit in reducing P(MAC|NMAC). MAC ratios were estimated between 0.55 and 0.25 for all the aircraft pairs analyzed.
- Four manned aircraft models and six sUAS models were used during the collision detection. These models originated from previous ASSURE research programs.
- This study also showed that the size of sUAS can be considered a passive MAC mitigation factor.
- The unmitigated P(MAC|NMAC) is lower by a factor of 2 from the smallest to the largest sUAS, assuming both aircraft have the same capabilities.
- MAC severity estimations:
  - Commercial Transport: MAC cases with sUAS over 25 lbs. showed significant impact severity, especially on the horizontal stabilizer (60% at level

4). Further research is required on fuselage and engine MACs due to limited data.

- Business Jet: There's a noticeable difference between unmitigated (avg. 2.06) and mitigated (avg. 1.69) severities. Concerns are from impacts on the vertical tail and windshield with severities of 2.58 and 3.15, but low sample sizes reduce confidence.
- General Aviation (Single-Engine): Studies on single-engine models indicated an average unmitigated severity of 3.31 versus a mitigated severity of 3.35. While wings showed the most impact, the broad confidence interval and limited data make definitive conclusions challenging.
- Rotorcraft: MAC evaluations for rotorcraft were limited due to data scarcity. Severity data from lighter sUAS were used to estimate impacts for 25 lbs. and 55 lbs. models. The limited evaluations underscore the need for more comprehensive data and analysis.

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UAS FLIGHT DATA RESEARCH IN SUPPORT OF ASIAS

LEAD UNIVERSITY : UNIVERSITY OF NORTH DAKOTA

A11L.UAS.43_A49

BACKGROUND:

This research will aggregate high quality UAS flight data with commercial and general aviation flight data and surveillance data, in order to develop enhanced safety analyses for National Airspace System (NAS) stakeholders and to support UAS integration in the NAS.

The overarching purpose of this research is to enable safe integration of UAS in the NAS through building upon existing aviation database and data-sharing efforts encouraged and endorsed by participating government-industry entities. Through this research, a data architecture for unmanned air and ground vehicles and operations will be developed in alignment with the FAA's Aviation Safety Information and Sharing (ASIAS) program.

This project will design and evaluate Flight Data Monitoring (FDM) for unmanned operations and integrate that data into the ASIAS system. In addition, this project will integrate the findings from ASSURE project A20 -UAS Parameters, Exceedances, and Recording Rates for ASIAS, which identified current UAS FDM capabilities and practices, including refresh/recording rate and robustness, and developed guidance for a UAS FDM standard. The team includes original members, UND and ERAU, who designed and deployed the National General Aviation Flight Information Database (NGAFID), which has successfully integrated and is data-sharing with ASIAS.

APPROACH:

Task 1: Configure Storage and Formatting Requirements of Unmanned Data.

The research team will configure storage and formatting requirements of unmanned data in the NGAFID database, or a database with the same look and underlying infrastructure.

Task 2: Configure and Implement a Prototype System to Collect Unmanned FDM Records From Industry and Academic Participants.

In this task the team will configure and implement a prototype system to collect unmanned FDM records from industry and academic participants, preferably combined with ngafid.org, or an equivalent.

Task 3: Collect Unmanned Flight Data Monitoring records.

In Task 3, the researchers will collect at least 1000 flights of Unmanned FDM records. Up to half of the flights may be simulated (FAA Tech Center and NASA offer to contribute), but representative of actual drone missions. The remaining flights must be actual flights over the US in the past two years. The flights will be diverse in duration (five to 90 minutes), weight (0.4 pound to 80 pounds), and configuration (transponder-equipped and not, quad-rotor and fixed wing), and will be published on a public website to display aggregate statistics and the diversity of the flights collected.

Task 4: Interface with Unmanned Communities and Gather Industry Feedback.

The researchers will interface with unmanned communities such as UAST through conferences and symposia to determine their biggest concerns with aviation safety risk. They will evaluate industry recommendations for encouraging voluntary submission of Unmanned Flight Data Monitoring. The research will include prioritization by industry of specific safety risks that are best analyzed with Unmanned Flight Data Monitoring.

Task 5: Measure the Risk of Collision Between Unmanned and Manned Aircraft.

This research will measure the risk of collision between unmanned and manned aircraft. The risk will be calculated using the flights collected previously. At a minimum, the team will calculate and model the risk of collision with proximity and closure rate and measure how closely this model approximates the performance of TCAS, ACAS, or similar algorithms currently used in aviation.

Task 6: Measure a Novel Risk Identified Through the Community Outreach Above.

The researchers will measure a novel risk identified through the community outreach in previous tasks, which will be displayed on the public webpage at an aggregate level.

Task 7: Create Visualizations of Collision Risk and Battery Performance.

Within Task 7, the researchers will create visualizations of collision risk and battery performance. These visualizations will be available at an aggregate level on the website published in previous tasks. The visualization will show locations and configurations with more than five incidents of high risk as calculated above and at least ten locations, each with more than five incidents of high risk.

Task 8: Final Report.

All of the findings will be summarized into a Final Report, including recommendations for future research based on the gaps identified during the execution of this research.

KEY FINDINGS:

The project built upon ASSURE project A20, which identified UAS parameters, exceedances, and recording rates for UAS and moved to incorporate the data into the NGAFID. The project successfully achieved its objectives by configuring storage and formatting requirements for unmanned data, developing a prototype system to collect unmanned Flight Data Monitoring records, collecting over 1000 flights of UAS data, and interfacing with unmanned communities to gather industry feedback.

The successful implementation of this project is a significant milestone for UAS safety. It provides valuable information and data on the safety and performance of UAS operations, which can help improve safety risk management and enable the development of new safety technologies for UAS. The project used a combination of information technology and outreach to a diverse assortment of stakeholders, including manufacturers, unmanned operators, and regulators, to ensure that the data collected and analyzed are relevant and representative of the industry. The project's success is a testament to the collaboration between industry and government in promoting UAS safety.

Based on the findings of the research team, there are numerous future research opportunities in the area of UAS flight data for the ASIAS program. The team identified challenges with data consistency, accuracy, and cleanliness and recommended future research to develop a data standardization framework. This framework should include data harmonization and a minimum data standard to ensure comparability with other flight data in the ASIAS program. Another area for future research is data accessibility, including identifying efficient means of accessing flight data and providing a data dictionary to decode flight data into logical parameters for analysis. Additionally, the quality of UAS flight data is largely uncontrolled and varies widely, so future research should focus on establishing data quality controls to ensure that safety analytic results are valid. Finally, future research should address the lack of a common naming convention or data unit standard for UAS flight data, with the aim of developing a minimum recording standard that all manufacturers can comply with.

Moving forward, the data collected by this project can be used to support research, policy development, and safety risk management activities related to UAS. The project's achievements have contributed to the development of a robust system to collect and process UAS flight data for the purposes of safety monitoring and system integration, which will continue to evolve as the UAS industry matures. It is essential to continue to collect and analyze data on UAS operations to improve safety and enable the safe integration of UAS into the NAS.

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SMALL UAS TRAFFIC ANALYSIS

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LEAD UNIVERSITY : EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

A11L.UAS.91_A50

BACKGROUND

A report by the National Academies of Science, Engineering, and Medicine (NASEM, 2018) suggests the FAA should expand on quantitative data collection to address risk as it pertains to UAS integration as the qualitative nature of current risk management approaches implemented to address UAS risk initiates results that fail to be repeatable, predictable, scalable, and transparent. According to the NASEM (2018) report "Assessing the Risks of Integrating Unmanned Aircraft Systems into the National Airspace System," there is an inherent need for an empirical data-driven approach to inform LEAD UAS policy decision-making. The report ascertains that successful UAS integration into the National Airspace System (NAS) is reliant

on the creation of probabilistic risk assessment as "Accepting risk is far easier when the risk is well quantified by relevant empirical data" (NASEM, 2018, p. 41). Nevertheless, the authors acknowledge the limitations associated with collecting the required empirical data, noting that such data are "expensive to collect, scarce, or non-existent, and in some cases not very reliable. . ." (NASEM, 2018, p. 39).

In order for the FAA to continuously manage the safety of UAS operations in the NAS, the FAA needs to identify, assess, mitigate, and monitor safety hazards and risks. The FAA also needs to proactively plan for future sUAS growth and future aviation risks associated with the integration of UAS in low-altitude airspace. The purpose of this research is to leverage near-real time and historical UAS detection data from emplaced UAS detection sensors placed across the country at various convenience sample locations across the NAS. The analysis of UAS traffic data will serve useful for monitoring the effectiveness of existing sUAS regulations. It will provide useful information for sUAS traffic forecasts to aid in identifying and assessing future aviation risks and support policy decision making.

Therefore, this research will serve as a foundation to address the inherent need to collect empirical data required to conduct sUAS traffic analysis that will support the FAA in conducting risk assessments, as well as forecasting, planning, and estimating compliance rates to existing and future regulations. Analysis is desired to estimate the effectiveness of current regulations, rates of sUAS that exceed Part 107 operations, sUAS encounters with manned aircraft, sUAS operations in proximity to airports, information useful for informing UAS Traffic Management (UTM) requirements, informing future Urban Air Mobility (UAM) route planning, market forecasts, and so forth.

This work addresses requirements in the FAA Reauthorization Act of 2018. Specifically:

- Section 342, where Congress tasked the FAA to consider "the use of models, threat assessments, probabilities, and other methods to distinguish between lawful and unlawful operations of unmanned aircraft."
- Section 44805, where Congress tasked the FAA to consider "Assessing varying levels of risk posed by different small unmanned aircraft systems and their operation and tailoring performance-based requirements to appropriately mitigate risk" before accepting consensus based standards.

- Section 44805, where Congress tasked the FAA "To the extent not considered previously by the consensus body that crafted consensus safety standards, cost-benefit and risk analyses of consensus safety standards that may be accepted pursuant to subsection (a) for newly designed small unmanned aircraft systems."
- Section 44807, where Congress grants special authority for the Secretary of Transportation to use a risk-based approach to determine if certain unmanned aircraft systems may operate safely in the national airspace system notwithstanding completion of the comprehensive plan and rulemaking required by Section 44802 or the guidance required by Section 44806. Special authority is granted to approve beyond visual line of sight operations provided that they do not create a hazard to users of the national airspace system. If deemed safe, the Secretary shall establish requirements for the safe operation of such aircraft systems.
- Section 376, where Congress tasked the FAA to assess the use of UTM services including "the potential for UTM services to manage unmanned aircraft systems carrying either cargo, payload, or passengers, weighing more than 55 pounds, and operating at altitudes higher than 400 feet above ground level" - sUAS traffic data will help inform the amount of traffic that UTM will need to manage.
- Section 44808 directs the FAA to plan for the carriage of property by small unmanned aircraft systems for compensation or hire. The FAA is to consider the unique characteristics of highly automated, small unmanned aircraft systems and include requirements for the safe operation of sUAS that address airworthiness. Small UAS traffic data will help to inform sUAS package delivery requirements, such as a Beyond Visual Line of Sight sUAS detecting and avoiding another sUAS. This work effort is an important contributor to developing policy and regulations for sUAS, including the effectiveness of sUAS detect and avoidance of other sUAS, sUAS package delivery, UTM, airspace planning, and future Urban Air Mobility plans. The research will inform the FAA on the effectiveness of Part 107 regulations and remote identification regulations.

Proposed Approach

- The revised research task plan aims to bolster the understanding of sUAS operations within the NAS using Remote Identification detection technology. With data sourced from select locations across the United States, the plan outlines a series of methodological tasks designed to provide a robust analytical framework. Specific emphasis is placed on the following objectives:
- Assessing the effectiveness of existing regulations under 14 CFR 107;
- Measuring exceedances to Part 107 operational limitations;
- Determining the state of sUAS operations and activity in proximity to aerodromes;
- Assessing the risk of potential sUAS encounters or collisions with aircraft operating within the NAS; and
- Providing findings and recommendations that may inform the development of UTM requirements and UAM route design.

The accomplishment of the aforementioned objectives should yield the following results:

- Supporting sUAS forecasting and planning processes;
- Furnishing data and analysis that supports sUAS operations risk assessment evaluations;
- Informing the development of future sUAS regulation and policy-making; and
- Creating analysis benchmarks and methodologies for assessing Remote Identification (RID) data

Task A: Analysis Tool Adaptation

The focus of this task is to modify existing Unmanned Robotics Systems Analysis (URSA) Airspace Awareness analytics platform tools, enabling it to integrate, process, and display new Remote ID datasets. These modifications will enable researchers to monitor the implementation of Remote ID among the population of sUAS at the project's several sampling locations.

Task B: Current State of sUAS Traffic within the National Airspace System

This task delves into a descriptive analysis of current sUAS traffic, based on Remote ID data trends. The research will use the Remote ID data to address questions surrounding traffic attributes in urban areas, estimated registration rates, and flight patterns.

Tasks C: Compliance and Exceedances of 14 CFR 107 Operational Limitations

In this task, the focus shifts to assessing compliance. The research team will assess sUAS operations adherence and exceedances to various provisions of Title 14 CFR, with emphasis on Parts 107 and 48. Through a series of subtasks, the researchers will identify exceedance rates of various operational restrictions, such as sUAS altitude, speed, line-of-sight, and other factors.

Task D: Near Aerodrome sUAS Operations & Encounter Risks with Manned Air Traffic

This task evaluates sUAS operations conducted in proximity to aerodromes. It aims to provide insights into the likelihood of near encounters between sUAS and manned aircraft and the identification of high-risk areas or "hotspots" where sUAS operations may be particularly problematic.

Task E: Forecasting Industry Growth and Potential Advanced Air Mobility Implications

This task is forward-looking, leveraging gathered data to make informed predictions about sUAS industry growth. The research team will assess strategies to improve sUAS integration and safety within the NAS. Potential implications to advanced aviation operations, such as Advanced Air Mobility (AAM) and UTM, will also be assessed.

Task F: Communicating Findings

This task will focus on the dissemination of study findings, culminating in written reports, briefings, and other deliverables in accordance with grant obligations. Importantly, project research findings will be shared with industry stakeholders to inform future standards and policy formulation.

KEY FINDINGS:

Preliminary findings are available on the ASSURE project website. Transitioning to new Remote ID data promises a more holistic analysis since researchers can observe sUAS activity from all sUAS platforms equipped with Remote ID-compliant equipment. The emphasis on RID, with its capabilities likened to a digital license plate for UAS, emphasizes the commitment to ensuring both safety and efficiency in the airspace. This shift also allows for a deeper exploration of Remote ID effectiveness. Over the remainder of the project, the research team will also evaluate sensor systems, antenna configurations, signal interference, and other potential impediments to the efficient application of Remote ID. Additionally, the involvement of external business partners leverage the combined expertise of academia and industry in producing data-driven insights about sUAS operations and development that will be pivotal for the FAA and the broader aviation community.

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BEST ENGINEERING PRACTICES FOR AUTOMATED SYSTEMS

LEAD UNIVERSITY : OREGON STATE UNIVERSITY

A11L.UAS.92_A51

BACKGROUND

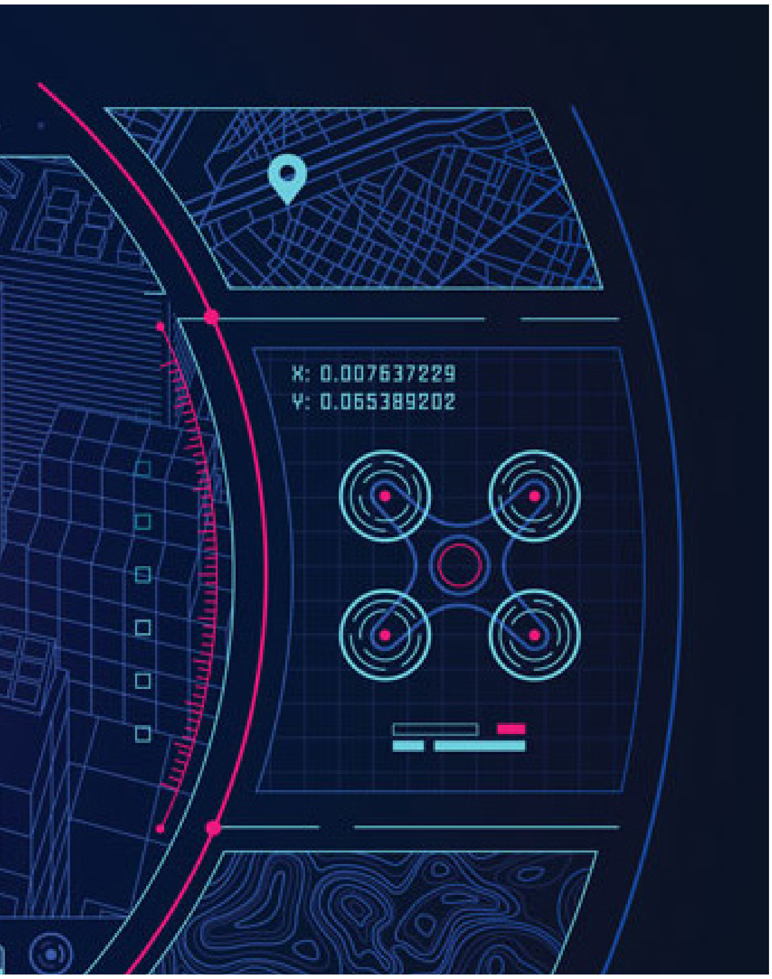
Advances in aviation are evolving towards a wider range of fully automated functions, all the way from perception (translating raw sensor data into actionable information) to control. Many of these advances are occurring with UAS (regardless of size), in which the trend is towards assigning the human over-the-loop control and allowing the automation to manage the perception-planning-control loop, operating beyond visual line of sight and flying in more densely populated areas. It is therefore essential to establish what potential risks and benefits there may be with increased automation in such environments and the best approaches

towards maximizing safety and efficiency. System architecture must be shown to be capable of handling contingencies, failures, and degraded performance, while continuing safe flight and landing.

APPROACH:

Task 1: Literature Review and Structured Interviews

The team performed a broad literature review of automation failures affecting UAS, and other highly automated aviation functions that are reused or re-usable in UAS. The literature review identified root causes of automation failures for UAS operations, and other aviation systems that are relevant to UAS. A significant portion of the literature review focused on UAS automation failures. The team complemented the literature review with structured interviews with Subject Matter Experts (SMEs) involved in the design, testing, and use of UAS and in traditional, manned aircraft operations.



Task 2: Risk Assessment and Preliminary Mitigations

This task determined whether existing design principles, guidance, tools, methods, etc., could have prevented the faults listed in Task 1 (had they been applied), or whether they might have even contributed to these faults. It also developed appropriate risk assessment methods in light of these findings.

The PIs, and structured interviews with SMEs serving as consultants on the project, identified existing mitigations for found root causes and contributing factors. The existing methods can be very roughly divided into design changes to the specific system that failed or the operational environment in which it was used, and broader design principles and methodologies.

Task 3: Develop Design Guidance and Best Engineering Practices

This task will 1) develop new guidance and engineering best practices for autonomous UAS and 2) put into practice new guidance for specific automated functions of UAS.

Task 4: Validation of Design Guidance

This task will validate the methods developed in Task 3 and apply the risk assessment methods developed in Task 2, in simulation, limited flight testing, and by expert review.

KEY FINDINGS:

This project is just completing Task 2 and will be delivering a report summarizing the research into methods to mitigate the failures of autonomous systems as identified from our literature review in Task 1. This report is focused on the following areas related to autonomous UAS: Perception, Sensors, Control Architectures, Runtime Verification, Cyber-Physical Security, Probabilistic Risk Assessment, Robust Inference, Environmental Modeling, and Flight Testing. A few of the preliminary conclusions and outcomes from this work are as follows.

1. Atmospheric turbulence limits the effective resolution of optical imaging in many long-range observation applications. Image processing techniques can mitigate some of these effects, but they apply to classical cameras in which the frame rate is typically too low to capture all the dynamics of the turbulence-induced changes in the images. Neuromorphic cameras do not record an entire frame but instead output an asynchronous stream of changes (so-called events) so that the bandwidth and the recording resources are best used to record the local dynamics of the scene. This additional information may improve the quality of the restored turbulence-free.
2. The perception survey has pointed to the difficulties of navigating dense airspace with less-than-great perception performance. Any motion planning algorithm must be demonstrably capable of meeting these difficulties. Right-of-way rules that might be proposed must also make a rigorous argument, backed by simulation or real flight, that they can ensure safety of air traffic under these perception conditions, and under these projected densities.
3. The robust inference survey noted that most mitigations do not consider the possibility of adversarial sensor data falsification even though many sensing modalities are known to be prone to it with cheap hardware. There is a need to develop mitigations that account for data falsification, guided by the known vulnerabilities identified by the security survey and by the practical possibilities supported by UAS builds.
4. There is a need for a catch-all function: one that detects (but does not necessarily diagnose) a change in the dynamical laws governing the UAS, and which re-learns the current applicable dynamical model to maintain minimal safe control.
5. The Flight-Testing survey has highlighted that Machine Learning (ML)-based controllers can outperform more traditional controllers in certain settings. However, as observed there, there isn't yet rigorous validation and verification of AI-based flight controllers, whether in design-time mathematical analysis, automated (formal methods-based) verification, or in-flight tests. This is a dangerous gap, since ML-based controllers are much less predictable than more traditional controllers. This research would aim at filling this gap, to establish a baseline of what is achievable before developing corresponding guidance.
6. A first general principle is that the accuracy of the Probabilistic Risk Analysis (PRA) will depend critically on the ability to characterize the uncertainty state space and to characterize or approximate the joint distribution on S. Researchers often use the term, "known unknowns", which emphasizes the underlying assumption, often not true in practice, that the risk assessor has sufficient information at the time of assessment about the CONOPS to meaningfully enumerate all sources of uncertainty that

may impact the hazard causes and/or hazard effects. Clearly, there are cases where even listing all such factors is not feasible, much less identifying their joint distribution. Without a meaningful joint distribution on the uncertainty state, however, this proposed framework cannot be relied upon to produce meaningful risk-related estimates. Much more, the researchers will assert that absent this information it will be difficult for any framework to produce meaningful risk-related estimates. Future work should investigate the extent to which the uncertainty state space can be described and the extent to which credible estimates of the joint distribution may be computed.

APPROACH:

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assert that absent this information it will be difficult for any framework to produce meaningful risk-related estimates. Future work should investigate the extent to which the uncertainty state space can be described and the extent to which credible estimates of the joint distribution may be computed.

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DISASTER PREPAREDNESS AND EMERGENCY RESPONSE - PHASE II

LEAD UNIVERSITY : UNIVERSITY OF ALABAMA – HUNTSVILLE

A11L.UAS.68_A52

BACKGROUND

In Phase I (A28), policies, procedures, guidelines, best practices, and a coordination framework for a UAS to aid in disaster preparedness and response were developed for different natural and human-made disasters with collaboration at the local, state, and federal level.

APPROACH:

This research will allow the research team to exercise via mock events and demonstrations the findings found in Phase I. The effort will focus on refinement of procedures, policies, and guidelines, and document lessons learned and training objectives.

KEY FINDINGS

There is a broad spectrum of knowledge, experience, and ability to contribute among likely first responders utilizing UAS. Similarly, there is a broad range of understanding within response organizations as to the most effective ways to use drones in disaster response situations. Therefore, there exists a need for a set of recognized Minimum Operational Proficiency Standards (MOPS) as suggested in recent A52 technical interchange meetings. This would enable UAS operators to be credentialed in recognition of certain minimum competencies and allow response organizations to better utilize the UAS through an understanding of operators' capabilities.

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GRADUATION OF STUDENTS:

REBECCA GARCIA, MSU	MAY 2023

PROPOSE UAS RIGHT-OF-WAY RULES FOR UNMANNED AIRCRAFT SYSTEMS (UAS) OPERATIONS AND SAFETY

LEAD UNIVERSITY : UNIVERSITY OF NORTH DAKOTA

A11L.UAS.97_A54

BACKGROUND

Right-of-way rules govern the interactions between non-cooperative aircraft in order to maintain safe interactions. Right-of-way rules were derived in part from the See-and-Be-Seen safety concept, the maneuverability limitations of aircraft types to give way, and other safety considerations. The research effort is to develop safety-based recommendations to the FAA for UAS right-ofway rules in order to better accommodate UAS integration into the National Airspace System (NAS). The research effort will also benefit UAS standards (e.g. Detect and Avoid [DAA], aircraft lighting, etc.) to improve safety and compliance with right-ofway rules.

The purpose of answering the research questions is to enable the research performers to develop and propose guidance, recommendations, and/or requirements useful for:

- FAA decision-making
  - Examples include: UAS waiver assessments, policy development, rule-making, etc.

for UAS right-ofway rules in order to better accommodate UAS integration into the National Airspace System (NAS). The research effort will also benefit UAS standards (e.g. Detect and Avoid [DAA], aircraft lighting, etc.) to improve safety and compliance with right-ofway rules.

The purpose of answering the research questions is to enable the research performers to develop and propose guidance, recommendations, and/or requirements useful for:

- FAA decision-making
  - Examples include: UAS waiver assessments, policy development, rule-making, etc.
- industry standards development
  - Examples include: design standards, training standards, operations and procedure standards, etc.

APPROACH:

Task 1: Background Report

The performer has performed a literature review on topics related to right-of-way rules for manned and unmanned aviation. The literature review included historical information and the pedigree of safety concepts that led to existing right-of-way rules to include the see-and-be-seen concept. It included domestic right-of-way rules and international right-of-way rules as applicable. It also included assumptions and other rules such as ceiling minimums or separation from clouds that existing right-of-way rules for UAS operations. The literature review included references to incidents or accidents that have occurred that were pertinent to the subject matter. The performer identified existing and future planned UAS operations that may have difficulty integrating into the NAS due to gaps in right-of-way rules. The literature review included information needed to answer the research questions listed in the background section to include research data on aircraft conspicuity, information on unmanned aircraft types, sizes, and number of aircraft, fielded and anticipated DAA systems, emerging UAS guidance decision-making capability using a range of traffic detection systems, the role of automation failures within a DAA system, industry plans and priorities for UAS integration that may impact research priorities with respect to right-of-way rules, and so forth. The literature review considered applicable AAM/UAM aircraft types and concepts of operation that should be considered when recommending updates to right-of-way rules. The literature review included academic, government, and industry sources. Based on the findings in the literature review, the performers developed an initial safety hierarchy useful for understanding and justifying existing aviation right-of-way rules. The safety hierarchy included the safety rationale or concepts that leads to different right-of-way priorities and rules. The performers also identified criteria for when additional right-of-way rules might be unnecessary or burdensome. The report included sufficient coverage of the subject matter to provide a broad background, inform follow on research tasks, and to be used as a reference for safety recommendations developed by the project. The report was peer reviewed by the ASSURE performers and appropriate subject matter experts determined by the FAA, and comments were adjudicated.

Task 2: UAS Gap Prioritization, UAS Safety Hierarchy, and Recommendations

The performers assessed identified gaps in right-of-way rules and prioritized them based on industry needs, safety considerations, ability for the researchers to providing meaningful data to help the FAA close those gaps, or other applicable criteria. The performers further developed the safety hierarchy to expand it to encompass a wide diversity of UAS operations and DAA capabilities. They used the expanded safety hierarchy and safety justifications to propose new right-of-way rules for UAS operations in areas where there are gaps. The performer also identified and prioritized the research needed to address gaps in UAS right-of-way rules. The performers peer reviewed the

prioritization of gaps in right-of-way rules as well as the proposed safety hierarchy and its justifications, any newly proposed right-of-way rules for UAS operations, and areas of research needed to close gaps with applicable subject matter experts.

Task 3: Research Planning

In coordination with the FAA sponsors, the performers have prioritized research to be conducted in follow-on tasks based on available resources, project schedule, industry need, safety considerations, and other applicable criteria that is needed to address the gaps in UAS right-of-way rules. Based on the research prioritization, the researchers developed a simulation plan and initial flight test plans to validate right-of-way rule recommendations or to collect the needed information to make right-of-way rule recommendations.

Some of the research plans will include:

- Simulations to validate proposed right-of-way rules using physics-based simulations of UAS and crewed aircraft maneuvering, including expected computational decision-making and communication latencies and automation failures.
- Simulations in Task 3 have included both single and multiple-UAS interactions with other UAS or crewed aircraft, focused primarily on Beyond Visual Line Of Sight (BVLOS) and below 400 Above Ground Level (AGL). The simulation plan has focused around 3 areas:

1. General Interactions - specifically related to existing right-of-way rules determined the effectiveness of those rules related to interaction with UAS and crewed aircraft.
2. Reserved Airspace Concept – In Task 2 it was identified that a reserved airspace concept that gave equal opportunity for access to both UAS and crewed aircraft may be a possible solution for certain BVLOS operations below 400ft AGL. Testing of this concept will be primarily conducted through physic-based simulations.
3. Use of Remote Identification (RID) – researching the effectiveness of RID to be used to inform and assist in filling the gaps of current right of way rules.

- Test Cards have been developed from the initial flight test plan for General Interactions area. The flight tests (Task 4) will further validate proposed right-of-way rules in those areas where physics-based simulations are unable to inform the researchers. In the initial flight test plans, the performer has identified the necessary tools and techniques to precisely capture the test conditions; the data to be collected; and how the data will be analyzed.

Task 4: Flight Test

The research team has developed an initial flight test plan that is being used to develop the flight test cards to be used to safely and effectively execute the flight tests of UAS and crewed aircraft encounters for the predetermined use cases related to the simulations efforts in Task 3.

The intent of flight testing and demonstrations is to refine and validate initial recommendations. The research team will plan, schedule, and execute aircraft

encounters with other (intruder) aircraft. Encounters will be evaluated for flight test safety and will maintain adequate vertical and/or horizontal separation. Encounters will be structured to facilitate the collection of data to address FAA knowledge gaps and support final recommendations related to right-of-way rules. The research team will utilize the available aircraft, aircrews, and equipment for testing. Due to the cost of technology and availability of technology, multiple UAS (such as swarm flights or multirobot systems) will be conducted during simulations. If needed, flights to simulate multiple UAS will be accomplished by KU using 2-3 multiple UAS systems.

Reports will interpret the significance of test outcomes and the degree to which results refine and validate prior assumptions, understandings, and recommendations. Reports should interpret whether the prior recommendations were supported by the research activities or if those recommendations need to be refined. Reports will document whether research test methods were appropriate for answering the research questions or if changes to test plans are recommended.

Task 5: Final Briefing and Final Report

The performer will summarize and aggregate all of the previous papers and reports into a final report package for the overall project.

The final report should answer the knowledge gaps and include research findings from the project tasking. The report should provide clear recommendations to the FAA and UAS standards development organizations. The report should include newly proposed UAS right-of-way rules with safety justification, metrics, thresholds, and other information to support proposals. The report should also highlight areas of future research needed to address remaining gaps in right-of-way rules. The report should discuss how project outcomes can be used to inform policy, regulations, advisory circulars, and industry consensus standards.

KEY FINDINGS

Task 2:

The team has completed UAS Gap Prioritization, UAS Safety Hierarchy, and identified various right-of-way scenarios for testing and initial right-of-way rules.

Task 3:

The team has completed the Simulation Plan deliverable in Task 3 and has completed simulation testing for General Interactions. Key findings have been related to identifying the distances needed between single and multiple UAS and crewed aircraft to remain well clear. Similarly, distances to remain outside of 100ft horizontally and 25ft vertically from single and multiple UAS have been determined. Initially 50ft horizontally and 15ft vertically was used, per request of FAA, but based on simulations and considering the various types of GPS receivers and their inaccuracies, it was determined that 100ft horizontally and 25ft vertically were more realistic figures related to what the research team is currently considering as a small UAS near Mid-Air Collision (sNMAC).

Task 4:

The team has completed the initial/draft flight test plan and submitted to the FAA. The FAA has reviewed and research teams are developing flight test cards that will coincide with the flight test plan.

Task 5:

Preliminary/draft results and interpretation for the flight tests is due on June 28, 2024.

Task 6:

Final briefing and report is due on July 30, 2024, with project closeout of October 31, 2024.

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IDENTIFY FLIGHT RECORDER REQUIREMENTS FOR UNMANNED AIRCRAFT SYSTEMS (UAS) INTEGRATION INTO THE NATIONAL AIRSPACE SYSTEM (NAS)

LEAD UNIVERSITY : UNIVERSITY OF NORTH DAKOTA

A11L.UAS.101_A55

BACKGROUND:

UAS operations are expected to evolve towards vehicles with a range of automated functions that could be capable of delivering cargo and/ or routinely transporting passengers. In order to ensure that UAS operations are safe as they evolve, it is important to learn from past accidents and incidents. Currently, the aviation industry uses technologies to get the most relevant information regarding aircraft accidents and incidents for a large number of manned aircraft operations. One of these technologies is the Flight Data Recorder (FDR), which collects aircraft state and performance data. The second technology is the CVR, which collects communication to and LEAD from crewmembers. FDR and CVR-like capabilities will need to be used in UAS but certain adjustments due to operational requirements and constraints will need to be taken into consideration. The American National Standards Institute (ANSI) Unmanned Aircraft Systems Standardization Collaborative (UASSC) standardization roadmap

v2.0 determined that there are knowledge gaps regarding flight data and voice recorders for UAS. Some of these gaps include size requirements based on the class of UAS, test procedures for crash survival, methods for recording data on the aircraft and control station, and the minimum data required. This project is intended to inform FAA decisions regarding data recorder technologies for UAS. This effort will inform FAA members writing FDR and CVR standards for UAS in industry accepted documents such as EUROCAE document ED-112B that is being revised at this time. It will also inform ASTM design standards for UAS that will need to incorporate data recorders into UAS designs.

APPROACH:

Task 1: Literature Review of Existing Data Recorder Standards, Technologies, and Unique Data Recorder Requirements for UAS and UAM Aircraft. *(Completed)*

The team performed a literature review on data recorders that includes existing industry standards, EUROCAE workgroup proposals for UAS, regulations, orders, policy, past research, and data recorder technologies. Also, the literature review included a search of UAS accidents and incidents to inform unique data recorder needs for UAS and UAM aircraft. The literature review also included the test methods and metrics for data recorder survivability (e.g., kinetic energy at impact, fire potential, temperature, vibrations, etc.). It provided recommendations for future study based on identified knowledge gaps in current flight and voice recorder technologies and requirements to a different class of UAS.

Task 2: Assess and Develop Proposed Data Recorder Requirements *(Ongoing)*

Based on Task 1, researchers will evaluate any standards or proposed data recorder requirements from EUROCAE and ASTM for sUAS, medium sized UAS, large UAS, and UAM aircraft. Researchers will evaluate proposals for safety benefit and whether the proposal adequately addresses the data needs to assess accidents and incidents for different types of UAS and UAM aircraft and their unique operations (e.g. automation, Detect and Avoid, package delivery, etc.). In addition to safety benefit, the researchers will also consider cost, size, weight, power, and ease of implementation for the various proposals and standards. The researchers will also develop and propose their own data recorder requirements if industry standards or proposals do not exist or if they feel that proposals did not adequately consider safety benefit, cost, size, weight, power, and ease of implementation for different types of UAS and UAM aircraft. Leveraging previous work conducted by National Institute for Aviation Research (NIAR) at WSU on incident/accident reconstructions to support National Transportation Safety Board (NTSB) investigations, researchers will develop and propose a minimum set of data channels and sampling rates required to conduct future UAS accident/incident investigations. Researchers will also develop an accident reconstruction demonstration example using NIAR's methods to support an accident investigation process. The purpose of this demonstration will be to identify and validate the minimum amount of data channels required to conduct an accident investigation analysis and for the FAA to visualize what type of information they may get with the proposed data channels and sampling rates.

Task 3: Crash Survivability of UAS Data Recorders *(Upcoming)*
Based on the inputs from previous tasks, the team will follow existing test procedures or propose a set of novel test procedures to evaluate the survivability of flight data recorders for sUAS and medium sized UAS. In this task, researchers will identify at least two commercially available UAS data recorders (one for smaller UAS (ex. SD Card within small survivable lightweight housing) and one for larger UAS) and conduct a series of computational and/or experimental tests to evaluate the proposed crash survivability criteria.

Task 4: Update Assessments and Proposals for Data Recorder Requirements *(Upcoming)*
Based on the results and lessons learned from testing, the team update previous data recorder assessments and proposed requirements.

Task 5: Final Briefing and Final Report *(Upcoming)*
The team will summarize and aggregate all papers and reports into a final package.

KEY FINDINGS:
This research is still ongoing and key findings are being gathered.

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EVALUATE UAS ELECTROMAGNETIC COMPATIBILITY (EMC)

LEAD UNIVERSITY : UNIVERSITY OF NORTH DAKOTA

A11L.UAS.96_A56

BACKGROUND:

As the advancement of technology, the use of UAS has tremendously expanded from military applications to many civilian uses such as aerial photography, scientific survey, infrastructure inspection, forestry, agriculture, disaster relief, search and rescue, policing surveillance, product delivery, public and commercial formation show, sports, and recreation. This wide adoption of UAS platforms has led to increasing numbers of small and medium sized UAS platforms that fly at low altitudes with various systems and payload sensors. These systems are often highly integrated into limited avionics space and operate using a variety of frequency bands.

At the same time regulatory authorities have worked to assign frequency allocations to support increasingly dense usage models. As a result, the potential of unpredictable behavior and loss of control of UAS increases due to interference from ubiquitous electromagnetic emissions. UAS Electromagnetic Compatibility (EMC) has therefore become a critical consideration in UAS design and operation in order to reduce any potential safety risks.

The primary goal of this project is to assess the safety risks of Electromagnetic Interference (EMI) on small and medium sized UAS. EMI is a broad category of potential interference and can be broken into two basic categories: (1) Static and Low Frequency Fields, and (2) Radio Frequency Interference (RFI) which occurs at frequencies that typically are used for wireless signal transmission. The first of these categories is addressed through the use of both laboratory-based measurements using simple equipment and components to simulate the effects of high-power transmission lines, and real-world flight tests near established power transmission lines.

APPROACH:

The approach includes the following tasks:

- **Task 1:** Literature Review and Risk Identification.
- **Task 2:** Research Planning.
- **Task 3:** Plan Execution.
- **Task 4:** Final Report.

KEY FINDINGS:

Recommendations are as follows:

- UAS platforms appear to be sensitive to signals in the Very High Frequency (VHF) band. It is recommended to test each platform over the band from 60.5 MHz to 335.5 MHz with 55MHz bandwidth using the recommended test setup (see the final report for details). Once the frequency span in the VHF band is identified, the level of sensitivity should be assessed by varying RFI power level and investigating signals obtained by the various on-board systems.
- The commonly held safety level for magnetic fields of 180 μT is overly restrictive. The team was not able to rigorously determine the upper magnetic field strength for safe operation, but the team recommends a threshold of at least 3,000 μT.
- All UAS platforms should have adequate shielding of critical components including C2 system (aside from the antenna) GPS system (aside from the antenna) and the compass.

- Robust Automatic Gain Control circuitry should be employed in the C2 link to reduce the potential for RFI on the front-door C2 link.
- Any C2 links that utilize the 2.4 GHz ISM band is likely to be sensitive to radiation from Wi-Fi access points and should operate at a significant distance from these points according to the results shown in Figure 4-19 of the final report. These C2 links are also like to be sensitive to radiation from 4G LTE or 5G NR signals using channel b41 or n41. When flying in a region with cellular ration in these channels, a safe flight distance may be calculated using Equation (2) and Figure 4-20 of the final report.
- It is recommended to fly at least 1,200m from operating ASR for general purpose UAS.
- Flight near power lines has demonstrated significant adverse impacts to compass/magnetometer performance. When flight near power transmission lines is required, alternative methods of direction determination than the compass/magnetometer is recommended.
- Affordable laboratory testing setups that could be employed by UAS manufacturers and operators as described in Section 2 of the final report are recommended to test any possible effects of strong magnetic and electric fields at lower frequencies.
- The effects of battery current changes due to long time exposure to the VHF RFI emissions on UAS operation safety and performance should be further investigated and evaluated.
- Additional investigation into appropriate shielding against back-door signals in the VHF range is recommended.

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INVESTIGATE DETECT AND AVOID (DAA)TRACK CLASSIFICATION AND FILTERING

THE OHIO STATE UNIVERSITY · EMBRY-RIDDLE AERONAUTICAL UNIVERSITY · MISSISSIPPI STATE UNIVERSITY · UNIVERSITY OF NORTH DAKOTA

LEAD UNIVERSITY : THE OHIO STATE UNIVERSITY

A11L.UAS.100_A57

BACKGROUND

Developing robust Detect and Avoid (DAA) systems is a key requirement for enabling routine Beyond Visual Line of Sight (BVLOS) missions in the National Airspace System (NAS). A hurdle to widespread adoption is a lack of track classification performance requirements related to publication of false or misleading information. The impact of such tracks on UAS incorporating autonomous response abilities, and those relying on human in the loop for deconfliction is unknown and may pose a significant hazard if unmitigated. This project will therefore focus on the development of validated risk models to understand the impact of track classifier performance and DAA clutter densities on overall system safety for a range of vehicle sizes (UAS to advanced air mobility), and equipage/operational scenarios. The research has been divided into two phases, with the first focusing on the detailed literature review and risk model development necessary to identify key hazards and risks associated with track clutter provided by both ground-based and airborne DAA systems. The risk models will be assessed in Phase 2 through simulation using representative DAA systems with UAS operated as fully autonomous agents and by human operators

to assess task saturation and downstream systemwide effects. Ultimately, track classifier performance metrics will be proposed to and disseminated to ASTM and RTCA standards bodies as well as to the FAA for inclusion in forthcoming rulemaking processes. Currently the FAA does not distinguish between misleading information caused by faulty hardware/software or from misclassified tracks within DAA system safety assessments. This work will inform possible updates to FAA safety assessments for DAA systems and their operations.

APPROACH:

Task 0: Program Management

OSU will lead the program management effort for this project.

Task 1: Literature Review & Risk Identification.

The team will conduct a literature review incorporating academic, industry, and standards body research to identify key sources of risk and uncertainty affecting air picture cleanliness.

Task 2: Risk Assessment.

The risk analysis process will be used to assign a likelihood and severity of the risks identified in Task 1. These metrics will be used to prioritize the risk assessment based on the DAA architecture and/or operations. As part of this process, common safety analysis tools such as a functional hazard analysis, failure modes, effects, criticality analysis, or fault trees may be used. Additionally, categorization and identification of the impact of misleading information on overall system risk will be investigated.

Mitigations to the prioritized risks will be developed. The risk mitigations may be strategic, operational, or material in nature. The mitigations will be sorted into categories like the risks and assessed for feasibility, utility, and effectiveness at a qualitative level. This task will be reinforced via the literature research and industry survey.

The risk prioritization and mitigation development tasks will heavily inform requirements and metrics development. Specifically, the team will develop requirements/metrics to guide air picture cleanliness, classification performance requirements, data filtering, and human factors for DAA systems. These requirements/metrics will be assessed for applicability across UAS mission and DAA system types. Developed requirements and metrics will be shared with applicable ASTM and RTCA standards committees for industry feedback solicitation.

A summary report for the risk assessment study will be provided with key recommendations regarding prioritization, mitigation, and requirements outlined. This report will form the basis for test planning in Task 3.

Task 3: DAA System Performance and Test Planning.

A test plan will be developed focused on air picture modeling. Scenarios will be developed to verify/validate developed air cleanliness, classification performance, and data filtering requirements and metrics using notional DAA system models/architectures identified in Task 1. A DAA package such as ACAS-Xu/sXu will be used to characterize DAA system performance and help evaluate the developed air cleanliness, classification performance, and data filtering requirements.

Specific modeling constraints for incorporating pilot-in-the-loop simulations will be identified to assess overall task loading based on airspace density and the number of UAS under control by the pilot in command. This framework will be incorporated into the modeling and simulation framework adopted in Phase 2 testing.

A final report for Task 3 will be developed to recommend testing to be conducted in Phase 2 of the research with specific recommendations for model development to enable the accurate assessment of air picture cleanliness.

Task 4: Peer Review / Feedback from Standards Bodies.

The test plans and risk assessments will be evaluated by peer review. Feedback from this process will be used in the refinement of the encounter scenarios considered in the Phase 2 research. The team will work with the FAA to identify key stakeholders for the peer review process. Feedback will be used to update the requirements definition.

Task 5: Scenario and Subsystem Model Refinement.

Phase 1 of this project culminates with FAA and industry review of developed and prioritized risks, risk mitigations, and requirements/metrics associated with air picture cleanliness, classification performance requirements, data

filtering, and human factors for DAA systems. During Phase 2, the team will review received feedback and update risks, risk mitigations, and requirements/metrics accordingly. The team will coordinate updates with the FAA to ensure their buy-in before finalization.

After the team has developed mature risks/metrics for DAA system and associated performance, the team will develop encounter scenarios to fully understand and exercise the interaction of developed performance requirements/metrics and risks to DAA systems. The encounter scenarios will be tailored to align with the prioritization of risks, risk mitigations, and requirements/metrics. Encounter scenarios will cover multiple facets of DAA systems including autonomy (human-in-the-loop to fully autonomous), aircraft size and associated performance (sUAS to large scale drones), and UAS mission types (package delivery, inspection, reconnaissance), etc. Additionally, encounter scenarios will be exercised in a variety of airspace densities (sparse to dense) and misleading surveillance information rates (low to high) to understand the impact to performance requirements/metrics and risks to DAA systems for a combination of airspace densities and misleading surveillance information.

Task 6: Modeling and Simulation Evaluation. The encounter scenarios outlined in Task 5 will be used to develop representative sensor models for ground and airborne DAA systems. These will be high-level models designed to incorporate variable levels of uncertainty in both position false-track rates associated with exercising the downstream DAA responses from both pilot in the loop and autonomous vehicle responses.

Data will be collected from representative DAA systems currently emplaced to assess clutter performance, track classification and filtering performance, and to provide repeatable test scenarios for evaluation in the modeling and simulation framework. These clutter representations will be non-dimensionalized to allow for extrapolation to the encounter scenarios developed in Task 5.

The reduced order models corresponding to different airspace characterization sensors and systems will be integrated into the modeling and simulation environment. The team has extensive experience in performing this type of integration work based on existing UAS Traffic Management DAA systems.

Task 7: Simulation Data Analysis and Gap Report.
A test report capturing the totality of testing performed in Tasks 3 and 6 will be generated. The results will cover the verification/validation of developed requirements/performance metrics relating to air picture usability, air picture cleanliness (surveillance operating limitations, classification performance, data filtering), and human factors.

Task 8: Final Report.
A final report and briefing will be created at the end of the program. The report will summarize and aggregate all previous work performed into a final report package. The report will address knowledge gaps and research findings from executed tasks. The report will also provide recommendations to the FAA, ASTM, and RTCA including proposed requirements performance metrics, guidance, and test methods for industry standards. The report will provide supporting rationale, safety arguments, analysis, test results, and discussion that support the proposed requirements and recommendations. Finally, the report will address how project results can be used to inform policy, regulations, etc. and provide recommendations for future research.

KEY FINDINGS:
The team has developed simulation-based models which capture key interactions between the sources of clutter, and the identified risks which include increased pilot workload, or potential failures of the DAA alerting systems. The team has captured real clutter data from a variety of ground and airborne sensors which captures a wide range of noise sources such as weather, birds, ground clutter, etc. Using this data and simulated encounter geometries used as test cases for the development of ACAS-sXU, the team has quantified the increases in numerous safety metrics such as near mid-air collision,

loss of well clear, etc. as a function of the superimposed clutter density. In parallel with this effort, Embry-Riddle Aeronautical University has developed a unified simulation engine to incorporate various sensor models and provide both real and fast-time simulations for the assessment of clutter density. This model has been architected to interface with DAA services provided by CAL Analytics which allows for rapid selection of different DAA algorithms to capture potential failure modes of the DAA service due to improper or erroneous cuing.

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ILLUSTRATE THE NEED FOR UAS CYBERSECURITY OVERSIGHT AND RISK MANAGEMENT

LEAD UNIVERSITY : UNIVERSITY OF KANSAS

A11L.UAS.95_A58

BACKGROUND:

As per the GAO publication "GAO-19-105: Agencies Need to Improve Implementation of Federal Approach to Securing Systems and Protecting against Intrusions", agencies throughout the Federal Government were found to be at risk or high risk for gaps in Cybersecurity. This research requirement will address the need for UAS Cybersecurity Oversight and Risk Management as it pertains to the relationship to the NAS and FAA systems.

APPROACH:

Task 0: Program Management

The researchers will manage this effort to ensure all tasks are in alignment with the tasks detailed in this Proposal.

Task 1: Literature Review and Industry Engagement

The researchers will review all publicly available information concerning the IG, GAO, and other reports that delineate Risk Management

Assessments elements, concerns, and best practices. Researchers will work from the GAO-19-105 and an initial with additional emphasis on cyberphysical issues common in UAS environments. Researchers will continue to work with industry partners to explore standards and processes common to their workflows.

Task 2: UAS Cybersecurity Oversight and Risk Management

The researchers will create a Tool or a Process that will provide a guide for the FAA to create a UAS Cybersecurity Oversight and Risk Management Program that will help facilitate best practices in the execution of such duties. To achieve this, the team is mapping static analysis, simulation, and cyber-physical system analysis to UAS specific cybersecurity tasks. The resulting framework will provide an initial roadmap for applying a framework to an operational system.

Task 3: Test Cybersecurity Oversight Tool or Process

The researchers will test the UAS Cybersecurity Oversight and Risk Management Tool or Process created in Task 2. They will develop Cybersecurity Scenarios to be tested against the Tool or Process in either a table-top simulation or live-test event. To achieve this, the team will select a common platform and apply the framework and associated tool to that platform. Both simulation and flight testing will be employed.

Task 4: Peer Reviewed Final Report and Final Briefing

The team will write a final report documenting:

1. The Cybersecurity Oversight Tool or Process
2. The process and results of testing the Cybersecurity Oversight Tool or Process
3. Areas of need and future research

In addition, they will deliver software and hardware developed for the research effort.

KEY FINDINGS:

The literature survey builds upon work from the A38 report detailing cybersecurity risks for UAS operation. The A38 report identifies threats by severity and likelihood. The researchers are identifying threats that specifically impact airspace. Specifically, operation of the UAS and safety of other nearby aircraft. Additionally, they are including a malware survey for embedded systems and review of the GAO-19-105 framework and the NIST framework with application to UAS operations.

The researchers have engaged in several technical investigations exploring threats and potential mitigation of those threats ranging from modeling and analysis through testing and demonstration. An extensive overview of malware threats was developed by Drexel University outlining potential threats specific to embedded systems. Similarly, KU developed an overview of cyberphysical issues focused on impacts of novel sensor attacks was performed that included GPS, accelerometer, barometer, and range finder spoofing done exclusively with sensor inputs. We reviewed results from cybersecurity research performed by DARPA examining the High Assurance Cyber Military Systems and Cyber Assured Systems Engineering programs that both focused on UAS platforms in their demonstrations and provider guidance for using formal techniques for hardening systems. Oregon State presented the physics of an accelerometer attack using acoustic injection techniques demonstrating how such attacks are executed with no physical access to the accelerometer.

Results from these investigations were shared at monthly team meetings and at semi-annual PMR meetings. These results clearly demonstrate the need for a framework that mitigates cyberattacks impacting UAVs in public airspace. Furthermore, they show a need to consider cybersecurity issues from high-level requirements through implementations. With feedback from sponsors and collaborators our studies form the basis for moving forward with a proposed framework. Over the remainder of the A58 effort the team will outline this framework while continuing experimentation and investigation.

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EVALUATION OF UNMANNED AIRCRAFT SYSTEMS (UAS) INTEGRATION SAFETY AND SECURITY TECHNOLOGIES IN THE NATIONAL AIRSPACE SYSTEM (NAS) PROGRAM

LEAD UNIVERSITY : UNIVERSITY OF ALASKA - FAIRBANKS

A11L.UAS.90_A60

BACKGROUND:

After years of close coordination, the FAA and "federal security partners" Departments of Defense, Energy, Justice, and Homeland Security obtained the authority to test, operate, and evaluate systems and technologies that help ensure the safe and secure integration of UAS into the United States National Airspace System (NAS). The National Defense Authorization Act (NDAA) of 2017 granted the DOD and DOE authorities to safeguard the NAS. The NDAA act of 2018 expanded the DOD's authorities by increasing the types of facilities and assets that could be covered by these technologies. The FAA Reauthorization Act of 2018 provided the DHS and DOJ similar authorities to those of DOD and DOE for specific mission sets. The FAA was also granted authority in the FAA Reauthorization Act of 2018 to employ these technologies for testing, research and development activities, and to support plans for standards derivations.

UAS technology offers tremendous benefits to our national economy and society. The limitless versatility of UAS also presents unique safety and security challenges. Technologies and processes for the detection, tracking, and identification of UAS cannot be truly effective without a means for differentiating legitimate, safe, and secure operations from those that may be unauthorized. The interdependency of these technologies, systems, processes, and procedures requires a holistic solution set that is suitably proven and interoperable. Any proposed solution must take into consideration a wide array of potential for misuses, maintain the security posture of interagency partners, provide a means for compliance with permissible operations, and support enforcement actions when necessary.

This research will support the development of cross-agency standards against which to test prospective UAS integration safety and security technologies including:

- Ensuring the efficacy and safety of the system;
- Ensuring the systems do not adversely affect or interfere with airborne avionics, CNS systems, Air Traffic Management (ATM) systems and other ground-based infrastructure such as lighting;
- Assessing the efficacy and safety of integrated platforms such as Common Operating Picture (COP) and UAS Traffic Management (UTM) systems;
- Ensuring the efficacy and safety of technologies, sensors, and systems for differentiating between legitimate UAS and unauthorized UAS;
- Ensuring the systems deployed do not adversely impact or interfere with each other; and
- Ensuring the systems do not interfere with first responder communications systems or adversely impact or interfere with the safe and efficient first responder operations.
- This research will support development aimed at solutions for critical national security problems affiliated with the hazardous and malicious operation of UAS. This development of solution is in the form of cross-agency standards against which to test UAS integration safety and security technologies.

This effort will apply prior research data obtained under the ASSURE COE Grant Program tasks:

- Demonstrate test methodologies and provide technical approaches for evaluating UAS safety and security technologies in the NAS to include airborne avionics, Communications, Navigation, and Surveillance (CNS) systems, ATM systems and other ground-based infrastructure such as lighting;
- Develop and analyze the efficacy and safety of technologies, sensors, and systems for differentiating between manned aircraft, legitimate UAS, and unauthorized UAS.

APPROACH:

Task 1: UAS Flight Operations

The Performer will conduct UAS flight operations demonstrating the various flight characteristics and scenarios developed to assess the detection, tracking, and identification systems' effects on the safety systems of the NAS. The data generated during these flight tests will be used to determine limitations, assess capabilities, develop procedures, and analyze the efficacy of UAS integration safety and security technologies, sensors, and systems.

The research team conducting this project includes the leaders of three of the seven FAA UAS Test Sites (i.e., the New Mexico UAS Flight Test Site, the Northern Plains UAS Test Site, and the University of Alaska UAS Test Site), who will oversee all flight operations. This oversight allows the research team to easily comply with the requirement that the project meets the FAA UAS Test Site Other Transaction Agreement Modification 4, Article 3 – Privacy, because the Test Sites already comply with this requirement in their planning and flight operations. Additionally, the Test Site teams are highly experienced in planning and safely executing challenging UAS operations under a wide variety of conditions. The team also includes the leaders of the DHS Science & Technology Small Unmanned Aircraft Systems Demonstration Range Facility at MSU and the Unmanned Aircraft Systems Program at UAH, which is partnered with Huntsville International Airport, one of the four airports chosen by the FAA to host a UAS Detection and Mitigation Research Program Test Site.

The research team currently possesses UAS of multiple types and sizes that meet the criteria for testing and can be used immediately. However, the team included funds for the purchase of UAS to meet all of the testing goals. New home-built UAS may also be utilized if this presents a more cost effective way of providing UAS assets for testing a variety of links. They have also included funding for travel costs to encourage vendors to participate in flight campaigns.

Task 2: Analysis and Recommendations for UAS Integration Safety and Security Technologies

The FAA's UAS integration effort and associated legislation has increasingly focused on ensuring the safety and security of UAS operations. The results of this effort will directly inform safety and security policy development and legislative requirements for:

- Ensuring that technologies or systems that are developed, tested, or deployed by Federal departments and agencies to detect and mitigate potential risks posed by errant or hostile UAS operations do not adversely impact or interfere with safe airport operations, navigation, air traffic services, or the safe and efficient operation of the NAS.
- Developing UAS integration safety and security systems to detect and mitigate unauthorized UAS that interfere with firefighting efforts in our nation.
- Developing UAS integration safety and security systems to detect, identify, and reduce the severity and impact of unauthorized UAS that interfere with approved manned and unmanned aircraft operations.

Task 1: FY 23 Activities

The FAA Security and Hazardous Materials Safety Office (ASH) and Office of National Security Programs and Incident Response conducted an extreme environment drone detection test event to evaluate the effects of detection, tracking, and identification capabilities of selected drone detection systems on FAA safety and security systems and First Responder communications systems under extremely cold and atmospherically inverted conditions. This test focused on passive, non-emitting, detection systems with minimal potential for interference with safety systems in the NAS, First Responder communications systems, and people and property on the ground. FAA ASH coordinated the co-planning, design, and execution of the test. The dates for this test event were January 23-February 3, 2023. The team garnered and codified the best processes, procedures, coordination, and best practices from this test.

The main objectives of this test were: 1) to evaluate the potential for the drone detection, tracking, and identification sensors to interfere with NAS safety systems, and people and property on the ground, and 2) to evaluate system capabilities in an arctic environment. The event took place on the UAF campus with the main vendor site being approximately 1.8 miles from the end of the main runway at Fairbanks International Airport. The area had a significant RF background, a strong temperature inversion that could cause ducting of RF signals and sounds, cold temperatures that could cause equipment failures, the ability to set up line of sight blockage flight paths, the potential for nighttime operations, and the participation of Fairbanks area First Responders to test the effect of detection activities on their communications and vice versa. The drone detection systems under test used passive detection, tracking, and identification techniques, specifically acoustic, infrasound, radar, and Remote Identification (RID) systems. The research team designed the test to determine any potential interference from the systems with the acoustic and RF environment near the systems, thereby identifying potential impacts on NAS safety systems, First Responder communications systems. The research team flew a variety of commercial drones, including some Do-It-Yourself (DIY) systems, with flight profiles that stressed and isolated the specific environmental challenges such as atmospheric inversions, to observe the systems' effectiveness in determining that a drone was present under a variety of environmental conditions.

The "Tahiti C-UAS Extreme Environment Test Plan" governed the operations during the January 23-February 3, 2023 flight campaign. The following subsections provide an overview of the original test and flight schedules, missions and sortie numbers, aircraft types and designators, and UAS launch points that were included in the Test Plan. This includes the detection sensor locations (vendor sites), multiple UAS launch point locations, the preliminary proposed list of aircraft to be flown, and more. The research team did not use all of the launch point locations and flight paths included in the Test Plan due to improved information generated during the tests that demonstrated that launching the aircraft from some of those sites would not have generated any additional information not already collected from closer launch sites. Additionally, the team determined that nighttime operations were not going to provide any benefit over daytime operations, especially since the coldest period of the day in Fairbanks in winter is as the sun rises. The proposed flight paths in this section were modified by the team and the program sponsors to optimize the flight times and paths to maximize the amount of useful data obtained per flight and the final flight paths for each scenario are included in flight test cards. The aircraft listed in this section were present for the event, but not all aircraft were able to fly under the environmental conditions encountered in the test.

Flight Campaign Location

The location for these flight tests was the Troth Yeddha' campus of UAF. The test area is semi-urban with small agricultural fields south and at a lower elevation than the main research buildings on the west end of campus (a.k.a., 'West Ridge') and a wooded area north of the campus buildings. There are satellite dishes for polar orbiting satellite data downloads on several campus buildings and in the woods to the west of the main research buildings on the West Ridge. The Alaska Railroad tracks run immediately north of the agricultural fields and south of the West Ridge buildings. Fairbanks International Airport's closest runway is approximately 1.8 miles from the vendor site. The campus is primarily surrounded by single-family housing developments, with the exception of businesses along Geist road to the south of the agricultural fields and a high school to the southeast of the easternmost primary launch site.

Flight Operations

The flight profile variables of this demonstration were target range, target azimuth, and target altitude measured in both daytime and nighttime lighting conditions and under temperature inversion conditions.

The unique target airframes that were flown and their target designations were determined during the development of the run of show and test cards for each flight. There was a minimum of two of each aircraft type so unique target designators were required to account for time flown on each aircraft the preparation of each aircraft prior to flight.

Flight Scenarios

A total of seven separate potential scenarios were defined in the test plan and included the following:

1. Scenario 1: Maximum Detection
2. Scenario 2: Effect of Altitude on Maximum Distance
3. Scenario 3: Inversion/Altitude Effects
4. Scenario 4: Ascend/descend into Field of View
5. Scenario 5: Pop-up
6. Scenario 6: All Directions
7. Scenario 7: Multiple Drones

January 2023 Flight Campaign Summary

During the January 2023 flight campaign the team achieved the following:

- 60 Research Test Card flights were completed
- 610 minutes of test card flight time
- 11 drone platforms used
- 15 Meteorological flights were conducted
- Total of 957 minutes of flight time recorded during the campaign

The team tested four DTI systems during the campaign: Acoustics-Squarehead, Remote ID-Pierce Aerospace, Radar-Echodyne, and Infrasound-WATC.

The State of Alaska Department of Public Safety provided the following support and information to the team:

- Frequencies of interest were the control channel frequencies of three ALMR sites in Fairbanks: Ester Dome, Peger Road, and Birch Hill.
- There were no noticeable changes in the noise floor and communications were not affected.
- System level checks did not reveal any anomalies during the test period.
- Radio transmissions on the UAS1 ALMR talk group channel were clear throughout the event.

Task 2 FY 23 Activities

The first Task 2 interim reports were submitted in November 2022. The sponsor comments were adjudicated and the final version of the reports were completed in February 2023. The teams' areas of effort on the report topics are described below:

Task 2.1 discusses the applications, characteristics and limitations of currently available sensors for differentiating and detecting UAS, as well as methods for assessing those characteristics and limitations.

Task 2.2 explores a list of hardware and software resources used by various entities to manage UAS and other assets. Most of these resources have been available for several years and may not meet the needs of civilian UAS operations in the NAS.

Task 2.3-2.4 present an overview of UAS and CUAS. For UAS, their details, applications, challenges, and threats are presented. For CUAS, their fundamental components (and the elements enclosed by each), market, performance metrics, and proposed operational procedures are presented.

Task 2.5 discusses multiple UAS detection and mitigation technologies and the associated effects of four operational environments on their capabilities. These environments include rugged mountainous, fluid US border settings, near wildfire containment efforts, and in and around critical infrastructure. Future research will be conducted to arrange reports that detail human factors and address software integration challenges associated with the four aforementioned operational environments. Finally, future iterations of this report will utilize the information contained in this document to produce minimum performance standards for UAS safety and security systems in a variety of operating environments.

Task 2.6- The Unmanned Aircraft System (UAS) Integration Safety and Security Technology Ontology (ISSTO) covers too large of a domain to efficiently develop a singular ontology. Therefore, ISSTO's domain has been broken up into nine smaller, local namespaces that will then form local ontologies. These local ontologies will later be combined into a complete ontology that covers ISSTO's domain. The Manchester Style syntax was chosen as it is the most human-readable syntax. An ontology editing software called Protégé has been sourced to interface with the OWL 2 code.

Four local domain ontologies have been completed so far. These domains have been evaluated with FOCA, a method of ontology evaluation. FOCA will be continuously used to evaluate ISSTO throughout the development process. These four local domains will be integrated to form an early iteration of ISSTO. Formal Concept Analysis, a method that helps identifies relationships between concepts, has been researched to aid in the integration of the local ontology domains. Future steps include the evaluation of the early integration of ISSTO and further work on the remaining local ontologies.

KEY FINDINGS:

Overall, the research team successfully conducted a flight test campaign in Fairbanks, Alaska, from January 23-February 3, 2023, to test drone detection systems' impacts on the environment while operating. The key finding of the flight test campaign is that the drone detection systems operated during this event (acoustic, infrasound, radar, and RID) had minimal to no impact on the surrounding RF environment and First Responder communications. The only observable signal captured while the systems were active that was not present in baseline data existed between 5815 MHz and 5835 MHz, which aligns precisely with channel 165 of the IEEE 802.11 WLAN standard. The source of this signal was most likely the Silvus StreamCaster MANET radio emplaced at the vendor site in order to transmit data to the base of operations on campus.

The research team analyzed White Cell data logs and correlated them with aircraft ground truth data to determine the corresponding altitude and distance from the vendor site for each flight scenario. The radar detected drones on average between 800-1000 ft from the vendor site, while the acoustic system detected drones on average between 1000-1200 ft from the vendor site. These distances did depend on the altitude of the drone and the atmospheric conditions. The RID system detected most drones as soon as the beacon was turned on, which was before drone takeoff. The RID beacon was a challenge to place on several of the commercially-produced systems and occasionally dropped track when on a fixed-wing aircraft that was banking. The infrasound system was a research system and does not record in near-real-time at this point. The infrasound analysis will be conducted at a later date.

The cold weather took a toll on the drones. Of the 26 drone types, the team was only able to fly 11 successfully. The team attempted to fly, but had challenges with, six systems that ranged from battery issues, to connection issues, to an inability of the visual observers to see the aircraft. The team did not attempt to fly the rest of the systems due to characteristics that had already proven to be problems with other systems.

The flight campaign suggests that the FAA and other agencies can safely implement the drone detection systems tested in this flight campaign with no adverse impacts on the NAS.

Lessons Learned

The following is a condensed list of best practices and insights from the January A60 flight campaign. These best practices and insights can be applied to future campaign to increase efficiency.

1. Use mechanical or regular writing pencils to avoid ink freezing in the cold climate.
2. Keep electronics and equipment warm. Especially equipment cables, which tend to fail in the cold climate. Eg. Cat5 cables failed/broke in cold weather. Wrap cables in Kevlar.
3. Time synchronized across all equipment and systems from vendors before flight campaign to improve data processing and data analysis. This also includes maintaining a reference time source and location source for the vendor systems and aircraft.
4. To ensure data accuracy, it is recommended to convert the sensing systems and manual logs to coordinated universal time and cross-reference them with the daily aircraft logs for ease of data processing and event correlation.
5. Separate vendors from test direction cell.
6. Utilize disposable batteries-Lithium batteries over alkaline batteries for cold weather (AA/AAA).
7. Account for zip ties and Velcro failing in the cold.
8. Issues with adding RID unit on flight performance.
    - Weight balance is off.
    - Skydio had issues with detections (need more info).
9. Conduct the initial Met Flight as soon as possible in the AM.
    - Twilight around 9 AM
    - Sunrise ~10 AM
    - NOTAM 10 AM
10. PixHawk 1's do not have heaters and will not fly in these cold conditions (Note: PixHawk 2's have heaters but were not available – out of stock).

11. Pilots fingers get very cold during operations. Trans-mitt does not work well since cannot see through screen. Will try to fly with controller inside mitts and screen held by a team member)
12. Clear communications between agencies and participants are essential for implementing drone detection testing programs.
13. Test cards mean different levels of detail to different people. Ensure everyone is clear on expectations.
14. Paperwork and permissions always take longer than expected.
15. DIY drones have more issues with cold than commercial systems.
16. There are limited numbers of places to mount RID on UAS
17. Vendor availability is a challenge due to multiple, simultaneous test and evaluation campaigns for difference agencies as well as the Ukraine war.
18. Vendors want to test mitigation more than detection and tracking.
19. Providing travel support for vendors encourages participation.
20. Flexibility in testing (like adding a gas-power drone at a vendor's request) allowed for the unanticipated collection of data of value to the vendors and research team.

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CONDUCT SCIENCE TECHNOLOGY ENGINEERING AND MATH (STEM) OUTREACH TO MINORITY K-12 STUDENTS USING UNMANNED AIRCRAFT SYSTEMS (UAS) AS A LEARNING PLATFORM

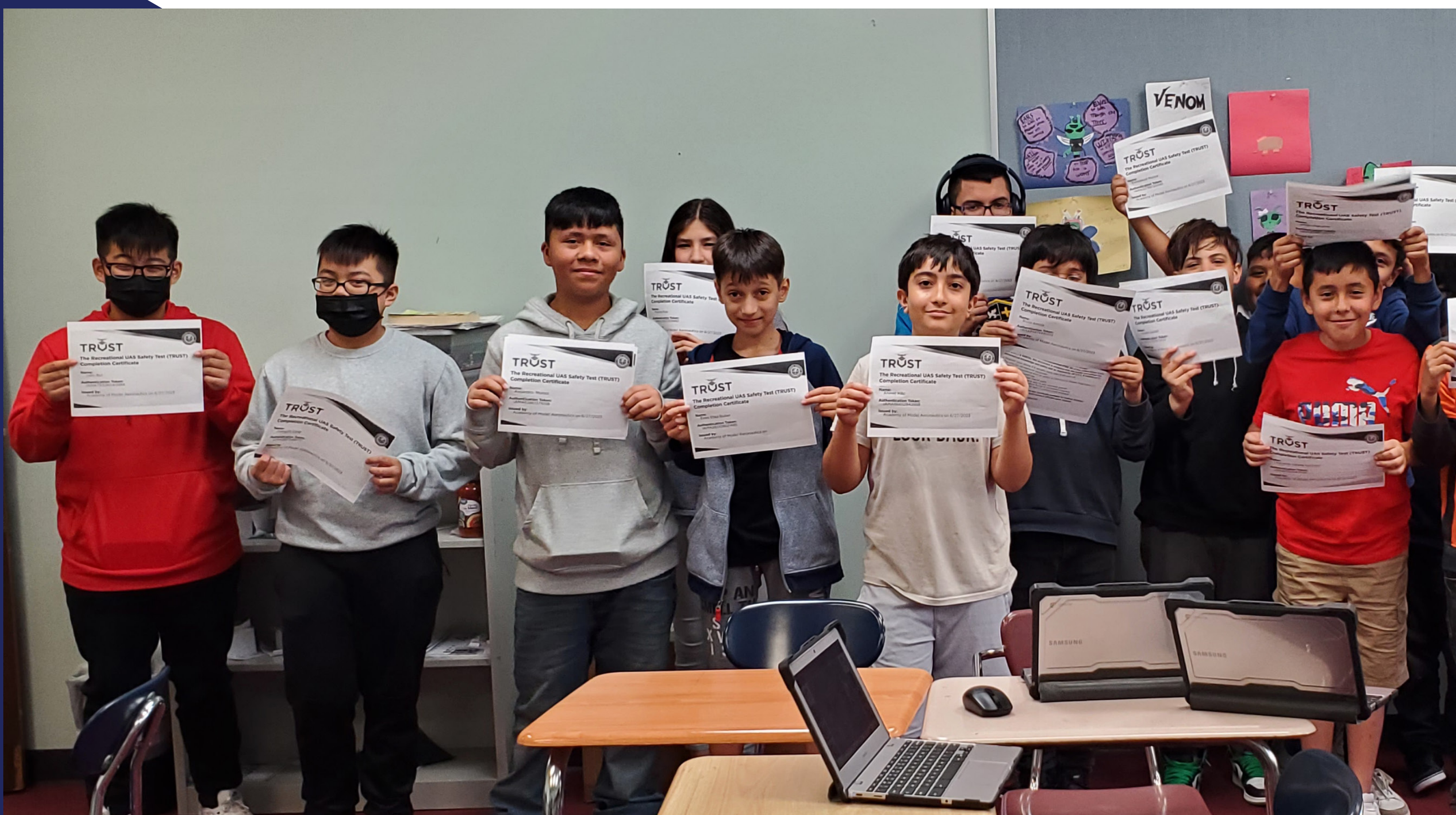
NC STATE UNIVERSITY | KANSAS STATE UNIVERSITY | National UAS Training and Certification Center

LEAD UNIVERSITY : NORTH CAROLINA STATE UNIVERSITY

A11L.UAS.53_A61

BACKGROUND:

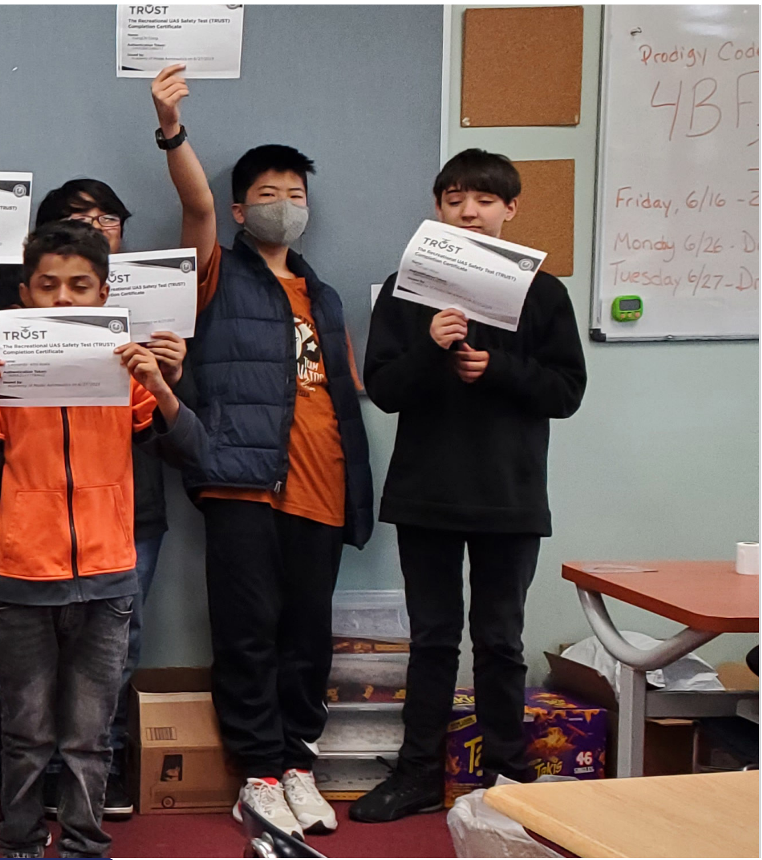
Science, Technology, Engineering, and Mathematics (STEM) career opportunities are projected to outpace the growth of career opportunities in non-STEM fields. A STEM capable workforce is key to meet this demand. While the STEM field has more job opportunities



and often higher wages, key groups, such as women and minorities, are underrepresented in STEM. To make STEM opportunities more accessible to underrepresented groups and to contribute to creating the next generation's interest in the UAS field, ASSURE is conducting STEM activities using UAS as the central learning platform. This project falls within the COE's mandate to educate and strategically facilitate the distribution of ASSURE research. This past research distribution will include as a minimum UAS engine ingestion, air mobility, cyber security, etc. The long-term goal of the project is to ignite an interest in UAS/STEM and, therefore, nurture part of the possible future UAS workforce.

APPROACH:

In keeping with Phases 1-3 of the STEM efforts funded by the FAA through ASSURE, each school was in control of their own specific approach to address the 2 main tasks: UAS Roadshows and Summer Camps. The schools were able to add additional outreach opportunities through an ad hoc task to cover events not initially planned at the time of the proposal.



NC State University

NC State, the lead University for this effort, handled the programmatic support for the project through TIMs and PMR updates. NC State was already active in K12 STEM education through myriad on and off campus programs. This funding allowed for increased capacity and a greater focus on UAS and aviation subjects within the broader STEM initiatives. In addition, many NC State programs already supported the FAA's focus on minority and under-resourced communities with respect to diversity in STEM fields.

In partnership with the NC Department of Transportation's Division of Aviation, NC State supported the Aviation Career Education (ACE) Academies to serve as the Roadshow events. This grant program hosts middle and high school students at local public airports in North Carolina. Many of these camps took place in rural regions and counties and highlighted the aviation industry, UAS, and related fields of study and work opportunities in those communities.

Two summer camp programs were supported through this project, both of which are ongoing university initiatives. The TRIO Pre-college program at NC State hosts a STEM Summer Camp for under-resourced high school students from across North Carolina. This program is one of only three others nationwide approved to host a NAF Future Ready Scholars Academy. While these camps are traditionally based on broad STEM topics, this funding increased the focus on aviation and UAS, and career opportunities in those industries. The Science House is another on-campus outreach unit with several STEM opportunities for middle and high school students. One of which, the Catalyst program, provides both weeklong summer camps and Saturday activities during the school year to students with disabilities. The priority is to help educate and prepare these students to participate in a growing STEM workforce.

Finally, NC State was able to work with a local school – Reedy Creek Magnet Middle – to expand the UAS curriculum in their Mechatronics courses. Through 5 days of combined instructional and hands on experience, these students were able to learn basic aerodynamic and aviation principles and fly multiple UAS platforms under direct supervision of a Part 107 pilot.

Kansas State University

Most employees in STEM fields are comprised of white males; the aviation industry is no exception. To help draw a more diverse level of interest in aviation career options, KSU proposed a mix of virtual and face-to-face engagements with middle school teachers and students from underrepresented communities in the state of Kansas. KSU targeted partnerships with schools with large percentages of Hispanic and Black students. Ultimately, eight schools were selected in Kansas City, Topeka, and Salina.

The objective is to motivate the next generation of UAS pilots and aviation leaders by exposing students to UAS recreational activities and career options. Student learning outcomes include: comprehending fundamentals of safe flight operations; understanding the delineation between hobbyist and commercial operations; successfully completing the FAA Recreational UAS Safety Test to become a recreational flyer; exploring recreational flyer and modeler community-based organizations in their local area; building, maintaining, and flying micro drone racing kits indoors; exploring basic flight fundamentals on a multirotor UAS; and participating in friendly competitions within their school and other schools.

During the Spring 2023 semester, KSU traveled to eight schools in Kansas City, Topeka, and Salina to introduce UAS to middle school students. These Roadshows allowed students and educators to better understand commercially used UAS and the various career opportunities.

The roadshows served as a means of identifying which schools would best benefit from the addition of a UAS curriculum. KSU used this opportunity to introduce the Drones in School program to educators and showcase its benefits. KSU procured two Startup Packages from Drones in School and a Race Gate Bundle to demonstrate at the roadshows how a race is flown and some of the equipment provided.

Building on the roadshow experience, KSU visited partner schools in Kansas City, Topeka, and Salina for a series of two-day camps. Holding summer camps at the schools' locations facilitated student and teacher travel logistics while maximizing available KSU resources to provide them with a fun, exciting, and informative experience.

Summer camps consisted of two full-day sessions with students learning and doing activities. During camp, students earned their FAA TRUST Certificate, learned about AMA fields, flew simulations, and learned basic aerodynamics.

To prepare for STEM outreach, the teachers at designated partner schools were trained in the Drones in School curriculum to allow them to plan on implementing it into their curricula or incorporating it into after-school programs for the Fall 2023 semester. Two of these schools have integrated the Drones in School program into their regular curriculum.

During the Fall 2023 semester, the pre-selected schools began the Drones in School UAS curriculum, focused around the Emax Tinyhawk III FPV Racing Drone. The curriculum revolves around core STEM components while simultaneously allowing flexibility in accommodating different focus areas, school and student resources, and adjustments to the included competition aspect. Students were placed into teams of 2-6 members consisting of a Project Manager, Manufacturing Engineer, Design Engineer, Drone Technician, Graphic Designer, and Marketing Coordinator. Members worked together to complete milestones leading up to a race and continued improving as they progressed through the semester. The layout of this curriculum guided students through a close representation of how a business formulates an idea, research solutions, tests selected solutions, markets a product, and improves the design based on needs.

The eight selected schools were not required to purchase equipment to complete the curriculum or compete in races with the other eight schools. Each school was provided with multiple drone kits and an assortment of spare parts and batteries. Furthermore, each school received a racing gate and flag bundle for practicing and competing. All racing events were held virtually, with students flying the standardized course head-to-head against other teams in a double-elimination style bracket. Points are awarded to teams based on their bracket results, with an overall race champion named at the end of the event along with overall placings. Schools will post their teams' results on an online form where they can also view other schools' results.

Other champion titles include Design and Engineering, Portfolio and Team Display, and Marketing Video Champion. With each event, teams must complete and submit an engineering and design task, create a portfolio and team display, and produce a marketing video. Judges will assess these elements using a provided scoring sheet and announce winners at the end of each event. During the final events in November 2023, KSU will travel to each school to watch and assist with judging the various components.

Sinclair College

Sinclair College, enabled through its National UAS Training and Certification Center, remains very active in UAS related STEM education. This has been partially supported through the ASSURE A29 STEM III and A61 STEM IV projects, as well as participation in many separate college hosted events or off-campus camps and hands-on activities. Additional support through this project enabled Sinclair to expand efforts reaching diverse students through directly hosted events and collaborations with partnering organizations.

Sinclair continued with off-campus engagement in middle-school classrooms, as well as museums and community events, through provision of UAS applications, technologies, and careers briefings, coupled with RealFlight UAS simulation experiences leveraging Sinclair laptops or deployed Mobile or Tactical Ground Control Stations. The network of schools and sites developed throughout the STEM III effort was leveraged to identify locations for these opportunities during the STEM IV project. Specifically during the project, Sinclair completed 20 outreach days at middle and high schools reaching 2,345 students and teachers. Sinclair also completed five outreach days during TechFest hosted at Sinclair, the Micro Drone Races hosted at the National Museum of the United States Air Force, and the Northeast Ohio Regional Airport Aviation Career Day reaching an additional 955 students. Finally, Sinclair organized and hosted UAS focused camps coordinated with various organizations to facilitate the Dayton Early College Academy Drone Camp; Air Camp Elementary School, Middle School, High School, and Teacher Camps; Wright Brothers Institute High School UAS Camp; WACO Aviation Learning Center Middle and High School Drone Camps. These 12 separate camps over 15 dates reaching 435 students and teachers.

Overall, Sinclair engaged with a total of 3,735 students, teachers, and members of the general public throughout Ohio between October 2022 and August 2023. Of note, highlights of ASSURE research projects were included in the presentation portions of each event to raise awareness of the important work occurring through the COE.

KEY FINDINGS:

NC State University

- Completed 11 aviation camps with NC DOT at airports across the state, highlighting aviation career opportunities in rural areas.
- Supported two NCSU initiatives for high school students with disabilities.
- Over the duration of the A61 STEM IV effort, NCSU had 628 students/contacts.

Kansas State University

- Middle School Roadshows focused on underrepresented urban schools in Kansas City, Topeka, and Salina to introduce UAS, leading to a two-day summer camp at each school where students earned FAA TRUST certificates.

- Drones in School partnership provided students with microdrone kits in a team setting to compete in indoor First-Person View races.
- Over the duration of the A61 STEM IV effort, KSU had 14,587 students/contacts.

Sinclair College

- Completed 20 outreach days at middle and high schools reaching 2,345 students and teachers.
- Completed five outreach days during TechFest hosted at Sinclair, the Micro Drone Races hosted at the National Museum of the United States Air Force, and the Northeast Ohio Regional Airport Aviation Career Day reaching 955 students and general public.
- Organized and hosted 12 separate elementary, middle, and high school student and teacher camps over 15 days reaching 435 participants in collaboration with various organizations to facilitate the Dayton Early College Academy Drone Camp; Air Camp Elementary School, Middle School, High School, and Teacher Camps; Wright Brothers Institute High School UAS Camp; WACO Aviation Learning Center Middle and High School Drone Camps.
- Over the duration of the A61 STEM IV effort, Sinclair engaged with 3,735 students, teachers, and members of the broader public.

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DISASTER PREPAREDNESS AND EMERGENCY RESPONSE – PHASE III

LEAD UNIVERSITY : UNIVERSITY OF ALABAMA – HUNTSVILLE

A11L.UAS.68_A62

BACKGROUND

There is a need for research that will explore the use of UAS in providing effective and efficient responses to different natural and human-made disasters and emergencies. The needed research must focus on procedures to coordinate with UAS operators from within federal agencies such as DOI and DHS (including FEMA), as well as local and state disaster preparedness and emergency response organizations, to ensure proper coordination during those emergencies. The results will help inform requirements, technical standards, and regulations needed to enable disaster preparedness and emergency response and recovery operations for UAS. This

research will also develop a database with data collected during the project to be analyzed to produce various key performance measures and metrics that characterize how overall pilot proficiency in a flight environment.

APPROACH:

UAS Disaster Preparedness and Emergency Response Research phase III will build off of the results, findings, and lessons learned from A28/Phase I and A52/Phase II.

KEY FINDINGS:

This project has recently started and it is still too early for many key findings. The final report from A52 will help focus A62 results. There is an enormous variety of technical (hardware and software) solutions that may contribute to disaster response capabilities for UAS. Examining and evaluating these emerging solutions will continue throughout A62. There is a need for standards that would apply to disaster response equipment and practices. The MOPS concept emerging from A52 is a potential means of standardizing disaster response practices among UAS first responders.

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IDENTIFY MODELS FOR ADVANCED AIR MOBILITY/ URBAN AIR MOBILITY SAFE AUTOMATION

The Ohio State University | Drexel University | Embry-Riddle Aeronautical University | Kansas State University | University of North Dakota

LEAD UNIVERSITY : THE OHIO STATE UNIVERSITY

A11L.UAS.98_A64

BACKGROUND:

Advanced Air Mobility (AAM) and Urban Air Mobility (UAM) operations are expected to involve significant amounts of machine automation in order for operations to be profitable. The focus of this project is on UAS used for passenger transport and cargo delivery in urban areas. This research will evaluate AAM/UAM core technology, system architecture, automation

design, and system functional concepts to aid the FAA and industry standards development organizations in creating paths forward for these new operational capabilities.

APPROACH:

The research consists of three tasks:

- **Task 1: Background Report.** A literature review has been conducted that includes consideration of AAM/UAM automation, human-automation interaction, aircraft system architectures and concepts of operation, as well as standards, regulation, certification, and policy. The literature review includes academic, government, standards development organizations, and industry sources.

- **Task 2: Risk and Technology Assessments**. A range of alternative safety risk assessment methods will be applied to develop case studies for different UAM/AAM subsystems to help evaluate their use in addressing UAM automation capabilities. This experience with then be used to recommend an integrated approach for safety risk assessment that takes advantage of the strengths of a combination of these safety risk assessment methods.

- **Task 3: Forming Recommendations.** Gaps and roadblocks to realizing future AAM/UAM operational capabilities will be identified. A technology path, a standards development path, and an FAA policy and standards path will each be developed to enable the advancement from current capabilities to future AAM/UAM capabilities at full maturity.

KEY FINDINGS:

Task 1. This task was completed during this project year. The literature review that was prepared included a focus on the following areas:

1. Detect and Avoid.
2. Power and propulsion.
3. Airspace and vertiport design.
4. Flight planning (ground objects; individual aircraft and aircraft sharing airspace) and strategic deconfliction.
5. Communications.
6. Navigation and surveillance.
7. Standards, regulation, certification, and policy.
8. Concept of Operations and system architecture.
9. Autonomous command and control. Human-automation interaction and hu-
10. man-human interactions.

In addition, a literature review on safety risk assessment methods was completed. 48 unique approaches, methodologies, or frameworks for hazard analysis, risk assessment, and safety management were identified. These methods range from traditional fault-error-failure analyses such as FMEA to more sophisticated approaches based on machine-learning and Bayesian belief networks. The team also found examples of real-time solutions and procedures based on systems and control theory.

The number and variety of existing approaches demonstrate that there is no “one size fits all” method to risk assessment for UAM/AAM. This conclusion is reflected by FAA 14CFR/CS 25.1309, which requires that a safety analysis be conducted to demonstrate that a new aviation system will continue to operate safely in all foreseeable situations; it does not specify the form that safety analysis should take. Instead, the sufficiency of the approach taken must be justified by the stakeholder conducting the analysis.

Ideally, the method used to assess risk should be consistent across applications. However, a single universal risk model is not practical given the unique challenges distinct operations face. Instead, policy should clearly define the important high-level components of the required risk assessment and identify the critical factors to be addressed.

The various risk assessment methodologies differ in their focus and principles, and they may incorporate different level(s) and/or type(s) of uncertainty. Some methods are more capable of analyzing complex systems, while others are better suited for simple function analysis. Using a mixture of multiple risk assessment methodologies might be called for to enhance the coverage of the entire safety assessment, as demonstrated by the number of hybrid approaches in the literature. This conclusion is being further evaluated in Task 2.

Task 2. This task is underway and will have two phases:

- Phase 1: Application and assessment of qualitative risk assessment methods.
- Phase 2: Quantitative risk assessment.

Qualitative risk assessments will be completed for a range of the subsystems listed previously as focus areas for the literature review. These assessments will focus on automation relevant to these subsystems and will include careful consideration of the interactions among these subsystems and the impact of environmental variables. The Phase 1 qualitative risk assessments will be structured according to the following four step plan:

- Step 1: Each performer characterizes the system.
- Step 2: The lead for Task 2 (Drexel) works with each performer to identify possible suitable application of qualitative risk assessment methods.
- Step 3: Each performer completes qualitative risk assessment on failure stories (scenarios). This includes:
  - Making a list of potential root causes of failures and of potential contributing factors relevant to their focus area (subsystem).
  - Describing interactions of that subsystem with other subsystems.
  - Describing the relevant environmental factors for this subsystem.
  - Describing what are the potential failure stories (scenarios) for the system.
  - Describing how estimates on probabilities and severities might be estimated.
  - Selecting a suitable qualitative risk assessment method (coordinated by Drexel to ensure a range of such methods are selected).
  - Performing the selected qualitative risk assessment on the various failure stories (scenarios).
  - Working with Drexel to compare the methods and results of these qualitative risk assessments to evaluate their applicability to UAM individually and as an integrated whole.

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DETECT AND AVOID RISK RATIO VALIDATION

LEAD UNIVERSITY : MISSISSIPPI STATE UNIVERSITY

A11L.UAS.105_A65

BACKGROUND:

The intended function of Detect and Avoid (DAA) systems is to serve as an alternate means of compliance to the duties of an onboard pilot to see-and-avoid other aircraft (Part 91.111, Part 91.113). This research will measure on-board pilot visual performance in seeing other aircraft in Class E, Class G, and in terminal airspace environments. Visual performance will be combined with simulated avoidance maneuvers to estimate pilot risk ratio performance in seeing and avoiding other aircraft. Pilot risk ratio values will then be used as part of the verification and validation of DAA risk ratio targets for a variety of UAS and Air Mobility (AM) operations. This research is necessary to derive minimum safety performance requirements so that DAA systems can be used as an adequate alternate means of compliance to existing

aviation regulations. The validation effort will also ensure that DAA risk ratio thresholds are adequate such that when an onboard pilot encounters a drone supported with DAA, that the onboard pilot does not experience greater collision likelihood than when encountering another aircraft with an onboard pilot.

The research requirement will address gaps in knowledge that are currently a barrier to validating safety performance thresholds for DAA systems which are required for the safe, efficient, and timely integration of UAS into the National Airspace System.

APPROACH:

Task 1: Flight Test Planning

The researchers reviewed past research projects to include ASSURE project A23 "Validation of Low-Altitude Detect and Avoid Standards" to inform flight testing efforts to measure see-and-avoid and see-and-be-seen pilot performance. The research team performed a Flight Test Effort Review to address the adequacy or need for refinement and validation for see-and-avoid and see-and-be-seen pilot performance. The output from Task 1 will be used to plan and execute forthcoming tasks.

Task 2: Simulation and Analysis Planning

The team performed a Risk Ratio Development Review of available and relevant literature on the development of Risk ratios within the ASSURE A23 project and other research and determined if they are adequate or need further refinement.

The team found previous Risk Ratio development efforts to need the following:

- More variety of encounter data (variety of geometries, closure rates, intruder types);
- Realistic pilot delay and response (previous research assumed large delay, and non-aggressive maneuvers for simulated pilots);
- Using the outputs from the risk ratio development review, the researchers, in conjunction with the FAA and other relevant stakeholders produced plans to address these inadequacies.

Task 3: Planning for Risk Ratio Tables and Tools to support Industry Standards

The team continues to coordinate with DAA industry standard workgroups and committees to understand how risk ratio tables in the ASTM work item 62668 appendix were created and update them accordingly. The researchers planned for the creation of a new appendix for the new ASTM work item 69690 tailored to current industry needs. The researchers planned for the creation of DAA simulation tools to be used in industry and standards bodies for DAA risk ratio analysis.

Task 4: Follow-on Planning

As this research effort progresses, the researchers will create follow-on flight test plans, simulation and analysis plans, and risk ratio tool planning to meet the objectives of the research project. The plans will be coordinated with the FAA to prioritize its currents needs and resource availability.

Task 5: Plan Execution & Reporting

The team will execute the plans approved by the FAA and document activities in the reports. Reports will include the measured data, results, interpretation of the results, and lessons learned.

Task 6: Final Report & Briefing

The team will summarize and aggregate all previous papers and reports into a final report package for the overall project that answers the research questions and provides risk ratio targets supported by rigorous flight test data, simulation, and analysis. The report will also include an assessment of proposed Well Clear distances and Detect and Avoid encounter sets when proposing risk ratio targets with recommendations to the FAA, ASTM, and RTCA. The report should include proposed requirements and test methods for industry standards. The report should discuss how project outcomes can be used to inform policy, regulations, advisory circulars, and industry consensus standards and recommendation for future research.

KEY FINDINGS:

The previous research A23, analyzed pilots' ability to see other pilots by using three action cameras, two of which faced out of the cockpit while one faced toward the pilot. This allowed researchers to manually determine when and where pilots visually acquired the intruder aircraft. Because this step needed to be done manually, it was a very time-consuming process that required substantial amount of personnel. Additionally, using three cameras on every flight event required that extra batteries and storage solutions were included to keep things running smoothly which had a huge impact on researcher workload for the project. When developing the plan for A65, the team decided to research new eye tracking technology and found Tobii, a Swedish company that specializes in eye tracking solutions for consumers and industry. The team purchased two sets of Tobii Pro Glasses 3 and used those glasses in a series of practice flights to ensure that they would be a good replacement for the three cockpit cameras. So far in A65, the glasses have allowed researchers to minimize the amount of equipment needed for a flight event which lowers workload. The glasses also allow for more efficient and accurate analyses after flight events.

There have been two flight test events in the past year for A65. The first test in July 2023 gathered head on and overtake encounters while also allowing the researchers to obtain data with the eye tracking glasses and practice installing them and following the data collection procedures. The second flight test event in September 2023 consisted purely of overtake encounters between a Cirrus SR20 (ownship) and a Cessna 172 (intruder), with 66 being recorded in the field, and 60 deemed usable during the analysis phase. Although ongoing analysis is limited, the team has been able to generate some flight test metrics such as mean detection distance, closest point of approach, and closing speeds. A "White Paper" document is currently being produced containing a high-level analysis of the overtake encounters. This document is not a deliverable and is intended as an update on the state of flight testing and analysis in hopes to garner discussion and gain valuable feedback. The data gathered will be compared to previous encounter geometries, and in the future, compared to overtakes between UAS and crewed aircraft. It is expected that this document will be completed and provided to ASSURE and the sponsor in early November.

Additionally, while the team awaits delivery of the 60% Clipped Wing Cub RC aircraft that are slated to be used for the flight tests, they have been gaining experience with a smaller test bed aircraft operated by Raspet Flight Research Laboratory. The autopilot software and components used to control the Bushmaster match those that will be implemented on the Cubs, allowing for a quick and seamless transition into flight testing once they arrive.

MSU Co-chairs the ASTM F38.01 Working Group 62669 for the development of test methods standard for testing and simulating DAA systems. As part of that role, MSU attends and leads weekly technical interchanges to work through the complicated nuances of adequately, and appropriately, testing DAA systems. Over the course of the year, the group finalized an approach to matching simulation results to a much smaller pool of flight test results. The draft standard is scheduled to begin subcommittee ballot in early November, prior to the Fall Face-to-Face meeting being held in Santa Clara, CA. The team also attended and led sessions during the Spring Face-to-Face in Washington, D.C., in April 2023, and in Conshohocken, PA, in 2022. MSU continues to co-chair and support ASTM groups as part of the requirement to engage with industry established by ASSURE RFPs. MSU encourages the FAA to request this requirement across the various fields within ASSURE research.

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DEVELOP METHODOLOGIES TO INFORM THE INTEGRATION OF ADVANCED AIR MOBILITY INTO THE NATIONAL AIR SPACE SYSTEM

LEAD UNIVERSITY : MISSISSIPPI STATE UNIVERSITY

A11L.UAS.106_A66

BACKGROUND:

The Office of Aviation Policy and Plans (APO) uses the TAF-M methodology to forecast airport enplanements and operations based on passenger flows. With the integration of Advanced Air Mobility (AAM)/Urban Air Mobility (UAM) and the emergence of new services,

smaller regional airports may experience rapid growth, potentially surpassing the 100,000 annual enplanements threshold. Conversely, established core commercial airports could see declines in services. APO aims to enhance its forecasting model to account for these changes, allowing inactive airports to become active and active ones to become inactive due to AAM's influence. This flexibility enables the FAA to adapt to AAM growth, aiding resource allocation and safe integration efforts.

APPROACH:

The multinomial choice model will be applied to estimate the passenger and operation flow of AAM/UAM in the top five metropolitan areas. Then, it will simulate the impact of passenger flow that affects the NAS. Furthermore, the linear regression model will be created to predict potential airports that could reach the 100,000 annual enplanements threshold in the future, and these airports will be included in the new TAF-M.

KEY FINDINGS:

This project has recently kicked off. Final results and deliverables are expected in 2025.

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COLLISION SEVERITY OF SMALL UNMANNED AIRCRAFT SYSTEMS IN FLIGHT CRITICAL ZONES OF PILOTED HELICOPTER

LEAD UNIVERSITY : WICHITA STATE UNIVERSITY'S NATIONAL INSTITUTE OF AVIATION RESEARCH

A11L.UAS.115_A67

BACKGROUND:

The FAA needs to evaluate the severity and likelihood of collisions between sUAS and manned aviation. As research continues to establish critical risk assessments for operational approvals of sUAS, the investigation of the severity of the impact of large sUAS with helicopters has yet to be quantified. With the FAA beginning to integrate AAM/UAM operations into the NAS, these sUAS to helicopter collision severity and risk assessments will inform future policy and operational development. The FAA will then utilize these findings to help support SMS assessments.

The research effort will investigate the severity metrics of the collision between multi-rotor and fixed-wing sUAS, weighing 2.7, 4, 10, 25, or 55 pounds with a manned helicopter during key phases of flight, such as hover, forward flight, and cruise. Recommendations from this research will help ATO guide future research of AAM/UAM. Prior collision severity research performed by ASSURE, Task A16, focuses on larger Part 29 helicopters encountering relatively small sUAS

(2.7lb (Quadcopter) and 4lb (Fixed Wing)). Research conducted under this current requirement will address encounters with that same small sUAS, as well as larger (10 lbs./25 lbs./55 lbs.)) sUAS, impacting medium-size Part 27 helicopters that are more representative of those found in the current NAS, specifically examining impacts in the following locations:

1. Horizontal Stabilizer
2. Rear Servo
3. Cowling
4. Main Blade
5. Windshield
6. Nose

Three different collision speed scenarios will be considered (note the impact speeds may be adjusted based on the technical specifications of the helicopter selected):

1. Forward flight at a collision speed of 94 kts. (Medium).
2. Cruise flight at a collision speed of 148 kts. (Max).
3. Hover condition with a speed of collision of 39 kts. In this condition, the severity of a lateral impact on the tail boom and the tail rotor needs to be considered.

To accelerate results, the lessons learned, and the sUAS Finite Element Models (FEM) developed in the previous ASSURE Task A16 will be used for analysis where possible. This research project started in November 2022 and is expected to be completed by June 2024.

APPROACH:

Task 1 – Research Task Plan and Helicopter Purchasing Process.

NIAR developed a Research Task Plan (RTP), which includes the following:

1. Definition of the detailed work plan.
2. A project schedule to track project activities, durations, and milestones. The project schedule includes identifying and tracking the schedule's critical path(s).
3. Establishment of Non-Disclosure/Data Sharing/Legal agreements for all stakeholders.

NIAR located and purchased a medium-sized Part 27 helicopter (Robinson R44). NIAR purchased a structurally complete vehicle (including all the structural and mechanical components necessary to flight) but might be missing avionics or other systems that do not allow the helicopter to be airworthy.

Task 2 – Helicopter Reverse Engineering.

To develop a representative Part 27 helicopter mode, the medium-sized Part 27 helicopter purchased in Task 1 will be reverse-engineered to create a Computer Aided Design (CAD) and Finite Element (FE) model representing its major structural components. The reverse engineering process will be divided into five major tasks:

1. Scanning
2. Hand Measurements and Repair Manual:
3. Weight Documentation
4. CAD Model
5. Material and Fastener Reverse Engineering

Task 3 – Helicopter Finite Element Model.
The 3D CAD model of the medium-sized Part 27 helicopter developed in Task 2 will be used to generate the detailed FEM for collision severity analysis. NIAR's internal processes and the building block approach will be used to generate the detailed FEM of the helicopter. Figure 1 outlines the process used for generating the helicopter FEM.

Figure 1. Flow chart for FEM.

Tasks 4 through 7 – Collision Evaluation with Eight sUAS
NIAR will set up and evaluate load cases for 2.7, 10, 25, 55 lbs quadcopters and 4, 12, 25, 55 lbs fixed-wing sUAS in these tasks. There will be six impact locations and three impact velocities for a total of 144 FEA cases.

A set of criteria is established to categorize the results of each load case relative to one another. The lowest damage category, Level 1, generally corresponds to minimal localized damage. The next category, Level 2, represents significant visible damage to the external surface of the aircraft, with some internal component damage but no appreciable skin rupture. The third category, Level 3, describes impact events where the aircraft's outer surface is compromised in a way that could allow ingress of foreign objects into the airframe, with some damage to the substructure. Finally, Level 4 indicates damage that includes all preceding aspects, extensive damage to internal components, and possibly compromising damage to the primary structure. In addition to these severity levels, the same evaluation criteria followed for Task A16 will be used to evaluate the level of damage on the main rotor blade for this Part 27 helicopter.

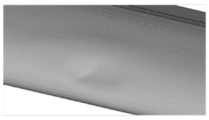
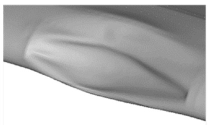
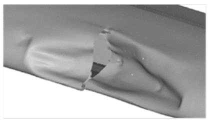
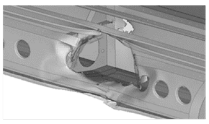
Severity	Description	Example
Level 1	• The airframe is undamaged. • Small deformations.	
Level 2	• Extensive permanent deformation on external surfaces. • Some deformation in internal structure. • No failure of skin.	
Level 3	• Skin fracture. • Penetration of at least one component into the airframe.	
Level 4	• Failure of the primary structure.	

Figure 2. Severity Levels.

Task 8 – Final Report – Collision Evaluation.
Research completed throughout Tasks 1 to 7 will be summarized into one single project report.

KEY FINDINGS:

- Task 1 has been completed, and a research plan has been defined.
- Task 2: A CAD model of an R44 helicopter was created, and detailed documentation is currently in progress.
- Task 3 is currently in progress. The result will be a FEM that will be used for impact severity evaluation in Tasks 4 through 7.

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ALLINSIPAS MONTOYA	MAY 2025

VALIDATE SUAS DAA WELL CLEAR REQUIREMENTS

LEAD UNIVERSITY : MISSISSIPPI STATE UNIVERSITY

A11L.UAS.117_A68

BACKGROUND:

Detect and Avoid (DAA) industry standards have proposed separation criteria to satisfy regulatory well clear requirements for sUAS DAA operations that maintain separation from manned aircraft. SUAS DAA well clear separation criteria are often supported by unmitigated simulation analysis but have yet to be assessed holistically for compliance with regulatory right-of-way rules, good human factors engineering, remote pilot usability, DAA surveillance limitations, mitigated simulation analysis that includes the DAA system, harmonization with proposed risk ratio values, behavior acceptance by other pilots to not interfere with crewed aircraft operations, and so forth.

APPROACH:

This project will assess, refine (if necessary), and validate well clear separation criteria for a variety of sUAS operations that avoid crewed air traffic. This project will also assess smaller separation criteria that is suitable for interactions between two sUAS for a variety of interactions near and away from flight obstacles at low altitudes. The project will be divided into three (3) phases:

Phase 1: Background Report

Task 1.1: Background Report

Phase 2: Creation of Planning Documents

Task 2.1: sUAS Well Clear Volume Validation
Task 2.2: Right of Way Quantification
Task 2.3: Remote Identification Field Testing
Task 2.4: UTM Service Field Testing

Phase 3: Test Plan Execution

Task 3.1: sUAS Well Clear Volume Validation
Task 3.2: Right-of-Way Quantification
Task 3.3: Remote Identification Field Testing
Task 3.4: UTM Services Field Testing
Task 3.5: Final Briefing and Report

NAME & ORIGIN OF RESEARCH PERSONNEL

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SCOTT KEANE, UND	UNITED STATES

KEY FINDINGS:

This project has recently kicked off. The final results and deliverables are expected in 2025.

GRADUATION OF STUDENTS:

DEEPAK SINGH, WSU	MAY 2023
ANDREW DODGE, KU	MAY 2024
SAFAE EL AMRANI, MSU	MAY 2024
ARAVIND BETHINI, MSU	DECEMBER 2024


FUTURE RESEARCH

UPCOMING RESEARCH

- Conduct Safety Risk Management Analysis on Small Unmanned Aircraft Detect and Avoid Systems
- Conduct Science Technology Engineering and Math (STEM) Outreach to Minority K-12 Students Using Unmanned Aircraft Systems (UAS) as a Learning Platform
- Increase Small Unmanned Aircraft Systems Conspicuity in Terminal Environments
- Assess the Vulnerabilities of Packaging and Package Containment Systems
- Evaluate the Applicability of Crashworthiness Standards for Urban Air Mobility
- Develop Risk Based UAS Operator Medical Certification Standards
- Develop Bird Strike Avoidance Requirements for Remotely Piloted Advanced Air Mobility Operations
- Develop small Unmanned Aircraft Detect and Avoid Human Factors Requirements
- Develop a Data Driven Framework to Inform Safety Risk Management (SRM) Mitigation Credit Estimates
- Analyze Drone Traffic
- Disaster Preparedness and Emergency Response Phase IV

PUBLICATIONS

Cuenca, A., Moncayo, H., Q-Learning Model Covariance Adaptation of Rao-Blackwellized Particle Filtering Estimations for Airborne Geomagnetic Navigation. IEEE/ION PLANS 2023, AI-Enhanced Navigation Systems, Monterey, CA. April, 2023.

Cuenca, A., Brutch, S., Moncayo, H., Performance Analysis of UAV Control Architectures Over Urban Environments with Degraded GNSS Accessibility. IEEE/ION PLANS 2023, Aerial Vehicle Navigation, Monterey, CA. April, 2023.

Cuenca, A. and Moncayo, H. Geomagnetic Aided Navigation using Rao Blackwellized Particle Filter, AIAA 2023-1452. AIAA SciTech 2023 Forum. National Harbor, MD. January 2023.

Cuenca, A., Gutierrez, T., Morillo, E., Steinfeldt, S., and Moncayo, H., Modeling of GPS Degradation Conditions for Risk Assessment of UAS Operations in Urban Environments, AIAA 2023-2648. AIAA SciTech 2023 Forum. National Harbor, MD. January 2023.

Gutierrez, T., Cuenca, A., Coulter, N., Moncayo, H., Steinfeldt, B., Development of a Simulation Environment for Validation and Verification of Small UAS Operations, GNC-02/IS-02, Guidance, and Control Architectures for Autonomous Systems I, January 2022, San Diego, Ca.

P. Pothana, J. Joy, P. Snyder and S. Vidhyadharan, "UAS Air-Risk Assessment In and Around Airports," 2023 Integrated Communication, Navigation and Surveillance Conference (ICNS), Herndon, VA, USA, 2023, pp. 1-11, doi: 10.1109/ICNS58246.2023.10124319.

SIGNIFICANT EVENTS

UAS Center of Excellence (COE) Selection announced by FAA Administrator Huerta	May 2015
UAS COE Kick-Off Meeting	Oct 2022
Initial Research Grants Awarded	September 2015
World of Drones and Robotics - London, England	October 2022
International Roundtable - Virtual	November 2022
Aerial Evolution Canada 2022 Conference & Exhibition - Calgary, Canada	November 2022
CASA Meeting - Brisbane, Australia	November 2022
CAA NZ Meeting - Wellington, New Zealand	November 2022
International Roundtable - Virtual	January 2023
International Roundtable - Virtual	March 2023
Program Management Review - Wichita, KS	March 2023
CORUS-XUAM Workshop - Bari, Italy	March 2023
Advanced Aviation Innovation Summit - Washington DC	April 2023
XPONENTIAL - Denver, CO	May 2023
NZ World of Drones and Robotics Conference - Auckland, New Zealand	May 2023
FAA Drone and AAM Conference - Baltimore, MD	August 2023
NASA ULI - Boston, MA	August 2023
Global Autonomous Systems Conference - Anchorage, AK	August 2023
Counter-UAS Summit - Alexandria, VA	August 2023
Program Management Review - Columbus, OH	September 2023
Commercial Drone Exhibition - Las Vegas, NV	September 2023
Unmanned Systems, West - San Diego, CA	September 2023

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Kansas State University

NM State University

National UAS Training and Certification Center

Drexel University

University of North Dakota

Oregon State University

Montana State University

WSU Wichita State University

The University of Vermont

Virginia Tech

NC State University

Auburn University

Indiana State University

Tuskegee University

Université Concordia University

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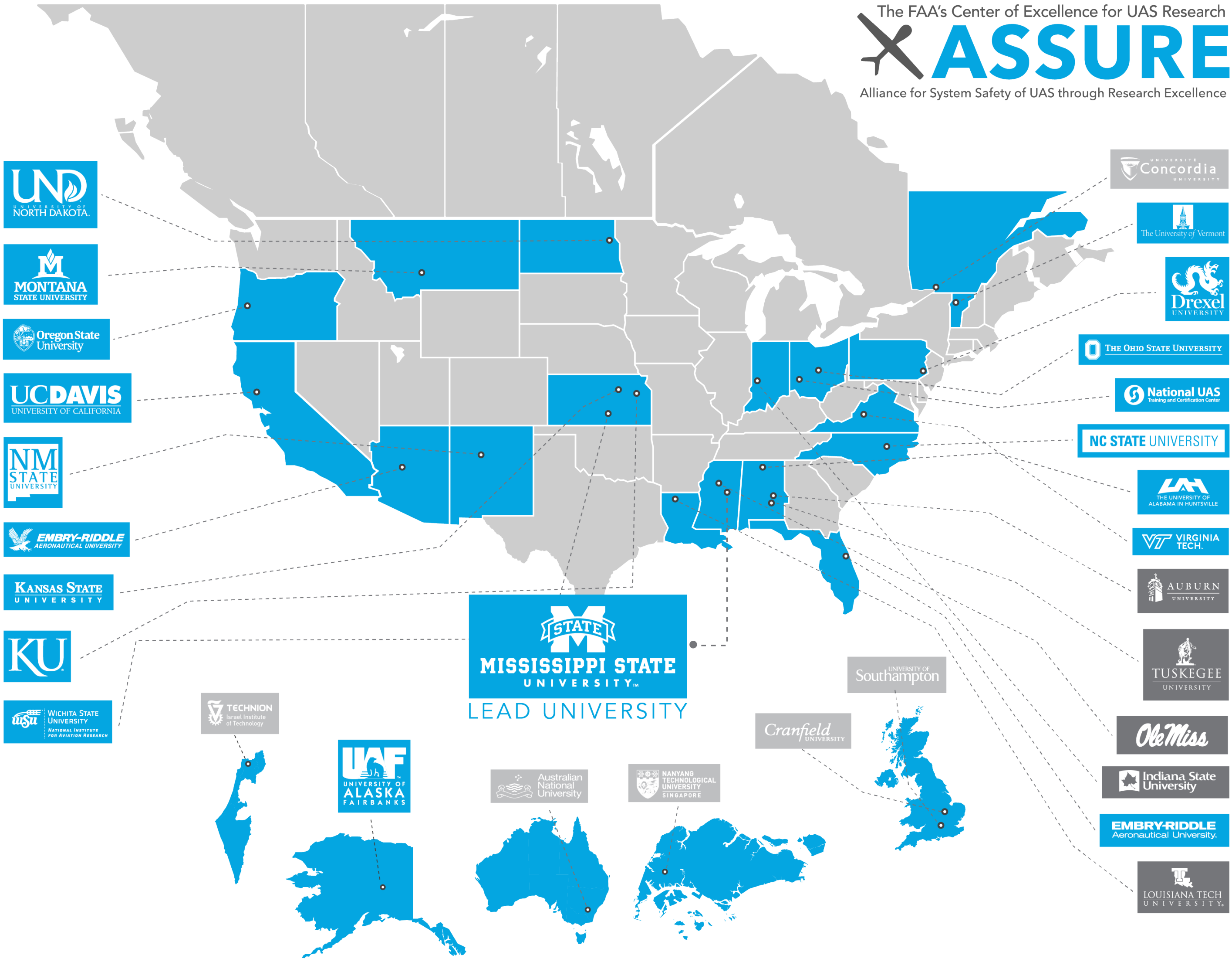
Nanyang Technological University Singapore

University of Southampton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ASSURE
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THE OHIO STATE UNIVERSITY
National UAS Training and Certification Center
NC STATE UNIVERSITY
UAH THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
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AUBURN UNIVERSITY
TUSKEGEE UNIVERSITY
Ole Miss
Indiana State University
EMBRY-RIDDLE Aeronautical University.
LOUISIANA TECH UNIVERSITY

The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

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